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Distributed Shared Memory on Loosely Coupled Systems

Vicente Cholvi-Juan
Department of Computer Science
University Jaume I
Campus Penyeta Roja, Castelló, Spain
E-mail: vcholvi@inf.uji.es
AND
Roy Campbell
Department of Computer Science
University of Illinois at Urbana-Champaign
1304 W. Springfield Av, Urbana, IL 61801
E-mail: roy@cs.uiuc.edu

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The distributed shared memory model (DSMM) is considered a feasible alternative to the traditional communication model (CM), especially in loosely coupled distributed systems. While the CM is usually considered a low-level model, the DSMM provides a shared address space that can be used in the same way as local memory.
This paper provides a taxonomy of distributed shared memory systems, focusing on different implementations and the factors which affect the behavior of those implementations.

1 Introduction

Many computational problems benefit from the availability of *parallel-processing* power: the computational problem is split into subproblems and each one is solved concurrently. There are many multiprocessor computers, ranging from only a few to thousands of processors. Typically, such a multicomputer is much more expensive than a collection of loosely coupled computers, having each only a few number of processors. The main advantage of the large multicomputer systems is the speed of the interconnection network joining its processors. However, trends in network technology will make possible to have high performance networks joining loosely coupled systems. In fact, the number of loosely coupled distributed systems being used as parallel computers is quickly increasing [4, 12, 32]. Thus, such systems constitute a low-cost approach entry into the parallel computing domain without necessarily requiring special (and often expensive) hardware. They can be easily upgraded and customized, and even though the performance gap between them and supercomputers is still relatively big, it is expected a notable reduction as high-speed networks become more popular (e.g., ATM or HiPPI networks). We will focus our work in this type of systems.

A typical (loosely coupled) distributed system is composed of a collection of independent computers interconnected through some type of network. In order to cooperate, applications written to span several computers on such a system need to have some mechanism to allow each one of their parts to exchange information.

Within the *communication model* (CM) [17, 18, 28], this information exchange is accomplished by means of explicit transfer of messages: a given node sends a message to another node using the following primitives:

– **send**(data,address)

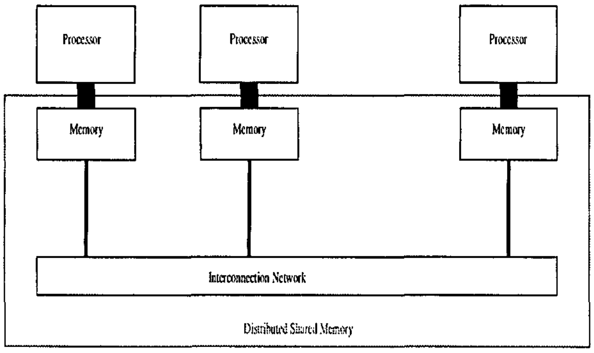

Figure 1: Distributed Shared Memory (DSM).

- **receive**(data)

The CM model provides explicit control over the communication to the programmers, being relatively easy to overlap communication with computation. Nevertheless, that explicit control constitutes the main disadvantage of the CM [17, 18], as it increases its complexity. Thus, it is necessary that the source process of a message knows the target processes. In addition, target processes must exist when data is sent, and must eventually be able to receive that data. Finally, each process must dynamically extract its state when receiving random messages.

On the other hand, the *shared memory model* (SMM) [51] provides a shared address space which can be used by processes in the same way as local memory, even if they are executed concurrently in different processors. Thus, every process can access any address by means of two basic operations:

- data = **read**(address)
- **write**(address,data)

read returns the *data* in *address*, and **write** associates *data* with *address*.

Using the SMM model has several important benefits. In the first place, it hides the particular communication mechanisms employed, thus application developers do not need to be involved in the management of messages, or know whether the application runs on a multiprocessor or on a distributed system (they should know, however, the cost of exchanging information, so they can decide on a performant partition). Besides, it allows complex shared structures to be passed by reference, providing a simple and well known paradigm.

When a SMM is built on top of a distributed system, we get what is known as a DSMM. Even though a DSMM is built on top of a CM (suggesting a decrease in the performance), it has been shown that DSMM can perform well [15]. Factors, such as high locality of references [23], allow communication costs to be compensated against multiple accesses. Multiple replicas can also reduce transfers between nodes, while distributing the communication over a larger interval of time (transfers of data are made on demand), increasing concurrence.

Of course, those paradigms do not have to be necessarily exclusive. Indeed, systems such as SAM [49], Locust [19] and CarlOS [38] support the DSMM, providing at the same time mechanisms for communication and synchronization.

The rest of the paper is organized as follows: Section 2.1 contains an overview of different approaches to implement the DSMM. Section 2.2 addresses implementation mechanisms. Section 2.3 focuses on the problem of consistency between shared units, while Section 2.4 analyzes the importance of the shared units structure. Finally, in Section 3 we give some concluding remarks and suggest future research directions.

2 Characterization of the DSMM

As we have pointed previously, the DSMM has to be built on the CM in such a manner that it transforms the memory access requests into messages between processes. There are a lot of factors that affect the way such transformations take place. In the next sections we identify principal issues that characterize the behavior of DSM systems, presenting some of the proposed implementations.

2.1 Implementation Approaches

The field of research in DSM systems was open up in 1985 by D.R. Cheriton [17]. Since then, a huge amount of work has been done in that area.

The earliest DSM systems provided implementations of the DSMM principally by using *operating system* resources, through virtual memory management mechanisms. IVY [43, 44] constitutes a classical example of a system that implements the DSMM by adding coherence mechanisms [1] to a distributed demand paging policy. More recently, Choices [48] incorporates custom designed distributed virtual memory protocols for different applications, which can be altered to trade off characteristics such as resiliee ncto packet loss, network loading, etc. In the same way, the virtual memory management system of Mach [47, 54], a well known operating system kernel that runs on a wide variety of architectures, is designed to be architecture and operating system independent, allowing programmers to handle directly memory as a system resource. Thus, individual memory manager systems that implement the DSMM can be customized for specific applications (e.g., Agora [11] or Midway [10]).

Another approach consists of making use of *hardware* components. For instance, MemNet [22, 52] is an entirely hardware implementation of the DSMM. Every node has a *MemNet-device* that includes both the host's system bus and the network interface, and a *MemNet-cache* (structured in blocks of 32 bytes) divided into a large cache and a reserved area. The cache is used to store the blocks whose reserved area is another node, while the reserved area is used to store the blocks which have to be flushed when a cache area become full. On every memory access, the local *MemNet-device* decides if it can alone handle that request. If it needs the cooperation of other devices, it will send a message and will block the node until receiving a reply. That message will circulate through the net (a token ring), being inspected by every *MemNet-device* (thus, the maximum reply time is limited). If there is a read access, the first *MemNet-device* with a copy will send it to the requester node, while if there is a write access, in addition it will be necessary to invalidate all the replicas in order to maintain some type of consistency between them.

Compilers can also provide support for transforming shared accesses into primitives to manage both coherency and synchronizations. Among the languages for implementing the DSMM we can mention EDS Lisp [30], an extension of an existing sequential language, and Orca [6], a new language designed from scratch in such a way that data shared structures can be accessed through higher level operations.

[1] Basically they are very similar to those used in the Berkeley multiprocessor system [5]

However, currently most of the efforts are addressed in order to implement DSM *environments*. They consist of user-level libraries providing operations that programmers can use directly [21]. For instance, TreadMarks [35] constitutes a DSM environment that implements the DSMM using standard Unix systems such as SunOS and Ultrix without requiring any modification of them (the implementation is done at user level), avoiding the performance problems by focusing on reducing the communication between nodes. Also SAM [49], a shared object system for distributed memory machines, has been implemented as a C library on a variety of platforms: on the CM-5, Intel iPSC/860, Intel Paragon, IBM SP1 and on heterogeneous networks of workstations using PVM. Other DSM environments are Quarks [16] and CarlOS [38].

2.2 Implementation Issues

Placement. The DSMM provides a shared address space which can be used by processes in the same way as local memory.

However, the implementation of such a shared address space requires placing physically shared units (*blocks*) at the local address spaces composing the global one.

That placement can be done *statically* in su ach way that the same block is always placed at the same node. A simple way to implement static placement consists of employing a central server which will store all the blocks. Thus it will manage every access to them [17, 18, 51]. Unfortunately, this implementation needs twice as much messages as the CM. Besides, the central server constitutes a potential bottleneck and although this problem can be solved by using several servers, troubles will still remain if load is not properly distributed.

Another possibility consists of using *dynamic* placement. In this case, blocks are transferred to the requester node before to be accessed. That approach avoids any communication between nodes if data is locally available, although it may force superfluous data transfers.

Location. While finding blocks can be done in a straightforward way when using static placement, if the placement is dynamic it is necessary to follow circulating blocks. In the same way as in the placement of blocks, the simplest way of controlling circulation consists of using a single node. But analogously to that case, if the node becomes heavily loaded, the entire system will also become overloaded. That problem can be also solved by using several controller nodes, but the effectiveness of that solution still will depend on the proper distribution of load. Also, it requires maintaining a mechanism to find the proper controller node, thus loading the system with a new task.

Replication. To increase concurrency, most of the DSM systems support *replication* of data. That allows different processes to use the same data at the same time. However, and in order to guarantee consistency of shared data, systems using replication must carry out control of replicas.

That control can be done by *invalidating* outdated replicas, as for instance systems as IVY [43] or Clouds [36] or by *propagating* data to outdated replicas. Stumm et al. [1, 51] have proposed several algorithms intended to propagate values. Basically they use a single node, varying only the moment when the propagation takes place.

Whereas propagation is more expensive than invalidation due that, in addition to the invalidating messages, data have to be sent, by using invalidation each block-fault (a block-fault happens when a request can not be locally served) leads to starting a process that will create a new replica, thus increasing latency.

Application Customization. Application-specific protocols constitute a well known approach to improve performance [17, 18]. However, although it has been shown to be an efficient means to reduce extra communication against general purpose protocols [26], it requires writing protocols from scratch, which has been also shown to be difficult and error-prone.

System-provided protocols, even though with reduced performance, seems to be a compromising solution to that problem. Indeed, experimental studies of several shared memory parallel programs [7, 15] support the hypothesis that a system employing a type-specific memory coherency scheme may outperform systems using only a single mechanism.

Nevertheless, that technique requires a relatively small number of identifiable patterns that characterize the behavior of the majority of blocks (so that customized mechanisms can be developed).

Fault tolerance. Fault tolerance and error recovery constitute topics also addressed by using the DSMM. Let's introduce the approach taken by Wu & Kent [53]. They have designed a recoverable distributed virtual memory system which stands up to fail-stop processors [50] without any global re-starting. To do that they use *security copies* that store the necessary data to restart the execution [8]. Given that every process shares the global memory, a backward propagation might be needed if each process simply creates an independent security copy [37]. That happens if a process, after creating a security copy, modifies the value of a page and sends it to another process. Then, if the first process fails, the second one will have to get a security copy created previously to that failure.

To solve this problem, every node creates a security copy before sending any modified page since the last checkpoint (also the operating system or even the program can create additional copies). That is done by using *twin* disk pages. One of them is a security copy. The other is either a work copy or a wrong copy (due to a failure or because it is an old security copy). Thus, every restart, the "right" page is chosen, which will avoid a backward propagation because data do not have to be invalidated in any node.

However, to develop truly reliable systems, both processors and memory failures must be considered. In this way, Hoepman et al. [33] have addressed the construction of self-stabilizing wait-free shared memory objects (these objects occur naturally in systems in which both processors and memory may be faulty).

2.3 Coherency Models

As it as been previously pointed out, the use of replication may increase concurrency. In turn, it is necessary to maintain some kind of *coherency* between replicas.

This problem is similar to the cache coherency problem in multiprocessor systems [5, 24], where several processors share the same data in local caches. In this case, the size of the caches is relatively small, the connections fast and the coherency protocols are implemented by hardware. On the contrary, in distributed systems the communication cost is bigger, and the coherency protocols are usually implemented by software.

A memory coherency model is characterized by its constrains on initiation and completion of memory accesses [20]. Depending on the properties guaranteed by the coherency model, algorithms will vary in complexity. Programmers must ensure that accesses to data conform to the rules of the model.

Basically coherency models can be split into *non-synchronized* and *synchronized*. Non-synchronized models use only read and write operations while synchronized ones have, in addition, another operations (synchronizations) intended to enforce dependencies at specific points.

Whereas most of the systems support only one coherency model, there are systems which support multiple coherency models within a single parallel program. For instance, Midway [10], which has been implemented using Mach 3.0 with CMU's Unix server on MPIS R3000-based DECstations and 5000/120s, supports release consistency, entry consistency and processor consistency (described below).

2.3.1 Non-Synchronized Models

One of the most widely known non-synchronized models is the *atomic*. It was formalized by Lamport [41] in the case of one writer, and by Misra [46] in the case of several writers. Also the *linearizability condition* for objects introduced by Herlihy and Wing [31] is equivalent to the atomic model when restricted to objects that support read and write operations. This model requires each read operation to obtain the "most recently written" value. It also preserves "real-time" ordering of operations without blocking every process while an operation is taking place. An interesting property of this model is that to guarantee that a system is atomic, it is enough to guarantee that each variable in isolation is atomic, i.e. the atomic model is compositional.

The *sequential* model [40] resembles the atomic, although this one does not preserve any kind of global order between operations (only operations from the same process are forced to preserve real-time ordering). Sequential memory, on the contrary to what happens to atomic memory, does not satisfy the compositional property. Thus, in contrast with the atomic model, it is not possible in general to obtain a sequential system out of the composition of independent sequential components.

On the other hand and in order to improve the performance, other coherency models do not preserve the "most recently written" property.

For instance, the *cache* model (it was introduced by Goodman as *cache consistency* [29]) forces only operations affecting the same variable to "appear" as executed under the sequential model.

That condition is also fulfilled by the *PRAM* (Pipelined RAM) model [45]. Only now, operations appearing as sequential are those in the same process and write ones. That allows pipelining of the write operations, which, even though may potentially delay the effect of write operations to different processes, permits programs take advantage of the better performance of a PRAM implementation as compared to a sequential implementation.

The *causal* model [2], besides to the conditions of the PRAM model, forces read operations to return the value written by the last causally ordered operation [42]. Similarly to PRAM implementations, implementations of the causal model result in far less communications than on sequential ones, providing also a good scalability.

Also, the *processor* model [29] imposes additional conditions on the PRAM one. Now, restrictions are imposed on the write operations to the same variable.

Finally, the *safe* and the *regular* models (they were introduced by Lamport [41] in order to provide a way for implementing stronger models in terms of weaker ones) force the restriction of their executions to the write and non-overlapping operations be atomic. Moreover and in the case of the regular model, read operations are forced to return the value of any previous or overlapping write operation to the same variable.

2.3.2 Synchronized Models

The approach of synchronized models consists of obtaining algorithms that behave sequentially by forcing explicit dependencies between events (by using synchronizations) when necessary. However, that requires identifying dependencies in a proper way, which may induce additional complexity in the design of programs.

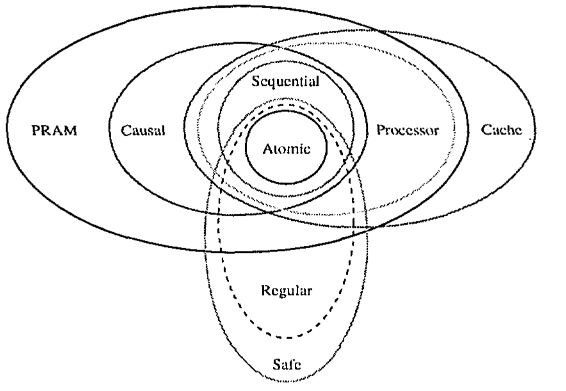

Figure 2: Relations between non-synchronized models: The sets represent the executions they allow.

We begin the description of synchronized models with the *weak* model [25]. It only uses a single synchronization type (*weak*). Roughly speaking, it forces dependencies between synchronizations and the preceding and following operations. However, slightly different versions of this model have been proposed varying the set of operations forced to be related with synchronizations.

Contrary to the weak model, both the *lazy-release* (LR) [34] and the *eager-release* (ER) models [27] use two types of synchronizations (*acq* and *rel*). That permits addressing typical problems (e.g., implementing critical sections) in an easier way.

Whereas the ER model sets up dependencies from the *rel* synchronizations to the whole set of operations, the LR model sets up dependencies from the *rel* synchronizations to the *acq* synchronizations.

Moreover, and independently from the set up dependencies, they require the first synchronization operation for each process to be an *acq* synchronization and impose an alternating use of the *acq* and *rel* synchronizations. Besides, after an *acq* synchronization completes, the next completing synchronization has to be executed by the same process.

The last synchronized model we introduce is the *entry* [9]. It is very similar to the LR model. Only now synchronizations are associated with "synchronization variables". As well as the release models, it requires the first synchronization for each process has to be an *acq* synchronization and it imposes an alternating use of the *acq* and *rel* synchronizations. Also, the *rel* synchronizations must be executed on the same variable that the previous *acq* synchronization, and after an *acq* synchronization completes, the next completing synchronization to the same variable has be executed by the same process.

2.4 Shared Data Characteristics

DSM systems are intended to provide an address space where data can be shared among several nodes. Therefore it is not surprising that the characteristics of those data may affect the behavior of such systems.

Heterogeneous size and structure greatly affect the system performance. That is due to the data conversion when interchanging information between modules (e.g., MMUs having to manage pages with different sizes [55]).

On the other hand, in loosely coupled distributed systems, sending a big packet of data is not, relatively speaking, much more expensive than sending a small packet. Therefore, if programs have a high locality and we use dynamic placement, using a big size of the shared units may reduce the number of block-faults. But the more we increase the size the more *false sharing* arises. False sharing occurs when two non-related variables, each one referred from a different node, are located in the same shared unit, thereby inducing unnecessary coherence operations. It is believed to be a serious problem for parallel program performance. This belief is also supported by experimental evidence [13].

Multi-writer protocols address that problem by allowing multiple nodes to write one block at the same time and merging changes in a consistent way at specified points. Examples of systems using multi-writer protocols are Munin [14] and TreadMarks [35].

Delayed protocols attack false sharing by communicating updates at the latest possible moment. For instance, synchronized models, because they only suffer delays at synchronization points, are used to reduce false sharing.

Systems supporting structured data provide the user with control of the shared units, which can be used to avoid false sharing. Orca [6], Indigo [39], Linda [3] or Agora [11] are examples of systems that allow data structures to be shared between nodes. In this case, a careful analysis must be done in such a way that data manipulated mostly by one process be allocated on shared units with no data for other processes. However, the analysis of data dependencies uses to be a difficult task.

3 Conclusions

While many studies have shown the usefulness of the DSMM and a big amount of work has been done to improve the performance of DSM systems, some areas still seem to require paying more attention [16, 19].

Performance of the DSMM is greatly affected by memory access patterns. As a matter of fact, the consistency mistmach between the DSM systems and the application programs constitutes one of the most important factors that favors low performance. Therefore, an important approach in order to avoid performance problems consists of exploiting data dependencies. However, that requires knowing access patterns, which may not be always available.

Real-time implementations and auto-configuring systems are other areas which also need deeper study.

Contrary to available message passing systems such as MPI or PVM, the DSMM has not yet had a significant impact on non-researcher users. The earliest systems provided experimental environments useful to be used as benchmarks. Now, new generation DSM systems are overcoming former problems, which allow us to envisage a wider acceptance of the DSMM.

References

[1] A. Krishnamurthy and K. Yelick. Optimizing parallel programming with explicit synchronization. In *Programming Language Design and Implementation*, June 1995.

[2] M. Ahamad, G. Neiger, J.E. Burns, P. Kohli, and P.W. Hutto. Causal memory: Definitions, implementation and programming. *Distributed Computing*, 9(1):37–49, August 1995.

[3] S. Ahuja, N. Carriero, and D. Gelernter. Linda and friends. *IEEE Computer*, 19(8):26–34, August 1986.

[4] T.E. Anderson, D.E. Culler, and D.A. Patterson. A case for NOW (networks of workstations). *IEEE Micro*, 15(1):54–64, February 1995.

[5] J. Archibals and J.L. Baer. Cache coherence protocols: Evaluation using a multiprocessor model. *ACM Transactions on Computer Systems*, 4(4):273–298, November 1986.

[6] H.E. Bal, M.F. Kaashoek, and A.S. Tanenbaum. Orca: A language for parallel programming of distributed systems. *IEEE Transactions on Software Engineering*, 18(3):190–205, March 1992.

[7] J.K. Bennett, J.B. Carter, and W. Zwaenepoel. Munin: Distributed shared memory based on type-specific memory coherence. In *Proceedings of the 1990 International Conference on Parallel Processing*, pages 168–176. ACM, 1990.

[8] P.A. Bernstein, N. Goodman, and V. Hadzilacos. Recovery algorithms for database systems. In *IFIP*, pages 799–807, 1983.

[9] B.N. Bershad and M.J. Zekauskas. Midway: Shared memory parallel programming with entry consistency for distributed memory multiprocessors. Technical Report CMU-CS-91-170, Carnegie-Mellon University, September 1991.

[10] B.N. Bershad, M.J. Zekauskas, and W.A. Sawdon. The Midway distributed shared memory system. In *COMPCON*, 1993.

[11] R. Bisiani and A. Forin. Architectural support for multilanguage parallel programming on heterogeneus systems. In *Proceedings of the Second International Conference on Architectural Support for Programming Languages and Operating Systems*, pages 21–30, October 1987.

[12] M.A. Blumrich, K. Li, R. Alpert, C. Dubnicki, E.W. Felten, and J. Sandberg. Virtual memory mapped network interface for the SHRIMP multicomputer. In *Proceedings of the 21th International Symposium on Computer Architectures*, April 1994.

[13] W.J. Bolosky and M.L. Scott. False sharing and its effects on shared memory performance. Technical report, Computer Science Department, University of Rochester, 1994.

[14] J.B. Carter, J.K. Bennett, and W. Zwaenepoel. Implementation and performance of Munin. *Operating System Review*, 25(5):152–164, October 1991.

[15] J.B. Carter, J.K. Bennett, and W. Zwaenepoel. Techniques for reducing consistency-related communication in distributed shared memory systems. *Transactions on Computer Systems*, 13(3):205–244, August 1995.

[16] J.B. Carter, D. Khandekar, and L. Kamb. Distributed shared memory: Where we are and where we should be headed. In *Proceedings of the 5th Workshop on Hot Topics in Operating Sytems*, May 1995.

[17] D.R. Cheriton. Preliminary thoughts on problem-oriented shared memory: A decentralized approach to distributed systems. *ACM Operating System Review*, pages 26–33, October 1985.

[18] D.R. Cheriton. Problem-oriented shared memory: A decentralizad approach to distributed system design. In *Proceedings of the Sixth International Conference on Distributed Computer Systems*, pages 190–197. IEEE, May 1986.

[19] T. Chiueh and M. Verma. A compiler-directed distributed shared memory system. In *International Conference on Supercomputing*, 1995.

[20] V. Cholvi-Juan. *Formalizing Memory Models.* PhD thesis, Department of Computer Science, Polytechnic University of Valencia, December 1994.

[21] V. Cholvi-Juan and J.M. Bernabéu-Aubán. Implementing a distributed compiler library that provides a $\mathcal{N}$-mixed memory model. In *IEEE/USP International Workshop on High Performance Computing*, pages 229–244, March 1994.

[22] G. Delp. *The Architecture and Implementation of MemNet: A High Speed-Shared Memory Computer Communication Network.* PhD thesis, Computer Science Department, University of Delaware, 1988.

[23] P.J. Denning. On modeling program behavior. In *Proceedings of the AFIPS Spring Joint Computer Conference*, pages 937–944, 1972.

[24] M. Dubois and C. Scheurich. Synchronization, coherence and event ordering in multiprocessors. *IEEE Computer*, pages 9–21, February 1988.

[25] M. Dubois, C. Scheurich, and F. Briggs. Memory access buffering in multiprocessors. In *Proceedings of the 13th Annual Symposium on Computer Architecture*, pages 434–442, June 1986.

[26] B. Falsafi, A.R. Lebeck, S.K. Reinhardt, I. Schoinas, M. Hill, J.R. Larus, A. Rogers, and D.A. Wood. Application-specific protocols for user-level shared memory. In *Supercomputing*, November 1994.

[27] K. Gharachorloo, D. Lenoski, J. Laudon, P. Gibbons, A. Gupta, and J. Hennessy. Memory consistency and event ordering in scalable shared-memory multiprocessors. In *Proceedings of the 17th Annual International Symposium on Computer Architecture*, pages 15–26. ACM, May 1990.

[28] D.K. Gifford and N. Glasser. Remote pipes and procedures for efficient distributed communication. *ACM Transactions on Computer Systems*, 6(3):258–283, August 1988.

[29] J.R. Goodman. Cache consistency and sequential consistency. Technical Report 61, IEEE Scalable Coherence Interface Working Group, March 1989.

[30] C. Hammer and T. Henties. Using a weak coherency model for a parallel lisp. In A. Bode, editor, *Distributed Memory Computing*, volume 487 of *Lecture Notes in Computer Science*, pages 42–51. 1991.

[31] M.P. Herlihy and J.M. Wing. Linearizability: A correctness condition for concurrent objects. *ACM Transactions on Programming*

Languages and Systems, 12(3):463–492, July 1990.

[32] M.D. Hill, J.R. Larus, and D.A. Wood. Tempest: A substrate for portable parallel programs. In *COMPCON Spring'95*, March 1995.

[33] J.-H. Hoepman, M. Papatriantafilou, and P. Tsigas. Toward self-stabilizing wait-free shared memory objects. Technical Report CS-R9514, Centrum voor Wiskunde en Informatica, 1995.

[34] P. Keleher, A. Cox, and W. Zwaenepoel. Lazy release consistency for software distributed shared memory. In *Proceedings of the 19th Annual Symposium on Computer Architecture*, pages 13–21, May 1992.

[35] P. Keleher, A.L. Cox, S. Dwarkadas, and W. Zwaenepoel. TreadMarks: Distributed shared memory on standard workstations and operating systems. In *Winter USENIX*, 1994.

[36] Y.A. Khalidi. *Hardware Support for Distributed Object-Based Systems.* PhD thesis, School of Information and Computer Science, Georgia Institute of Technology, 1989.

[37] K.H. Kim. Programmer-transparent coordination of recovery concurrent processes: Philosophy and rules for efficient implementation. *IEEE Transactions on Software Engenieering*, 14(8):810–821, June 1988.

[38] P.T. Koch, R.J. Fowler, and E. Jul. Message-driven relaxed consistency in a software distributed shared memory. In *First Symposium on Operating System Design and Implementation*, pages 75–85. USENIX Association, November 1994.

[39] P. Kohli, M. Ahamad, and K. Schwan. Indigo: User-level support for building distributed shared abstractions. Technical Report GIT-ICS-94/53, School of Information and Computer Science, Georgia Institute of Technology, March 1995.

[40] L. Lamport. How to make a multiprocessor computer that correctly executes multiprocess programs. *IEEE Transactions on Computers*, 28(9):690–691, September 1979.

[41] L. Lamport. On interprocess communication: Parts I and II. *Distributed Commputing*, 1(2):77–1101, 1986.

[42] L. Lamport. Time, clocks and the ordering of events in a distributed system. *Communications of the ACM*, 21(7):558–565, July 1991.

[43] K. Li and P. Hudak. Memory coherence in shared virtual memory systems. In *Proceedings of the 5th Annual ACM Symposium on Principles of Distributed Computing*, pages 229–239. ACM, August 1986.

[44] K. Li and P. Hudak. Memory coherence in shared memory systems. *ACM Transactions on Computer Systems*, 7(4):321–359, November 1989.

[45] R.J. Lipton and J.S. Sandberg. PRAM: A scalable shared memory. Technical Report CS-TR-180-88, Princeton University, Department of Computer Science, September 1988.

[46] J. Misra. Axioms for memory access in asynchronous hardware systems. *ACM Transactions on Programming Languages and Systems*, 8(1):142–153, January 1986.

[47] R.F. Rashid et al. Machine-independent virtual memory management for paged uniprocessor and multiprocessor architectures. In *Proceedings of the 2nd Symposium on Architectural Support for Programming Languages and Operating Systems*, October 1987.

[48] A. Sane, K. MacGregor, and R. Campbell. Distributed virtual memory consistency protocols: Design and performance. In *Second IEEE Workshop on Experimental Distributed Systems*, 1990.

[49] D.J. Scales and M.S. Lam. The design and evaluation of a shared object system for distributed memory machines. In *First Symposium on Operating Systems Design and Implementation.* USENIX.

[50] F.B. Schneider. Fail-stop processors. In *Proceedings IEEE*, pages 66–70. IEEE, 1983.

[51] S. Stumm and S. Zhou. Algorithms implementing distributed shared memory. *IEEE Computer*, 23(5):54–64, May 1988.

[52] S. Sureshchandran and T.A. Gonsalves. The performance of the MemNet distributed shared memory architectures. Technical Report TR-CSE-90-02, Department of Computer Science, Indian Institute of Technology, January 1990.

[53] K.-L. Wu and W.K. Fuchs. Recoverable distributed shared virtual memory. *IEEE Transactions on Computers*, 39(4):460–469, April 1990.

[54] M. Young et al. The duality of memory and communication in the implementation of a multiprocessor operating system. In *Proceedings of the Eleventh ACM Symposium on Operating Systems Principles*, pages 63–76. ACM, November 1987.

[55] S. Zhou, M. Stumm, and T. McInerney. Extending distributed shared memory to heterogeneous environments. In *Proceedings of the 10th International Conference on Distributed Computing Systems*, pages 30–37. IEEE, 1990.

Human Adaptation to Qualitatively Novel Environment: The Role of Information and Knowledge in Developing Countries

A. Dreimanis
Environmental State Inspectorate
25 Rúpniecibas Str., LV-1877 Riga, Latvia

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A systemic analysis of information and knowledge functions in human adaptation to qualitatively novel environment is proposed. The term "environment", being treated in line of C. Popper's and J. Eccle's concept of human's three worlds — the set of: 1) physical and 2) mental objects and states as well as that of 3) mental products — would include a multitude of various economical-material, social, cultural and psychological conditions. Knowledge and information — the necessary factors, in order humans and society could develop and elevate their internal variety. Acquired and transferred knowledge — efficient source of proper adaptation and harmonization in qualitatively novel environment. Capabilities of a developing system to be in harmony with changing environment will depend on mutual interrelations between information adaptation and self-creativity, and, in particularly, on creative use of available knowledge and information.

1 Introduction

The main tendencies of developmental processes of our world are certainly directed towards a permanent increase of its complexity and, correspondingly, to the emergence of a whole set of actual problems of various degree of complexity and solvability, which especially clearly is being manifested during the last decade. Just in this period there has been risen an essentially novel set of economical, social, political and psychological problems, caused by disappearance of the previous two mutually incompatible political and socio-economic systems.

Accordingly, we are faced up with a general global phenomenon — breakdown of the previous long-lasting poltical, economical and social relations in the East Europe countries, corresponding to the socialistic order, and, therefore, with a concomitant transition in these countries from the previous closed society to an open society. It is just the system's openess which provides the considering versatile phenomenon with a multitude of external factors which afffect on the elements of the developing system as well as impart to the forementioned transition a non-equilibrium character. Furthermore, such transition period is being characterized by an elevated degree of chaos on the level of the whole society and its political and economical order.

2 Key approaches to study basic principles of socio-economic development

2.1 The key methodological principles

Therefore, for the seeking of basic principles of faourable socio-economic development of these transition countries to an open society(system), let us refer to the: 1) concepts of a generalized non-linear science — synergetics, in particulary, to the aspects of self-organization(SO) processes of qualitatively novel structures, as well as of chaotic phenomena being, in particulary, the basis of such fundamental concepts as adaptation, information and complexity, and 2) W.R.Ashby principle of requisite variety [2], requiring that for successful development and survival of the given system its own or inherent complexity should exceed the complexity of its environment.

2.2 The basic survival and adaptation problem

Such openess actualizes to a significant degre the problem of individual's survival in a changing complex environment: namely, an urgent necessity is set in for the people of the East European countries in order to cope with a whole set of the forming essentially novel for them conditions and requirements. Therefore, as one of the basic problem of the forementioned survival strategy could be defined in the following manner: how should an individual of such society organize his activities and to evolve his own world (the inner as well as outer) in order to adapt to the changing fundamental values of the socio-economical life and, thus, as far as possible, to harmonize his own world. Furthermore, "general thinking and economic motivations of the individual people who are the microelements of a society, and millions of these people combine to make a macroscopic system, which undergo oscillations and unstable behaviour" [8].

Such an individual's problem is self-consistently connected with the more global transition process — being of non-linear character — of the whole society to a generally novel system, where, according to the self-consistency principle, "the individual members of society contribute, via their cultural and economical activities, to the generation of a general field of civilization" [16], consisting of political, economical, social and cultural components and determining the socio-political atmosphere and the economical situation of society. Therefore, one can argue: it is the collective field which governs the basic activities of society and, thus, could be considered as the Order parameter of society.

3 The extended concept of environment and the principle of requisite variety

When stressing the complex system-environment interaction approch to the analysis of evolving society and of their members to the qualitatively novel conditions, then — for the purposes of a detail study of human-environment interaction — the concept "environment" could be understood in line of the concept of human's three worlds, argued by Popper and Eccles [12] — the set of 1) physical and 2) mental objects and states, as well as that of 3) mental products. Thus, the concept "environment" would include a multitude of various economic-material, social, cultural and psychological conditions.

Having specified the meaning of the extended concept "environment" in the aboveconsidered sense , we subsequently acquire the capability to conclude that, according to the forementioned principle of requisite variety, the necessary condition of efficient adaptation of the individual to the new, open environment will be predominance of the human's inherent self-variety over the environmental variety. Correspondingly, it is necessary for th individuals as well as for the whole society to evolve themselve(s), in particulary, by acquiring knowledge or organized information, being considered by Kuhn and Lehman [11] as the complexity factor and envisaged in order to better comprehend human's functioning in complex environment.

Furthermore, according to the thesis [15] "these are the systems with self-learnig ability which can react with environment at two different levels", thereby to a significant degree enhancing capabilities and efficiency of adaptaton to a changing environment. Moreover, it is reasonable to consider the viewpoint argued by Keel- Sleswik [9] that just information, knowledge and meaning will be the basic ways we relate to our environment by means of SO procsses.

4 Adaptation: its role and interrelations to information, knowledge and SO

4.1 Adaptation, information and uncertainty

In order to elaborate further the concept of the inherent self-variety as well as to find out the possible routes of its enhancing, it is reasonable to develop an unified analysis of the SO, adaptation and information concepts. First of all, one should once more emphasize that both — adaptation and information — are ultimately based on such concepts as chaos and diversity: namely, the probability of adaptation occurrence as well as of information generation is basically provided by chaotic attractors. In particulary, it is just the chaotic attractor which will be able to create sufficient flexibility of behaviour due to random change of "initial conditions" [17]. Besides, information as well as adaptation will proced by means of self-selection.

Furthemore, as the next essential joint manifestation, in particulary, between chaos, adaptation and information (or its deficiency) is to be emphasized that system's adaptability will emerge from the system's ability to anticipate environmental perturbations [13, 14]. At the same time, one of the three basic adaptability components is the behavioral uncertainty component of adaptability [5]. Actually, it is just the behavioral uncertainty which will allow the system to cope with unpredictability of the environment and with its external disturbance. Thus, this last thesis clearly substantiates the necessity of non-standard and unexpected approaches and activities of individuals in the processes of choosing and achieving their economical and social goals, especially in the transition period to an open society.

On the other hand, let us note that, at the same time, adaptability is the use of information to handle environmental uncertainty [5] and is brought in, in order to replenish deficiency in the necessary information. Furtermore, the existing marked uncertainty, corresponding to a lack in necessary information, being especially strong during the transition period when there are no certain regulations and guidelines for actions, is put in the forefront of the process of generation of adequate reliable information. It is just such information which is urgently necessary for the individuals to design their activities which should be directed towards their adaptation and harmonization in the changing environment.

4.2 Knowledge, its SO and role in adaptation

Taking into account the forementionned interrelations between information, adaptation and SO, as well as the view at the concept "knowledge" as an organized form of information, one can deduce that a necessary condition of successful adaptation to qualitatively novel environment would be possessing of adequate knowledge about the world. For the problem under consideration one would be particularly reasonble to distinguish following components of the knowledge about the world [10]: a) knowledges about our own abilities (or limitations thereof), 2) possible human intentions, and c) possible relations between objects.

Moreover, knowledge as such is not only the product of SO (of information), but also proposedly is itself capable of further SO in efficient high-level forms. Namely, an essential favourable condition of origin of novel advantegous solutions of adaptation to novel conditions would be a synthesized and self-organized knowledge. Thus, knowledge synthesis and integration in the form of interdisciplinar knowledge would be basis of emergence of a knew, higher-level knowledge about complex current O On the other hand, as argued by [7] "the SO of the work which roots in creative man, but transcends him becomes evident is the structure of knowledges no less than the structures of art".

4.3 Informational stressors and self-organization

In particular, such adaptation proceeds by means of SO processes being initiated by small internal and/or external(environmental) perturbations or stressors. As the most important informational stressors or agents should be distinguished the following ones: 1) the lack in available information being necessary in order to plan subsequent activities, 2) the prevalence of infoemation which is subjectively negative for the particular individual, and 3) the necessity for information processing in a too limited time-interval. These informational stressors manifest themselves as actual factors of emergence of considerable psychoemotional stress, with a subsequent unfavourable effect on the individual's viability, health and capability to perform a qualitative and efficient job. In general, the problem of beneficial adaptation to such information stressors is to be regarded as one of the key elements of harmonization of the human's Self in a crucially changing stressful environment.

5 Variety Of Adaptation Manifestations In The Transition Process To The Openess

5.1 The two levels of an adaptation process

Further, let us take into account the thesis, proposed by Ashby, of a self-organizing system as a system consisting of an organism and of its environmental medium. In the present problem under consideration — about the socio-eonomic evolution of society and its members — it will be the following complex parameter, namely — the environmntal novelty — which is driving the SO processes of the whole society as well as of its members — individuals — to a crucially distinguishing open system and correspondingly emerging requirements. In particulary, the environmental novelty is formed by two distinguishing phenomena: (a) the processes being arisen due to the transition from a closed to an open environment in a local area of the human's Self, and (b) by the second-level adaptation of the local environment (the elementary structure of the newly forming society) to the prevailing environment on the global scale.

As the most urgent element of the first, i.e., (a), of these two abovementiond phenomena one can specify the following one: the individual's social, economical and psychological adaptation to the demands of competition and cooperation as the necessary prerequisites of it's successful functioning and survival in conditions of environmental openess and competiveness. Moreover, the fact that these basic principles of socio-economical system in an open, market-type society, namely — cooperaion and competition — correspond to the key principles of SO of forming new systems, substantiates, therefore, the appropriateness of synergetical approach to the problem of a human's adaptation to an open society and socio-economical system.

On the other hand, the basic feature of the second, i.e., (b)-type phenomena, consist in the dual nature of the local environment — such environment presents itself simultaneously as 1) the adaptation target, as well as 2) an adapting subject. Therefore, it is reasonable to expect that just on this level there will be manifested synergic coadaptation of the human's Self and of his local environment to global environment and of its corresponding requirements, to which are faced up the evolving society and its particular members.

5.2 Mutual interrelations between passive and active adaptation

In view of the occurrence of such multilevel adaptation which characterizes the procsses of socio-economic development in the transition countries as well noting the viewpoint [15] about the system with self-learning ability as reacting with environment at two different levels, it is reasonable to set up the problem of mutual interrelation of a pure or passive adaptation to existing environment (namely: the system is mainly evolving in the environment) and an active adaptation (or self-creativity), where the system evolves its environment. For the problem of harmonious involvement of a human into a changing socio-economic environment would be essential a following moment [15]: between "traditional stabilizing adaptation and the active self-creativity various tensions exist", which have harmonizing functions and are manifested most eficiently just at the border between the passive adaptation and active adaptation. Just this border region is characterized by an optimal flexibility which is necessary for beneficial multilevel coadaptation of individuals and of their environment. Actually, a human should, on the one hand, to adapt to the novel socio-economic environment, but, on the other hand, he should at the same time to create by himself such environment, in order to provide maximally favourable conditions for the system to accomplish efficient adaptation and evolution. Therefore, by considering the problems of socio-economic development of a new type of society and of harmonization of its members to the novel complex environment, pronouncely emerges a fundamental problem of mutual interrelation of active and passive adaptation.

6 Harmonization To A Changing Environment: essence and principles

6.1 Self-creativity as active adaptation factor

In particulary, the capabilities of an evolving system to be in harmony with a changing environment will depend on the mutual interrelations between the active self- creativity, information and adaptation. Because one of the necessary requirements of successful involvement of a human in the novel socio-economic environment consists in breaking of the previous stereotypes of economical thinking and development of nonlinear, flexible and integral thinking, such an evolution of the human's approach to the forming process of his interrelations with the novel socio-economic environment could be regarded, according to Banath'ies proposal [3], as creative reaching out of the system's own boundaries, where "under self-creativity and adaptability self-organizing system will reach the upper limit of the ordinary environment at the end of evolution by gradual and sudden changes and finally break the limits of ordinary environment" [15]. The importance of such flexible and creative approach one could be emphasized by the fact that markets, as argued by Allen and Phong [1], will always drive themselves to edge of predictability , and, therefore, first of all, one should learn to manage the changes in the economic environment. Moreover, Crutchfield [6] argued that there exists a following fundamental tendency of most of complex systems — to behave between chaos and order, to move at the border between structure and ucertainty. Therefore, just on such border region between the traditional status (the order or structure) and the novel and still yet uncertain factors, will most likely emerge the necessary high flexibility and efficient adaptability, and, in general, sufficient level of complexity and self-variety of the developing system.

6.2 Current problems of education optimization

Practical improvement of human adaptation to novel environment and of their competence in different areas and, therefore, the readiness to cope with currrent problems is one of the basic tasks of contemporary education at all levels and, thus, the main objective of an efficient optimization of education system. Here there one is reasonable to distinguish (conventionally) three basic levels of education:

1) primary and secondary school level — the main emphasis proposedly is to be put on development of individuals' capability of creative, non-standard approach to solving of complex problems, and, in general, of such mental characteristic as integral thinking. The possible route of achieving such capabilities would be intesive development and training of right-hemisphere functions of our brain, by means of lessions in different arts;

2) high and higher school level — optimization of education programmes, taking into account the current and future needs, as well as strengthening of international cooperation with developd countries, participation in international education and research programmes and networks;

3) the adult education — the most significat problem, in view of the urgent necessity to carry out the basic reforms within as short as possible time-period, with the main emphasis — to provide the individual with such general education basis, which would efficiently succeed to acquiring of several specialities, requalification and efficient competiveness in the job market.

7 Conclusion

Having revealed and analyzed the nature of some of the basic problems of human's involvement in a new, open socio-economical world, it is worthwhile to emphasize that C.Godel and, thereafter, G.Chaitin [4] have proven that even simple problems can have answers so complicated that they contain more information than the human's entire logical pattern. Correspondingly, it is reasonable to expect beneficial results from a further elaboration of the foreconsidered nonlinear approach, in particularly, the joint integral analysis and the use of concepts of self-organization, information, adaptation and creativity as well as analysis of their mutual interrelations, in order better to comprehend and solve vital contemporary human problems, for example, the problem of adaptation to the novel socio-economic environment, which, in turn, itself is being formed during the transition process to a qualitatively distinguishing state's system. As one of the key elements of an individual's efficient adaptation of such type would be elevation of his self-variety by evolving his knowledge system, in particularly, about the environment in its wide sense (taking into account that such evolving is a typical feature of the developing system), as well as creative, flexible use of this knowledge, with the tendency to develop not only an open, but also an informational society, which would elevate economical processes to a totally new level [7].

References

[1] Allen, P. and Phong, H. (1993). Evolution, creativity and intelligence. In Herman Haken, editor, Interdisciplinar Approaches To Nonlinear Complex Systems, 12–31, Springer, Berlin.

[2] Ashby, W.R. (1959). The Introduction to Cybernetics (in Russian). Inostrannaya Literatura, Moscow.

[3] Banathy, B. (1993). From evolutionary creativity to guided evolution. World Futures, 36, 73–79.

[4] Chaitin, G. (1987). Information, Randomness and Incompleteness. World Scientific, Singapore.

[5] Conrad, M. (1983). Adaptability. Plenum Press, New York.

[6] Crutchfield, J. (1991). Reconstructing language hierarchies. In H.Atmanspacher and H.Scheingraber, editors, Information Dynamics, Plenum Press, New York.

[7] Jantsch, E. (1980). The Self-Organizing Universe. Pergamon Press, Oxford.

[8] Jaynes, E. (1985). Macroscopic prediction. In Herman Haken, editor, Complex Systems — Operational Approaches In Neurobiology, Physics and Computers, 254–269, Springer, Berlin.

[9] Keel-Sleswik, R. (1992). Artifacts in software design. In C.Floyd et al., editors, Software Development and Reality Construction, 168–188, Springer, Berlin.

[10] Kobsa, A. (1984). Knowledge representation: a survey of its semantics, a sketch of its semantics. Cybernetics and Systems, 15, 41–89.

[11] Kuhn, H. and Lehman, U. (1984). Transition from the non-living state into living state. In R.K.Mishra, editor, The Living State, 300–317, Delhi.

[12] Popper, K. and Eccles, J. (1977). The Self and Its Brain. Springer, Berlin.

[13] Rosen, R. (1985). Anticipatory Systems: philosophical, mathematical and methodological foundations. Pergamon Press, Oxford.

[14] Salthe, S. (1992). Hierarchical self-organization as the new post-cybernetic perspective. In G.van de Vijer, editor, New Perspectives on Cybernetics: Self- Organization, Autonomy and Connectionism, 49–58, Kluwer, Dordrecht.

[15] Tao, H. (1993). The structure of Multistasis: on the evaluation of self-organizing systems. World Futures, 37, 1–28.

[16] Weidlich, H. (!991). Physics and social science — the approach of synergetics. Physics Reports, 240, 1–163.

[17] Zak, M. (1990). Creative dynamics approach to neural intelligence. Biological Cybernetics, 64,15–23.

On the Performance of Back-Propagation Networks in Econometric Analysis

Montserrat Guillén and Carlos Soldevilla
Dept. Econometria, Estadística i Economia Espanyola, Universidad de Barcelona
Tte. Cor. Valenzuela, 1-11. 08034 Barcelona, Spain
Phone: (343) 402 14 09, Fax: (343) 402 18 21
E-mail: guillen@riscd2.eco.ub.es, csolde@riscd2.eco.ub.es

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Neural networks may be applied in the context of econometric analysis, both when discussing issues that have traditionally been attached to multivariate analysis and in the field of time series. This paper compares the performance of backpropagation networks with classical approaches. Firstly, an example in banking is presented. The network outperforms discriminant analysis and logistic regression when conditional classificafion error is considered. Secondly, the identification of simple stationary time series is analyzed. Some series following simple autoregressive, moving average schemes were simulated, and the network successfully identified them. Conclusions are presented in the closing section.

1 Introduction

To date, neural networks techniques have been applied in many areas, such as pattern recognition, robotic control and decision making [6], [16]. In the field of applied economics and econometrics, the experience is still recent and rather short (see, for example, [1], [2], [4], [9] and [15]). In this respect, several outstanding contributions that relate neural networks and statistical analysis ([10], [11]) must also be cited.

Artificial neural networks mimic the neurophysical structure of the brain using mathematical models and interaction algorithms. Every neural unit in this process transforms input signals into a single output, that is transmited to other elements. Interconnections are constantly adjusted throughout the learning process.

In the first step, every signal is multiplied by its corresponding connection weight. The sum of these products is called the *net input.* In the second step, an *activation function* converts the input into a *net output* signal. Typically, two kinds of *activation functions* are used for this purpose: step functions, that compare the *net input* to a certain threshold, and sigmoidal functions, that allow for a non linear relationship.

Although several authors are successfully applying neural network models in the context of applied economics, some of those situations had already been discussed using classical statistical or econometric methodology (see [1] and [4]). Studies tend to either apply neural networks without comparing their performance with other methods or similarities with traditional statistical techniques, in a theoretical framework.

This article is concerned with artificial neural networks for data analysis. The aim of our paper is twofold: a) A comparison between Discriminant Analysis, Logistic Regression and a Neural Network approach, will be discussed using a classical data set in the field of banking. b) The performance of a neural network model when identifying the structure of a time series, given the ACF (Autocorrelation function) and the PACF (Partial-autocorrelation function) will also be studied.

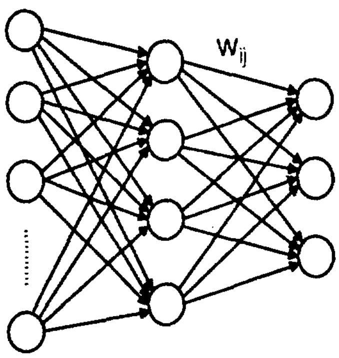

Figure 1. Structure of a feed-forward network.

2 Feed-Forward Neural Networks and Statistical Methods

Several types of neural network models are available. This paper concentrates on *feed-forward* networks, which have the following structure: neural network processing units are grouped in three (or more) layers. The input layer directly receives information from input data, hidden layers connect input and output layers and, finally, the output layer provides output information. Figure 1 shows the simple topology just described. An extensive treatment of the relationship between neural networks and graph theory may be found in [2].

A network learning process aims to find the "optimal" connection between input and output. Given P vectors $(x_1, y_1), \dots (x_P, y_P)$, where x_i is the input data and y_i the corresponding output data, with an unknown correspondence:

$$Y = \phi(X): \quad X \in \Re^N, Y \in \Re^M,$$

an algorithm must train the network, so that $\phi^*(\cdot)$, an approximation of $\phi(\cdot)$, is found.

Weights w_{ij} are calculated in order to minimize the approximation error. Quadratic errors, i.e.,

$$\sum_{i=1}^{P} (\phi^*(x_i) - y_i)^2$$

are usually considered.

One of the most popular algorithms that has been used successfully in many applications is the *backpropagation learning algorithm* in a *feed-forward* network [11]. It is based on numerical methods for several variable functions. By starting at the output, the algorithm modifies the weights in order to reduce the observed prediction errors using a sweeping backwards process. This process is repeated with each new input-output combination and along several iterations all over the learning sample until a certain precision criterium is met. After the training process, the network must be able to generalize and predict the output of a new input.

The basic idea underlying the standard backpropagation algorithm is as follows: given an input data set and starting values for the weights relating the layers, the output values are calculated (fitted). The error function is also computed. In the next step, the weights are slightly modified (proportionally on the derivative of the error function with respect to the w_{ij}). Iterations (cycles) are repeated until the error is small enough. Details about this algorithm and some modifications that accelerate its convergence are available in [13].

The backpropagation algorithm has proved to be very efficient in multi-layer networks, especially when input and output are non-linearly related. Differences between the neural network approach and the statistical methodology have extensively been discussed in [10] and [12]. Essentially they agree on the fact that, although neural networks are useful for statistical applications they remain as black boxes predicting rather than explaining.

Here, we are going to overview some examples of typical statistical models and their corresponding neural network counterparts. A Simple Linear Regression may be represented by a neural network with a unit in the input layer (taking the input from the independent variable), a single output unit and an activating function equal to the identity. Figure 2 shows this kind of structure. Its generalization to Multiple Linear Regression is easily acheived by increasing the number of input neural units.

Whenever activating functions equal to step functions are used, the network corresponds to Discriminant Analysis scenario. Moreover, when taking logistic functions in the structure shown in Figure 3, the equivalent to a logistic model is found. In logistic regression, the behaviour of a dichotomous dependent variable (output) is modelled so that its probability of being equal to one, P_i, depends non-linearly on a linear combination of covariates:

$$P_i = \frac{1}{1 + \exp(\beta' x_i)} \quad (1)$$

where β is a vector parameter [7].

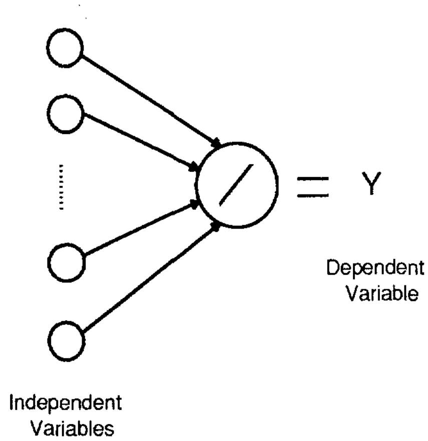

Figure 2. Linear Regression Neural Network

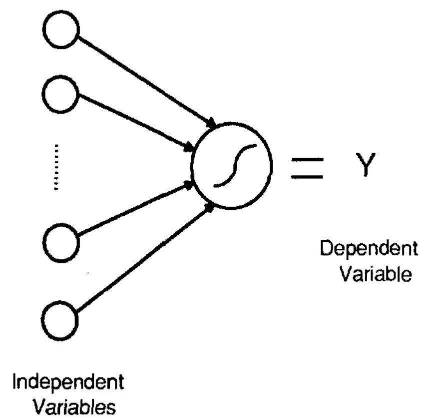

Figure 3. Logistic Regression Neural Network

Altman *et al.* [1] claim that *"neural networks are not a clearly dominant mathematical technique compared to traditional statistical techniques, such as discriminant analysis"*. These authors recommend to use both approaches in tandem. There seems to be a general agreement in encouraging balanced discussions that not only show advantages and disadvantatges, but that compare the performance of a neural network modelling against classical statistical methodologies. In fact, a similar controversy arose, some years ago, when discrete choice models (logit and probit) entered the econometric scene, as a novel alternative to multivariate analysis.

In Application 1 we are going to study the performance of an artificial neural network, and compare its results with those obtained using standard techniques. It is well known that Discriminant Analysis is based on strong statistical hypothesis about the distribution of the explanatory variables, while Logistic Regression introduces a specification restriction with the use of the link function in equation (1).

Application 2 will be devoted to a completely different problem, where no alternative statistical procedure is widely accepted. The identification of the autocorrelation function patterns in time series analysis has traditionally been based on expertise, due to the poor performance of alternative approaches. Results from a neural network analysis will be shown.

3 Application 1: Interest Rate Choice

An important decision process in the context of banking is choosing between fixed and adjustable rate mortgages. This issue has been discussed by several authors ([5], [14] and the references therein). In the theoretical literature, some authors agree on the fact that individual characteristics do not influence the choice, but that the terms of the contract do. Others suggest that, in the presence of asymmetric information, borrowers' characteristics may have a potencial impact on the decision choice. A straightforward method to study this problem is either Discriminant Analysis or Logistic (or Probit) Regression.

3.1 The Data

The sample includes 78 loans from a USA national mortgage banker collected over the time period January 1983 to Febreary 1984. Details about the data set may be found in [5]. The variables considered are the following:

Dependient variable:

ADJ: Dichotomous, equals 0.5 if the client chooses and adjustable interest rate and -0.5 otherwise.

Exogeneous variables indicating market and contract characteristics:

FI: Fixed interest rate.

MAR: Margin on the adjustable rate mortgage.

YLD: Difference between the 10-year Treasury rate less the the 1-year Treasury rate.

PTS: Ratio of points paid on adjustable to fixed rate mortgages.

MAT: Ratio of maturities on adjustable to fixed rate mortgages.

Exogeneous variables indicating personal characteristics:

BA: Age of the borrower.

BS: Number of years of school.

FTB: Dichotomous, equals 1 if the borrower is a first-time homebuyer, 0 otherwise.

CB: Dichotomous, equals 1 if there is a co-borrower, 0 otherwise.

MC: Dichotomous, equals 1 if the borrower is married, 0 otherwise.

SE: Dichotomous, equals 1 if the borrower is a self-employed, 0 otherwise.

MOB: Number of years at present address.

Exogeneous variables indicating economic characteristics:

NW: Net worth of the borrower.

LA: Liquid assests.

STL: Short-term liabilities.

As suggested by Serrano [14] and using graphical plots, it can easily be seen that there is an outlier observation that may distort the analysis. Therefore, this observation was eliminated from the study.

Following [4], a Stepwise Discriminant Analysis and a Stepwise Logit were used to select the variables to be included in the models. Finally, only eight variables, were used in the specification (FI, MAR, PTS, BA, CB, SE, LA and STL). Since variable ranges were very dissimilar, the following scaling was needed:

$$x^*_{ij} = \frac{x_{ij} - \min X_i}{\max X_i - \min X_i},$$

where x_{ij} is observation j for variable i and X_i is the vector of all observations of variable i.

3.2 Results

The learning set was formed by randomly selecting 50 observations. Figure 4 reproduces the structure of the neural network that was used for this purpose: 8 units in the input layer, 3 units in the hidden layer and 2 output units. In fact, outputs were taken to be (ADJ_i, -ADJ_i).

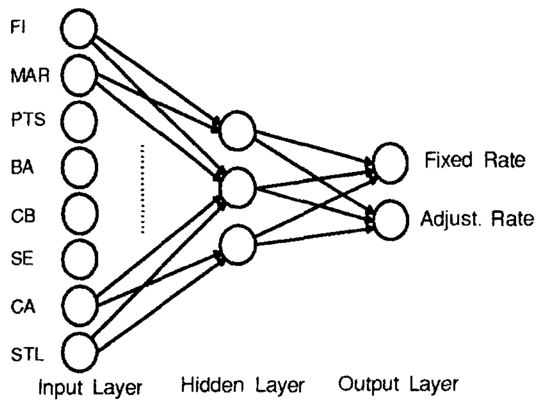

Figure 4. Neural Network for Interest Rate Choice.

Using the Aspirin/MIGRANES software [8] on an IBM Risc/6000 machine, and after iterating, the conditional classification rates shown in Tables 1 and 2 were obtained. The backpropagation algorithm described above was used and the learning process took 4,000 cycles. The results indicate that the learning set was correctly classified and that, for example, 27.2% of the clients that chose an adjustable interest rate were classified incorrectly in the test set.

	Predicted	
Observed	Adjustable rate	Fixed rate
Adjustable	100.0%	0%
Fixed	0%	100.0%

Table 1: Classification rates for the learning set

	Predicted	
Observed	Adjustable rate	Fixed rate
Adjustable	72.7%	27.2%
Fixed	12.5%	87.5%

Table 2: Classification rates for the test set

Table 3 shows the conditional classification results in the overall sample for every method, i.e., neural network (NN), discriminant analysis (DA) and logistic regression (LR).

		Predicted	
Observed		Adjustable rate	Fixed rate
Adj.	NN	90.6%	9.4%
	DA	84.3%	15.6%
	LR	84.3%	15.6%
Fix.	NN	4.4%	95.5%
	DA	20.0%	80.0%
	LR	11.1%	88.8%

Table 3: Classification rates for the data set

3.3 Discussion

As shown in Table 3, the prediction performance of the neural network is better in the group of customers that chose a fixed interest rate than in the group that chose an adjustable rate. It is also the method with least classification error, both globally and conditionally. Of course, the classification rates in the classical methods may be improved by optimizing the classification threshold, but results do not vary substantially.

We conclude that, in this example, a neural network approach is recommended when the prediction performance is crucial. On the other hand, the structure of the network does not allow to identify the relative importance of each input variable in the decision process, and therefore, does not allow to test the hypothesis of individual characteristics influencing the choice.

This application leaves some room for further research, such as the effect of not excluding the outlier observation in the data set and the behaviour of the network in the presence of sample selection.

4 Application 2: Time Series Identification

Box-Jenkins analysis of time series is based on the identification of the ARIMA process by recognizing the theoretical pattern of the Autocorrelation (ACF) and Partial-autocorrelation (PACF) sample functions (see, [7]). By examining a plot of those functions, it is possible to classify an observed time series into a type of ARIMA model.

In econometric analysis time series are usually short, therefore, sampling variability makes it difficult to identify the model. A lot of experience, and sometimes several attempts, are needed to correctly classify the series. Identification is not only important for prediction purposes, but also as an explanatory tool of the economic trends.

4.1 The Data

We focussed on a limited amount of ARIMA models. So, we chose first and second-order stationary autoregressive schemes (i.e., AR(1) and AR(2)), and first and second-order invertible moving average schemes (i.e., MA(1) and MA(2)). We took the first eight values of both the ACF and the PACF, because they are usually enough to recognize the time series structure. So, 16 values were the input to the neural network model.

Since an AR(1) model with positive parameter has a decreasing ACF, which is similar to the behaviour expected for a MA(1), the output layer distinguished between positive and negative parameters in the first-order models. Therefore, the network used 6 output neural units in the output layer. Figure 5 shows the neural network structure used to dentify the series.

4.2 Results

The learning set for the network was formed by the theoretical values of the ACF and the PACF for models AR(1) and MA(1), with parameters $-0.9, \ldots, -0.1, 0.1, \ldots, 0.9$. For second-order models, parameters were chosen such that

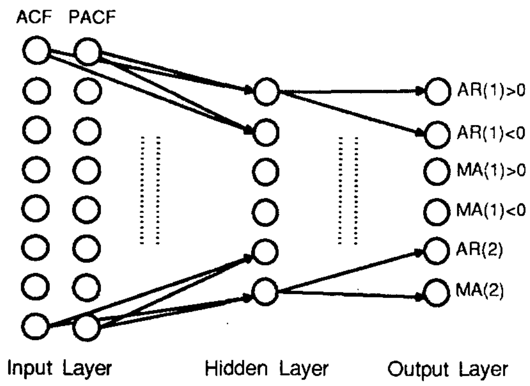

Figure 5. Neural Network for Time Series Identification.

	Predicted model			
	AR(1)	MA(1)	AR(2)	MA(2)
AR(1)	2	.	.	1
AR(1)	1	.	.	.
AR(1)	1	.	.	.
MA(1)	.	2	.	1
MA(1)	.	1	.	.
MA(1)	.	1	.	.
AR(2)	.	.	1	.
AR(2)	.	.	1	.
AR(2)	.	1	2	.
MA(2)	.	.	.	1
MA(2)	.	.	.	1
MA(2)	.	.	.	1

1, 2 indicate first and second prediction choice

Table 4: Prediction results for the test set.

stationarity and invertibility conditions were satisfied. The first parameter was equal to $-1.5, -1, \ldots, 1, 1.5$, and the second parameter was equal to $-0.75, -0.5, -0.25, 0.25, 0.5, 0.75$. The learning set had 80 observations, each one being a 16-component vector.

The test set was created with the simulation of 16 time series of 2,000 observations. The net correctly classified the series in the training set and was wrong in classifying a MA(2) series as a MA(1) model in the test set.

Finally, 12 series of 200 observations were simulated, three series for every model under consideration. The experiment consisted in obtaining a classification from the network and another from an expert in the field. As a result, the expert correctly identified all the time series. The network incorrectly classified 3 series, which means an error of 25%, although using a distance based on the sign, the second best choice was always the correct one. These results are shown in Table 4.

The simulations were done on an IBM Risc/-6000 machine using the Aspirin/MIGRANES software [8], the backpropagation algorithm and a network with six units in the hidden layer.

4.3 Discussion

Results seem to be promising, the network performs correctly in recognizing the ACF and PACF patterns. We think that a larger amount of values of the ACF and PACF in the input layer may improve the results and make them similar to the conclusions given by a human expert. The elimination of extreme observations in the learning set (such as AR(1) with a 0.1 parameter) may also improve the neural network performance.

5 Concluding Remarks

Although somehow limited in scope, our study covers two main areas in econometric analysis. Our aim was to evaluate the capability of a neural network to provide new insights in this context.

The first application compares the classification results with those of tradicional methods, but there is a need to further study the statistical robustness of a neural network model against some typical statistical problems, which have already been discribed in the discussion.

The second application shows that pattern recognition is also a necessary tool for economists, so that any advance in this area will be welcome.

6 Acknowledgements

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References

[1] Altman, E.I., Marco, G. and Varetto, F. (1994) "Corporate distress diagnosis: Comparisons using linear discriminant analysis

and neural networks (the Italian experience)". *Journal of Banking and Finance*, Vol. 18, 505-529.

[2] Gil Aluja, J. and Kaufmman, A. (1996) *Grafos Neuronales para la economía y la gestión de empresas.* Ed. Pirámide.

[3] Anguita, D. (1993) "MBP-Matrix Back Propagation v1.1 User's Manual". *DIBE-University of Genova. Via Opera Pia 11A. 16145 Genova. ITALY.*

[4] Brockett, P.L. and Cooper, W.W. (1994) "A Neural Network for Obtaining an Early Warning of Insurer Insolvency". *Journal Risk and Insurance*, Vol. 61, N. 3, 402-424.

[5] Dhillon, U.S., Shilling, J.D. and Sirmans, C.F. (1987) "Choosing between Fixed and Adjustable Rate Mortgages", *Jounal of Money, Credit Banking*, Vol. 19, N. 1, 260-267.

[6] Freeman, J.A. and Skapura, D.M. (1991) *Neural Networks, Algorithms, Applications and Programming Techniques*, Addison-Wesley.

[7] Greene, W.AH. (1993) *Econometric Analysis*, MacMillan Publishing Co.

[8] Leighton, R.R. (1992) *The Aspirin/MIGRAINES Neural Network Software.*

[9] Otero, J.M. and Trujillo, F. (1993) "Predicción multivariante y multiperíodo de una serie temporal económica mediante una red neuronal" *Estadística Española*, Vol. 35, N. 133, 345-375.

[10] Ripley, B.D. (1994) "Neural Networks and Related Methods for Classification". *Journal of the Royal Statistical Society*, B, 56, 3, 409-456.

[11] Rumelhart, D. E., Hinton, G.E. and Williams, R.J. (1986) "Learning Representations by Backpropagatins Errors", *Nature*, Vol. 323, 533-536.

[12] Sarle, W.S.(1994) "Neural Netwoks and Statistical Models". *Proceedings of the Nineteenth Annual SAS Users Group International Conference.*

[13] Schiffman, W., Joost, M. and Werner, R. (1993) "Optimization of the BackPropagation algorithm for training multilayer perpectrons". Technical Report, University of Koblenz, Institute of Physics.

[14] Serrano, G.R. (1994) "Estadísticos para la detección de observaciones anómalas en modelos de elección binaria: una aplicación con datos reales". *Symposium de Análisis Económico. Universidad Autónoma de Barcelona.*

[15] Serrano-Cinca, C. (1996) "Beyond Z-Analysis: Self Organizing Neural Networks for Financial Diagnosis", *Decision Support Systems*, accepted for publication.

[16] White, H. (1992) *Artificial Neural Networks. Approximation and Learning Theory*, Ed. Blackwell Publisher.

The Challenge of Integrating Knowledge Representation and Databases

Paolo Bresciani
Istituto per la Ricerca Scientifica e Tecnologica
via Sommarive 18, I-38050 Povo (Trento), Italy
Email: bresciani@irst.itc.it

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Two different aspects of data management are addressed by Knowledge Representation (KR) and Databases (DB): the semantic organization of data and powerful reasoning services by KR, and their efficient management and access by DB. It is recently emerging that experiences from both KR and DB should profitably cross-fertilize each other, and a great interest is rising about this topic. In particular, among several ways to approach knowledge representation, Description Logics (DL) are gaining, in the last years, a privileged place. In this paper, after briefly showing the importance of an integrated view of description logics and databases, our approach to this topic is presented. Our technique allows uniform access – by means of a DL-based query language – to information distributed over knowledge bases and databases. The separately existing retrieving functions of description logics management systems and of database management systems are integrated, in our extended paradigm, in order to allow, via a query language grounded on a DL-based schema knowledge, uniformly formulating and answering queries and, thus, uniform retrieval from mixed knowledge/data bases.

1 Introduction

Traditional Information Science applications that need the storage and management of large amounts of data rely on database tools, while AI applications that need the managing and reasoning about more structured data – like for example expert systems applications, natural language interfaces [12], decision support systems – rely on knowledge representation systems.

In fact, the main difference between knowledge representation and database systems is that the latter are oriented to the efficient management of large amounts of data, while the former seeks to give a more structured representation of the universe of discourse in which data are placed. More specifically, in some knowledge representation systems the application domain is described by means of a collection of complex terms – or *concepts* – that are placed into a taxonomy. The capability of *classifying* concepts to form taxonomies, accordingly with well defined semantics, is given by an appropriate calculus, whose first goal is to provide a *subsumption* algorithm. Concept languages together with semantically grounded subsumption calculi are called description logics.[1] Databases, instead, are suited to manage data efficiently, with little concern about their dimension, but the formalism for organizing them in a structured way is quite absent, as well as the capability to infer new information from that already existing. Thus, two different aspects of data management are addressed by Description Logics Management Systems (DLMS) and by Database Management Systems (DBMS): the semantic organization of data by DLMS, and their efficient management and access by DBMS.

[1] Description logics are the most recent formalization of a family of knowledge representation languages and systems, known with several but almost equivalent names, as, e.g., Conceptual Languages, Terminological Logics, KL-ONE-like Systems [10], etc.

The importance of knowledge representation in general has been regarded as fundamental for the construction of good Intelligent Information Systems [17] for more than ten years (see, e.g., [31]), but only recently the theoretical foundations of a uniform approach to description logics and databases have been established [18].

From another point of view, KR-based applications and, more generally, AI-based applications can be widely enhanced by AI/DB interfaces [28, 26].

More in general, it is recently emerging that experiences from both KR and DB should profitably cross-fertilize each other, and a wide interest is rising on this topic (see [2, 3, 4]).

In this paper, description logics are considered as a privileged knowledge representation formalism, and it is proposed to deal with both description logics and databases together, using them in an integrated way, to manage different kinds of information. Of course, a uniform way to retrieve information from mixed knowledge/data bases is needed. Thus, it is shown how this task can be performed in a way completely transparent to the user. To this end, a semantically sound linking between the DL knowledge bases and databases is needed. Within the technique here presented, this is achieved by *tightly coupling* DLMS and DBMS [8].

In Section 2 a very brief and informal introduction to description logics is given. Then, in Section 3, some application fields of DL and DB, that can get advantages by using a uniform approach, are presented. Section 4, the main part of the paper, describes our technique for uniformly accessing – by means of a DL-based query language – information distributed over knowledge bases (KB) and databases. Some conclusive notes are conveyed in Section 5.

Construct	FOL Semantics
(NOT C)	$\neg F_C(\gamma)$
(AND C D)	$F_C(\gamma) \wedge F_D(\gamma)$
(OR C D)	$F_C(\gamma) \vee F_D(\gamma)$
(ALL R C)	$\forall x.F_R(\gamma, x) \Rightarrow F_C(x)$
(SOME R C)	$\exists x.F_R(\gamma, x) \wedge F_C(x)$
(FILLED-BY R a)	$F_R(\gamma, a)$
⋮	⋮
(INVERSE R)	$F_R(\beta, \alpha)$
(COMPOSE R Q)	$\exists x.F_R(\alpha, x) \wedge F_Q(x, \beta)$
(AND-ROLE R Q)	$F_R(\alpha, \beta) \wedge F_Q(\alpha, \beta)$
⋮	⋮

Table 1: FOL transformational semantics for a sample DL.

2 Description Logics

Description logics are, essentially, variable-free concise reformulations of decidable restricted parts of First Order Logic (FOL). The syntax of DL is aimed to allow to define *concepts* (unary relation symbols), *roles* (binary relation symbols), and *individuals* (constants). FOL atomic sentences about constants can be expressed in DL by saying that an individual is an *instance* of a concept, or that a role holds between two individuals. In different DL slightly different languages are used, with different levels of expressiveness. In all of them [21] complex concepts (and in some also complex roles) can be built starting from the atomic ones using different sets of operators to form *term descriptions*. Typical concept-forming operators are AND, OR, NOT, ALL, SOME, FILLED-BY; typical role-forming operators are INVERSE, COMPOSE, AND-ROLE. In the following, an intuitive LISP-like syntax for a generic DL will be used.

Description logics semantics can be briefly given by mapping DL expressions into FOL formulæ [18], as well as by a direct set-theoretic interpretation. Of course, these semantics are equivalent. We briefly give, here, the FOL transformational semantics: an atomic concept A, an atomic role P, and an individual a are respectively mapped – or *interpreted* – to the FOL open atomic formulæ $A(\gamma)$, $P(\alpha, \beta)$, and to the individual constant a. In table 1 for some DL complex concepts C the corresponding FOL open formulæ (with one free variable) $F_C(\gamma)$ are recursively given; similarly, for some DL complex roles R the corresponding FOL open formulæ (with two free variables) $F_R(\alpha, \beta)$ are recursively given.

For example, and very intuitively, the concept:

```
(AND
  Person
  (FILLED-BY has-sex FEMALE)
  (SOME has-children Person)
  (ALL has-children
       (AND
         Person
         (FILLED-BY has-sex MALE))))
```

denotes the class of mothers with only male children.[2] In every DLMS new atomic concepts can be *defined* by giving names to concept expressions. In this case, of course, their semantics are those of their defining expressions. Also, *primitive* definitions can be formulated: a primitive definition gives only necessary but not sufficient conditions for an individual to belong to the primitively defined concept; that is, it cannot be inferred that an individual belong to a primitively defined concept unless it is explicitly asserted that it belongs to it or to a more specific concept in the taxonomy.[3] In other words, the semantics of a primitively defined concept is only partially given by the semantics of the primitively defining expression, and can be completed with any arbitrary restriction. A primitively defined concept (role) is simply called a *primitive concept* (*primitive role*).

For example, the previous concept expression could be the definition of `Mother-with-only--male-children`. Also the concepts `Mother` and `Woman` could be defined, as follows:

```
Mother ≐ (AND
           Woman
           (SOME has-children Person))

Woman ≐ (AND
          Person
          (FILLED-BY has-sex FEMALE)).
```

For each interpretation that is given to the atomic terms `Person`, `has-sex`, `has-children` (bound to no definition), and to the individuals `FEMALE`, and `MALE`, it is always the case that the class `Mother` includes the class `Mother--with-only-male-children`, as can be correctly checked by any DLMS whose language comprises the operators used in the example. It is said that `Mother` *subsumes* `Mother-with-only-ma-le-children`.[4] The operation of organizing terms in a taxonomy based on subsumption is called *classification*.

Except for trivial cases, classification cannot be automatically performed in the entity relationship models of databases, even when concerning object oriented databases. On this respect, as it will be shown below, description logics can be useful in databases applications. On the other hand, DLMS are less efficient than DBMS in managing data about individual entities.

Typically, a DLMS contains not only a term definition module (TBox) – where concepts (and roles) definitions like those shown above are managed and classified – but also an assertional module (ABox) – where *assertions* about individuals are stated. Thus, relatively to the previous example, the following can be *asserted* in the ABox:

```
Person(SUE)
has-sex(SUE,FEMALE)
Person(TOM)
has-sex(TOM,MALE)
has-children(SUE,TOM)
```

that means that the individual `SUE` is an instance of the concept `Person`, the role `has-sex` holds between the two individuals `SUE` and `FEMALE`, and so on. From this, `Mother(SUE)` and – under the so called *closed world assumption* (CWA)[5] – `Mother-with-only-male-children(SUE)` follow.[6] This kind of inference is called *realization*.

An important tradeoff of DLMS is between the expressiveness of the description language characterizing the TBox and the inefficiency in managing large amounts of data in the ABox, even when the knowledge is organized in simple form based on primitive concepts, and, therefore, the realization is completely a-priori given. By contrast, DBMS are suited to manage data efficiently,

[2] Of course, this holds if we assume to give to the concept `Person`, to the roles `has-sex` and `has-children`, and to the individuals `FEMALE` and `MALE`, the "natural meaning" their identifiers have in English.

[3] On the contrary, of course, an individual inherits all the properties of the concept it belongs to.

[4] According to the given FOL transformational semantics of DL, it can be said that a concept C subsumes a concept D iff $\forall x.F_D(x) \Rightarrow F_C(x)$.

[5] The CWA states that there are no other instances of a concept (or pairs of a role) except those provable to be [29]. The CWA represent, indeed, a crucial difference between databases semantics (that always assume it) and description logics semantics (that typically do not assume it), and is not yet fully addressed by the research here described.

[6] Because, for the CWA, her only child is `TOM`.

with little concern about their amount, but their formalism for organizing data in a structured way is quite absent, as is the capability to infer new information from the existing one. The technique proposed in section 4 has been developed as a tool to overcome these DLMS and DBMS limitations.

3 Integrated use of DL and DB

Here, some application fields of DL and DB, where integrated approaches like the one mentioned above can be useful, are briefly listed. Far from being exhaustive, this short list can well be regarded as a sufficient motivation for going on in facing the challenge of integrating DL and DB.

3.1 Using DB for improving DL applications

DL applications can get benefits by using DB technology, for example in the following aspects.

- *Large ABox management.*
  As mentioned, the usual DLMS lack efficiency in managing large amount of data in the ABox. Our experience [12] suggests that, in realistic applications, knowledge bases not only can be complex, but can also involve a large number of individuals, difficult – when not impossible – to manage with the existing DLMS ABoxes. A large portion of data about them can be managed better by a DBMS.

- *Integrated KB and DB.*
  As noted in [8], KB based on DL are often used in applications where they need access to large amounts of data stored in already existing databases. Also in this case the approach proposed in section 4 is fruitful. A practical application of this can be found in the system TAMIC [5].

- *Knowledge Acquisition.*
  As observed in [13, 12] the task of acquiring knowledge for a real knowledge based application often includes a great amount of raw data collecting. For this subtask, instead of using ABox user interfaces, it can be more adequate to use databases, and their more robust front-ends. This is easily realizable when the paradigm proposed in the present paper is adopted.

3.2 Using DL for improving DB applications

DL can be useful in several fields of DB. Here, only the following few are listed.

- *Data Archaeology.*
  In *data archaeology* the main task is the search and extraction of previously ignored knowledge from several and possibly large databases, by means of an interactive and iterative process of analysis and refinement [11]. In this case, the use of intelligent front-ends based on DL can be helpful [20]. The use of friendly and powerful interfaces is even more important when data are widely and easily available to several kinds of users, but scarcely inter-organized and spread over several sites as in the case of the WWW [23]. In this case our architecture – that is not limited to databases access, but can be extended to more generic data collecting engines (see [13]) – can be used as a building block for defining DL mediated access systems.

- *Distributed and Heterogeneous Databases.*
  In this case the problem is to plan the optimal access to many, distributed, and eventually heterogeneous databases [22, 24]. DL is crucial on both the site descriptions meta-level, as noted in [24], and on the data level, as noted in [22]. Our paradigm can be used as a basic uniform access tool to the proposed DL/DB architecture.

- *Query Optimization.*
  This topic is worth of mention, even if the less related with our present work. Several query optimization techniques can be based on DL, both for a pure semantic organization of queries [18, 6], and as an aid for the pre-evaluation of the cardinality of queries in partially indexed databases [30].

Many other research trends on how description logics can be used for solving typical database problems are currently being explored. Two short surveys about them can be found in [15, 16].

4 DL access to DB

In the present section it is shown how assertional knowledge of DLMS and data of DBMS can be uniformly accessed from the DLMS in a way completely transparent to the user. This calls for a semantically sound linking between the DL knowledge base and the databases. It can be obtained by *coupling* DLMS and DBMS [8]: primitive concepts and relations in a KB are made to correspond respectively to unary and binary tables in a DB. In [8] two possible way to couple DLMS and DBMS are proposed:

- *loose coupling*, that requires a pre-loading of the data from the DB into the KB;
- *tight coupling*, that implements a *on demand* access to the DB;

but in the system presented in [20, 8] only the loose coupling paradigm is implemented.

Our approach, instead, is based on tight coupling of DLMS with DBMS, allowing the following advantages:

- complex compound queries (other than simply asking for the instances of a concept) can be done; for instance, conjunctive queries involving concepts and roles like $\mathtt{C}(x) \wedge \mathtt{R}(x,y) \wedge \mathtt{D}(y)$ can be done;
- no memory space is wasted in the DLMS in order to keep descriptions of DB data;
- answers are given on the basis of the current state of the KB and the DB;
- no periodical updating of the KB with new or modified data from the DB is needed.

4.1 DBox as an Extension of the ABox

The basic idea of our approach is to extend the traditional DLMS ABox with an external source of extensional data, called *DBox*.[7] By means of it, it is possible to couple the standard TBox/ABox architecture with one or more, possibly heterogeneous and distributed, databases, so that the user can make queries to this extended system without any concern on which DB or the KB have to be accessed, and the system is able to answer them uniformly.

In the following, the notation of [27] is adopted: a collection of term definitions – concepts and roles in a TBox – is called a *terminology* $\mathcal{T}$,[8] and a collection of assertions about individuals – in a ABox – is called a *world description* $\mathcal{W}$.[9] Moreover, the set of data expressed in a DBox is called a *data base* $\mathcal{D}$. Assuming that two distinct complete query answering functions exist (one for the ABox and one for the DBox), and defined a *knowledge base* as $\mathcal{KB} = \langle \mathcal{T}, \mathcal{W}, \mathcal{D} \rangle$, a uniform query function, based on the two distinct answering functions, can be implemented. No special capability is required from the DBox, except the one of (quickly) retrieving items or pairs of items satisfying requested conditions. These conditions are of the kind of *being in a class* – i.e., belonging to a unary table – or *being in relation with other items* – i.e., belonging to a binary table – and logical combinations of these, as it can be, for example, expressed in SQL.[10] Therefore, for the sake of simplicity, it will be assumed, here, that the DBox is implemented with a relational DBMS supporting SQL. Thus, in the following, tables and views are intended as usual in relational DBMS.

4.2 Coupling

Coupling the terminology $\mathcal{T}$ with the data base $\mathcal{D}$ corresponds to associating some terms (concepts and roles) of $\mathcal{T}$ with tables or views in the DB representing $\mathcal{D}$. The coupling of $\mathcal{T}$ with $\mathcal{D}$ is performed in two steps. First, a partial mapping PM between primitive terms in $\mathcal{T}$ and the tables in DB must be given. Giving a mapping of a primitive term into a DB-table corresponds to giving its extension in the DB. Let the terms for which PM is defined be called $\mathcal{D}$-terms. Then, using PM, also non-primitive concepts can be recursively mapped into views of the DB. If the expanded definition[11]

[7] *D* for data.

[8] $\mathcal{T}$ will be used to denote also the set of atomic terms appearing in $\mathcal{T}$, correctly classified in the taxonomy on the basis of their definitions.

[9] By $\mathcal{W}$ also the set of individuals described in $\mathcal{W}$ will be denoted.

[10] Of course, the external source of information, where the DBox searches for data, could be of any kind, provided only that it can be accessed via a sufficiently powerful query language (i.e., any query language equivalent to the portion of SQL used here), allowing, in this way, to manage also heterogeneous data sources.

[11] An *expanded* definition is a definition where each atom

of a non-primitive concept contains both $\mathcal{D}$-terms and non-$\mathcal{D}$-terms, the view in which the concept is mapped does not contain all the instances of the concept. Therefore, non-primitive concepts with expanded definition containing both $\mathcal{D}$-term and non-$\mathcal{D}$-term cannot be completely managed in our system.

Thus, it must be assumed that the following conditions on $\mathcal{KB} = \langle \mathcal{T}, \mathcal{W}, \mathcal{D} \rangle$ are satisfied:

1. Every table in $\mathcal{D}$ must correspond to one primitive term in $\mathcal{T}$, called $\mathcal{D}$-term; $\mathcal{D}$-terms cannot be used in the expanded definition of any primitive term in $\mathcal{T}$.

2. The expanded definitions of non-primitive concepts in $\mathcal{T}$ must contain only $\mathcal{D}$-terms or no $\mathcal{D}$-term at all.

The aim of the constraint 1 is to avoid any need of consistency checking in case of conflicts between defining concepts and those used in the definitions. If, to ensure the avoidance of such conflicts, an exhaustive checking – that could involve also the extensional analysis of DB-tables – were provided, this constraint could be released.

All the information needed to correctly drive the query answering mechanism is the association of some terms with the corresponding tables or views in the DB. To this end, it is enough to know this association for primitive terms. Thus, only a partial mapping

$$PM : \mathcal{PT} \rightarrow DBtable$$

(where $\mathcal{PT}$ is the set of primitive terms in $\mathcal{T}$, and *DBtable* the set of tables in the DB) must be given. The views corresponding to non-primitive concepts can be built via a recursive partial mapping

$$RM : \mathcal{T} \rightarrow DBtable \cup DBview$$

(where *DBview* is the *virtual* set of views in the DB) that maps DL-expressions into corresponding SQL-expressions.

In the following, to simplify the description, it is assumed that concepts are mapped into unary tables with one column called `left`, and roles into binary tables with two columns called `left` and `right`. In the implemented system, of course, translation tables provide the substitution with the true names.

As an example, assume that non-primitively defined concepts that contain $\mathcal{D}$-terms in their expanded definition are constrained to use the sub-language with the only `AND` and `SOME` operators; in this case RM can be defined as follows:[12]

RM((`AND` C D)) =

```
  SELECT DISTINCT  left
  FROM             RM(C), RM(D)
  WHERE            RM(C).left =
                     RM(D).left
```

if both $RM(C)$ and $RM(D)$ are defined;

RM((`SOME R` D)) =

```
  SELECT DISTINCT  left
  FROM             RM(R)
  WHERE            RM(R).right IN
                     RM(D)
```

if both RM(`R`) and $RM(D)$ are defined;

RM(`T`) = PM(`T`)

if $PM(T)$ is defined;

and

```
RM(T) =  SELECT DISTINCT  *
         FROM             T_1
         UNION
         ⋮
         SELECT DISTINCT  *
         FROM             T_n
```

if $M(\mathtt{T}) = \{T_1, \dots, T_n\}$, and $n > 0$.

Note that the last part of this definition (see below for the definition of M) takes into account all the tables and views corresponding to terms subsumed by `T`, whatever `T` is.

Of course RM could be extended to more general concepts, but in some cases the mapping would have to be carefully handled, due to the different semantics of DL and DB (e.g., for the

is replaced by its expanded definition recursively (if it has one). Of course, only acyclic definitions are allowed in $\mathcal{T}$.

[12]Note that `R` stands for a role name, i.e., for an atomic role in $\mathcal{T}$, while C and D stand for concept names and expressions. In general, the `TYPEWRITER` font will be used for atomic terms.

NOT and the ALL operators).[13]

Note that, due to limitations of SQL in using sub-queries, the SELECT used in the definition of RM are not exactly legal, due to the recursive application of RM. This problem can be easily overcome if a CREATE VIEW corresponds to each application of RM, and the names of the corresponding views are placed in lieu of the recursive applications of RM.[14]

The function

$$M : \mathcal{T} \rightarrow 2^{DBtable \cup DBview}$$

used in the definition of RM returns the (possibly empty) set of tables/views necessary to retrieve all the instances (pairs) of a given concept (role) from the DB, that is:

$$M(\mathtt{T}) = \{RM(x) \mid x \in subs(\mathtt{T}) \text{ and } RM(x) \text{ is defined}\}$$

where $subs(\mathtt{T})$ is the set of $\mathcal{T}$ terms classified under T. Observe that RM and M are built starting from PM; thus, it is enough to include PM in the $\mathcal{KB}$ definition: $\mathcal{KB} = \langle \mathcal{T}, \mathcal{W}, \mathcal{D}, PM \rangle$.

4.3 Query Answering

The task of answering a query can now be described. Here, it is assumed that a *query* to $\mathcal{KB} = \langle \mathcal{T}, \mathcal{W}, \mathcal{D}, PM \rangle$ is an expression of the form $\lambda\overline{x}.(P_1 \wedge \ldots \wedge P_n)$, where $P_1, \ldots, P_n$ are atoms of the form $\mathtt{C}(x)$ or $\mathtt{R}(x, y)$, where C and R are concepts and roles in $\mathcal{T}$, and each of x and y appears in the tuple of variables $\overline{x} = \langle x_1, \ldots, x_m \rangle$ or is an individual constant in $\mathcal{W} \cup \mathcal{D}$. *Answering* a query to $\mathcal{KB}$ means finding a set $\{\overline{x}^1, \ldots, \overline{x}^m\}$ of tuples of individuals such that, for each tuple $\overline{x}^i$, $\lambda\overline{x}.(P_1 \wedge \ldots \wedge P_n)[\overline{x}^i]$ holds – explicitly or implicitly – in $\mathcal{KB}$. Such tuples will be called *answers* to the query and the set of all of them the *answer set*.

From the definition of answer to a query, it is obvious that, to avoid the generation of huge answer sets, free variables must not be used, that is, each variable appearing in $\overline{x}$ must appear also in the query body. Indeed, even stronger restrictions, that allow for a more efficient management of queries than the one here presented, are adopted (see [13]).

A query, to be answered, must be split into sub-queries that can be answered by the two specialized query answering functions of the DLMS and the DBMS. To this end, a *marking* of all the possible atomic sub-queries, corresponding to the terms in $\mathcal{T}$, is needed; a term P is said to be:

- KB-marked iff $RM(P)$ is undefined;
- Mixed-marked otherwise.

This marking reflect the fact that the instances (pairs of instances) of P are all in $\mathcal{W}$, or part in $\mathcal{W}$ and part in $\mathcal{D}$, respectively. The case of queries in which the atomic sub-queries correspond all to KB-marked terms is trivial (it is enough to submit it to the DLMS answering function). The case of queries with also Mixed-marked predicates is more difficult.

Let a generic query be written as

$$\lambda\overline{x}.(P_1^{KB} \wedge \ldots \wedge P_m^{KB} \wedge P_1^M \wedge \ldots \wedge P_n^M)$$

where the P_i^{KB} correspond to the KB-marked terms, and the P_i^M to the Mixed-marked terms. This query can be split in the two sub-queries

$$q^{KB} = \lambda\overline{x}_{KB} \cdot (P_1^{KB} \wedge \ldots \wedge P_m^{KB})$$

and

$$q^M = \lambda\overline{x}_M \cdot (P_1^M \wedge \ldots \wedge P_n^M).$$

As mentioned, q^{KB} can be straight answered by the DLMS. It will be shown below how it is possible to find an answer to q^M too.

4.3.1 Translating Queries into SQL

Because each predicate in the query

$$q^M = \lambda\overline{x}_M.(P_1^M \wedge \ldots \wedge P_n^M)$$

corresponds to a view in the DB – where the answers have to be searched in addition to those in the ABox – a translation of them into equivalent SQL queries must be provided. Of course, the views can easily be found via the recursive mapping RM. For each of the P_i^M in q^M the translation into an equivalent view is simply given by $RM(P_i^M)$. Thus, the SQL query corresponding to $q_i^M = \lambda\overline{y}_i.P_i^M$ – where $\overline{y}_i$ is the sub-tuple of $\overline{x}_M$ containing the only one or two variables used

[13]See footnote 5.

[14]Of course, this requires a pre-compilation of the DB with respect to the KB, but this is not a real overload of the presented query answering mechanism.

in P_i^M – is:

```
SELECT DISTINCT   select-body
FROM              RM(P_i^M)
WHERE             where-body
```

where the *select-body* contains $RM(P_i^M)$.left, $RM(P_i^M)$.right, or both, according to the fact that P_i^M is of the kind $\mathtt{C}(x)$ or $\mathtt{R}(x, a)$, $\mathtt{R}(a, y)$, or $\mathtt{R}(x, y)$, respectively – with x and y variables, and a constant. The WHERE clause is present only if $P_i^M = \mathtt{R}(x, a)$ or $P_i^M = \mathtt{R}(a, y)$; in these cases the *where-body* is

$$RM(\mathtt{R}).\mathtt{left} = a$$

or

$$RM(\mathtt{R}).\mathtt{right} = a$$

respectively.

In this way n partial answer sets (one for each P_i^M) are obtained. Of course, the queries have to be submitted also to the DLMS, in case also some individuals of $\mathcal{W}$ satisfy them.

Now, it is, ideally, enough to get the intersection of all the partial answer sets obtained by processing the sub-queries of q^M and q^{KB}, but, due to the scope of the variables of the queries, this cannot be efficiently performed in a direct way: a *merging* of the results is needed.

4.3.2 Merging the Results

A merging mechanism for partial answer sets must be provided. In fact, in each sub-query some of the variables in $\overline{x}$ may be unbound – that is, the proper tuple $\overline{y}$ of variables appearing in the sub-query may be a sub-tuple of $\overline{x}$. Therefore, the corresponding answer set has to be *completed*, that is, each unbound variable in $\overline{x}$ – i.e., those not appearing in $\overline{y}$ – must be made correspond to each instance in $\mathcal{KB}$, for all the found answers, considering all the possible combinations. However, in this way huge answer sets would be generated.

To solve this problem, a compact representation for the answer sets is needed. Let a generic partial answer set of a sub-query be written as $AS_{\overline{y}}$, where the variables of the original complete variable tuple $\overline{x}$ missing in $\overline{y}$ are $x_{p_1}, \ldots, x_{p_k}$. Its completion can be represented in a compact way as

$$AS_{\overline{x}} = \{\overline{I}^\star \mid \overline{I} \in AS_{\overline{y}}\}$$

where each $\overline{I}^\star$ is equal to $\overline{I}$ except that it is lengthened by filling the k missing positions $p_1, \ldots, p_k$ with any marker, e.g., a star '$\star$'. The star stands for any individual in $\mathcal{KB}$. Using this representation, the *merging* of answers sets can be efficiently managed, using the following MERGE algorithm.

$$\mathtt{MERGE}(AS^1_{\overline{x}}, AS^2_{\overline{x}}, \ldots, AS^n_{\overline{x}}):$$

4.1 let result-list=$\{AS^1_{\overline{x}}, AS^2_{\overline{x}}, \ldots, AS^n_{\overline{x}}\}$;

4.2 choose two answer sets, AS_1 and AS_2, in result-list, where answers have at least one common position filled by individuals, i.e., not $\star$;[15]

4.3 merge AS_1 and AS_2 by collecting only those answers in AS_1 where each non-$\star$ filled position is filled by the same individual or by $\star$ in some answers in AS_2, and replace in the collected answers each $\star$ with the individuals in the corresponding position in all the matching answers of AS_2;

4.4 replace AS_1 and AS_2 in result-list with their merging computed in step 4.3;

4.5 REPEAT from step 4.2 UNTIL only one item is left in result-list;

4.6 RETURN the only item left in result-list.

The steps to be performed to correctly answer a query can now be summarized as follows:

1 split the query as shown at the beginning of section 4.3 into q^{KB} and q^M;

2 submit q^{KB} to DLMS, and each of the atomic sub-queries $q_1^M, \ldots, q_n^M$ of q^M to the DBMS, after translation into SQL, and to the DLMS, as shown in section 4.3.1;

3 using the compact notation shown above, *complete* the answer sets $AS^{KB}_{\overline{x}_{KB}}$, $AS^{M_1}_{\overline{x}_{M_1}}$, $\ldots, AS^{M_n}_{\overline{x}_{M_n}}$ obtained with step 2, and generate $AS^{KB}_{\overline{x}}, AS^{M_1}_{\overline{x}}, \ldots, AS^{M_n}_{\overline{x}}$;

4 the overall answer set is

$$\mathtt{MERGE}(AS^{KB}_{\overline{x}}, AS^{M_1}_{\overline{x}}, \ldots AS^{M_n}_{\overline{x}}).$$

[15] Such two sets always exist (see [13]).

5 Conclusions

The importance of an integrated view of description logics and databases has been shown, and our approach to deal with this topic has been presented. Within our technique, a third component – a DBox – can be added to the traditional TBox/ABox architecture of DLMS. By means of the DBox it is possible to couple the DLMS with several, possibly distributed and heterogeneous, source of data, and to use all the systems for uniformly answering queries to knowledge bases realized with this extended paradigm.

In our first implementation of the system[16] the DLMS is LOOM [25], and the database query language is SQL, but also other systems could be easily used.

At present our tool is used in a natural language dialogue system prototype [12], whose domain and linguistic knowledge is represented in a LOOM KB and, for some large amount of raw data, in an INGRES DB. Currently, our system supports a more expressive query language than the one previously presented: existentially quantified conjunctions of atomic formulæ can also be used. The study of the use of even more complex query-languages is planned, as well as a wider coverage of DL operators.

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References

[1] *KARP-95 Second International Symposium on Knowledge Acquisition, Representation, and Processing*, Auburn, AL, September 1995.

[2] F. Baader, M. Buchheit, M. A. Jeusfeld, and W. Nutt, editors. *Working Notes of the KI'94 Workshop: KRDB'94 - Reasoning about Structured Objects: Knowledge Representation meets Databases*, number D-94-11 in DFKI Documents, Saarbrücken, Germany, September 1994. DFKI GmbH.

[3] F. Baader, M. Buchheit, M. A. Jeusfeld, and W. Nutt, editors. *KRDB'95: Reasoning about structured objects: Knowledge representation meets databases*, number D-95-12 in DFKI-Research-Report, Saarbrücken, Germany, 1995. DFKI GmbH.

[4] F. Baader, M. Buchheit, M. A. Jeusfeld, and W. Nutt, editors. *Working Notes of the ECAI-96 Workshop "Knowledge Representation Meets Databas (KRDB-96)"*, Budapest, August 1996.

[5] Clara Bagnasco, Paolo Bresciani, Bernardo Magnini, and Carlo Strapparava. Natural language interpretation for public administration database querying in the TAMIC demonstrator. In R.P. van de Riet, J.F.M. Burg, and A.J. van der Vos, editors, *Applications of Natural Language to Information Systems*, pages 163–174, Amsterdam, June 1996. IOS Press. Proceedings of the Second International Workshop.

[6] Domenico Beneventano, Sonia Bergamaschi, Stefano Lodi, and Claudio Sartori. Using subsumption in semantic query optimization. In A. Napoli, editor, *IJCAI Workshop on Object-Based Representation Systems*, pages 704–709, Chambery, France, August 1993.

[7] Sonia Bergamaschi and Claudio Sartori. On taxonomic reasoning in conceptual design. *ACM Transactions on Database Systems*, 17(3):385–422, September 1992.

[8] Alex Borgida and Ronald J. Brachman. Loading data into description reasoners. In *Proceeding of ACM SIGMOD '93*, 1993.

[9] Alexander Borgida. Knowledge representation, semantic modeling: Similarities and differnces. In Hannu Kangassalo, editor, *Entity-Relationship Approach: The Core of Conceptual Modelling*, pages 1–25. North-Holland,

[16] Indeed, the answering algorithm has been implemented in a more sophisticated way than the one presented in section 4.3, including also optimizations for reducing the number of accesses to the DB (see [13]).

1991. Proceedings of the Ninth International Conference on the Entity-Relationship Approach.

[10] R. J. Brachman and J. G. Schmolze. An overview of the KL-ONE knowledge representation system. *Cognitive Science*, 9(2):171–216, 1985.

[11] Ronald J. Brachman, Peter G. Selfridge, Loren G. Terveen, Boris Altman, Alex Borgida, Fern Halpern, Thomas Kirk, Alan Lazar, Deborah L. McGuinness, and Lori Alperin Resnick. Integrated support for data archaeology. In *ISMM International Conference on Information and Knowledge Management*, Baltimore, MA, November 1992.

[12] Paolo Bresciani. Use of loom for domain representation in a natural language dialogue system. Technical Report 9203-01, IRST, Povo, TN, Italy, March 1992. presented at LOOM Users Workshop, Los Angeles, March 23-24, 1992.

[13] Paolo Bresciani. Uniformly querying knowledge bases and data bases. In Baader et al. [2], pages 58–62.

[14] Paolo Bresciani. Querying databases from description logics. In Baader et al. [3], pages 1–4.

[15] Paolo Bresciani. Some research trends in knowledge representation and databases. In Baader et al. [4], pages 10–13.

[16] Paolo Bresciani and Enrico Franconi. Description logics for information access. In *Working Notes of the AI*IA 1996 Workshop on "Access, Extraction and Integration of Knowledge"*, Napoli, September 1996.

[17] Michael L. Brodie. Future Intelligent Information Systems: AI and database technologies working together. In *Readings in Artificial Intelligence and Databases*, chapter Epilogue, pages 623–641. Morgan Kaufman, San Matteo, California, 1988.

[18] Martin Buchheit, Manfred A. Jeusfeld, Werner Nutt, and Martin Staudt. Subsumption between queries to object-oriented databases. *Information Systems*, 19(1):33–54, 1994.

[19] *Proceedings of Second Conference on Information and Knowledge Management (CIKM '93)*, 1993.

[20] Premkumar T. Devanbu. Translating description logics to information server queries. In CIKM '93 [19].

[21] F. M. Donini, M. Lenzerini, D. Nardi, and W. Nutt. The complexity of concept languages. In *Proc. of the 2nd International Conference on Principles of Knowledge Representation and Reasoning*, pages 151–162, Cambridge, MA, 1991.

[22] Chun-Nan Hsu and Craig A. Knoblock. Reformulating query plans for multidatabase systems. In CIKM '93 [19].

[23] Thomas Kirk, Alon Y. Levy, and Divesh Srivastava. The information manifold. In *1994 CAIA Workshop on Intelligent Access to Libraries*, 1994.

[24] Alon Y. Levy, Yehoshua Sagiv, and Divesh Srivastava. Toward efficient information gathering agents. In *Working Notes of the AAAI Spring Symposium "Software Agents"*, March 1994.

[25] R. MacGregor. Inside the LOOM description classifier. *SIGART Bulletin*, 2(3):88–92, 1991.

[26] Don P. McKay, Tim W. Finin, and Anthony O'Hare. The intelligent database interface. In *Proc. of AAAI-90*, pages 677–684, Boston, MA, 1990.

[27] B. Nebel. *Reasoning and Revision in Hybrid Representation Systems*, Volume 422 of *Lecture Notes in Artificial Intelligence*. Springer-Verlag, Berlin, Heidelberg, New York, 1990.

[28] Jon A. Pastor, Donald P. McKay, and Timothy W. Finin. View-concepts: Knowledge-based access to databases. In *Proceedings of First Conference on Information and Knowledge Management (CIKM '92)*, Baltimore, 1992.

[29] Raymond Reiter. On closed-world data bases. In H. Gallaire and J. Minker, editors, *Logic nad Data Bases*, pages 55–76. Plenum Press, 1978.

[30] Albrecht Schmiedel. Semantic indexing based on description logics. In Baader et al. [2], pages 41–44.

[31] F. Tou, M. Williams, R. Fikes, A. Henderson, and T. Malone. Rabbit: An intelligent database assistant. In *Proc. AAAI'82*, 1982.

Rough Sets: Facts Versus Misconceptions

Jerzy W. Grzymala-Busse
Department of Computer Science and Electrical Engineering
University of Kansas
Lawrence, KS 66045, USA
E-mail: Jerzy@eecs.ukans.edu
AND
Jerzy Stefanowski
Institute of Computing Science
Poznań University of Technology
60-965 Poznań, Poland
E-mail: Stefanj@pozn1v.put.poznan.pl
AND
Wojciech Ziarko
Department of Computer Science
University of Regina
Regina, SK, Canada S4S 0A2
E-mail: Ziarko@cs.uregina.ca

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This article is a response to the critical assessment of the role of the methodology of rough sets in Machine Learning as presented by Kononenko and Zorc in their paper Critical Analysis of Rough Sets Approach to Machine Learning, *Informatica* **18**, *pp. 305-313. We correct the inaccuracies and respond to unfounded claims made by the authors while trying to present the rough set theory in the broader context of scientific and engineering methodologies and practical applications utilizing the theory of rough sets as their basic theoretical paradigm.*

1 Introduction

The main objective of this note is to correct mistakes made by Kononenko and Zorc in their paper [20]. While the paper makes strong claims, the authors seem to lack of comprehensive view of the area of rough sets which results in misunderstanding of the basic issues and misleading conclusions.

The theory of rough sets is a result of many years of research by computer scientists, logicians and mathematicians. Rough set theory was originated by Zdzislaw Pawlak, known for his numerous essential contributions to Computer Science. The key concept of the rough set approach is the formal recognition of the fact that the ability to describe a set of objects is constrained by our limitation in distinguishing individual members of the set. In other words, in general, only classes of objects rather than individuals can be distinguished. It, in turn, leads to the approximate specification of a set in terms of set lower and upper approximations, with the presence of the set boundary reflecting information ambiguity of the set definition. This kind of situation appears very often in real-world applications, such as, for example, in medicine, where symptoms may, or may not carry sufficient information to come up with certain diagnosis. The rough set theory, in its essence, provides a fundamental mathematical tool to study such decision problems and to develop solutions to them, including methods of rule induction from data.

The acceptance of the rough set theory as a methodological tool to study data mining, classification, control and other problems is growing fast. The formal correctness of rough set theory has been recognized long time ago by many authors. It has been studied and accepted as a research tool by a large number of computer scientists, resulting in hundreds of research papers and several software systems for data mining and machine learning, some of them available commercially on international market. Currently, there are three books on the subject ([33, 47, 65], two special issues of scientific journals [51, 67], with two other issues planned for 1996, and numerous invited survey papers in well known international journals (e.g. [14, 34, 37, 48]). Since 1992 research and application results in this area have been regularly presented in very well attended annual international workshops and sessions at major conferences (see, e.g., [24, 25, 26, 50]). For example, a session on rough set theory applications to data mining took place at the First International Conference on Knowledge Discovery and Data Mining held in Montreal, Canada [6].

From the application perspective, rough set theory can be perceived as a methodological tool for handling vagueness and uncertainty in data. In fact, the basic concepts of the rough set theory such as the indiscernibility relation, approximation space, lower and upper approximations of the set and of the classification, rough measure, quality of lower and upper approximations, dependency of attributes and the concept of reduct are directly applicable to the problems of analysis of vague and uncertain data. In particular, rough set theory is applicable to the problem of a limited discernibility of objects by their features - attributes (see, e.g., [33]). There are also well known interesting links of the rough set theory with other approaches to vagueness and uncertainty such as fuzzy sets or Dempster-Shafer theory (see, e.g., [4, 27, 44]). Rough set theory is also applicable to machine learning, as discussed in the sequel, but it is not the dominant area for this methodology. It is used as a theoretical background in the following fields:

- set theory, topology and logic (see, e.g., [5, 31]),
- decision analysis (see, e.g., [36, 37]),
- knowledge discovery and data mining (see, e.g., [18, 39]),
- knowledge acquisition for expert systems (see, e.g., [9]).

The important application areas for rough sets are:

- medical diagnosis (see, e.g., [15, 35, 46, 63]),
- pharmacology (see, e.g., [21]),
- stock market prediction and financial data analysis (see, e.g., [7]),
- banking (see, e.g., [55]),
- market research (see, e.g., [38]),
- information storage and retrieval systems (see, e.g., [62]),
- pattern recognition, including speech and handwriting recognition (see, e.g., [3]),
- control system design (see, [40]),
- image processing (see, e.g., [19], [22]),
- digital logic design (see, e.g., [28]).

There is a few other research areas and application fields that are not yet quite developed.

2 Machine Learning and Rough Sets

In this section we attempt to clarify the role of rough set methodology in the context of its applications to the development of learning systems. Our presentation, however, does not exhaust this topic. The objective here is essentially to clear up the potential confusion caused by unfounded comments made by Kononenko and Zorc.

First of all, Kononenko and Zorc mistakenly imply that there exists only one, unique "rough set approach" to machine learning. This is absolutely incorrect. There are many different approaches to machine learning based on rough set theory. Rough sets are used on different stages of the process of rule induction and data preprocessing, a fact that is apparent from references cited by Kononenko and Zorc, but is not seen in their arguments/discussion. Their critical analysis is built around the algorithm based on the so-called discriminant coefficient [61] which is one of the first, oldest proposals for using rough set theory in rule induction. Nowadays, the most representative approaches (see, e.g., [25, 51, 65]) which are used in the majority of last year applications are:

- system LERS (Learning from Examples based on Rough Sets) (see, e.g., [1, 11]) which itself has four different options of rule induction, the most popular of them seems to be LEM2 algorithm, its variant is also reimplemented in one of the options of system RoughDAS [8],
- approaches based on a discernibility matrix ([45] or a decision matrix [42],
- systems Dataquest and DataLogic, distributed commercially and used for data pattern identification. System DataLogic [59] identifies deterministic or probabilistic patterns in data, in form of rules, using the probabilistic extension of the original rough set model called *variable precision rough sets* model [64],
- system KDD-R, oriented towards data mining applications from large commercial databases and capable of finding strongly supported rules in incomplete data sets [66],
- an approach focused on inducing the set of decision rules satisfying the given decision analyst's requirements (e.g. expressing preferences to getting strong rules) [58] - used in decision analysis tasks or also in data mining applications.

The system LERS is a good example, illustrating how the elements of rough set theory are connected with the rule induction process. The detailed description of all algorithms implemented in LERS can be found in [11], also cited by Kononenko and Zorc. Although LERS has four different options of rule induction, the common rough set-based method is used for all four options in the case of inconsistent input data. If input data are inconsistent LERS computes first the lower and upper approximations of all concepts, thus reducing the task of rule induction from inconsistent data to rule induction from consistent data, since both lower and upper approximations of the concept make it feasible. This is, in fact, the only step of the process where the elements of the rough set theory are used in rule induction.

LERS has proven its applicability having been used for two years by NASA Johnson Space Center (Automation and Robotics Division), as a tool to develop expert systems of the type most likely to be used in medical decision-making on board the Space Station Freedom. LERS was also used to enhance facility compliance under Sections 311, 312, and 313 of Title III, the Emergency Planning and Community Right to Know [12]. The project was funded by the U. S. Environmental Protection Agency. System LERS was used in other areas as well, e.g., in the medical field to assess preterm labor risk for pregnant women and to compare the effects of warming devices for postoperative patients [63]. Currently used traditional methods to assess preterm labor risk have 17-38% accuracy, while the expert system with the rule base induced by LERS has 68-90% accuracy [15]. For the recent uses of LERS see [16] and [30].

The analogous way of handling inconsistency by rough sets is presented in the rule option of RoughDAS system [8], where lower approximations and boundary regions are taken as target concepts for rule induction performed by the modified version of the algorithm LEM2. The same preprocessing of input examples exists in the so called "two stage approach" presented in [58]. The RoughDAS system, supported in some cases by other classification tools such as RoughClass [56] and VCRClass [49, 52, 57], has been successfully used in several applications concerning medical diagnosis of different diseases and the patients' treatments (see, e.g., [46], processing of histological images [19], analysis of chemical structures of pharmaceutical compounds [21], technical diagnostics of industrial machinery (see, e.g., [32]), financial data analysis or analysis of multiattribute decision problems [55].

The system Datalogic [59] uses similar algorithms based on rough set theory by adapting the concept of the generalized reduct known in the variable precision rough set model, to produce maximally general rules with attached probabilistic certainty coefficients. As other systems based on rough sets, Datalogic computes concept approximations prior to computing rules, which

Table 1: Error Rate for LERS, AQ15, and C4.5

Data sets	Compared Systems		
	AQ15	C4.5	LERS
Lymphography	18-20%	23%	19%
Breast cancer	32-34%	33%	30%
Primary tumor	59-71%	60%	67%

Table 2: Error Rate for C4.5 and VCRClass

Data sets	Compared Systems	
	C4.5rules	VCRClass
large soybean disease	11.8%	12.1%
breast cancer	32.4%	32.9%
lymphography	19.6%	14.8%
small soybean disease	2.2%	2.2%
election	10.4%	10.6%
rolling bearings	6.2%	4.6%
concrete	12.9%	11.1%

is one of many data transformation steps leading to the final result.

Kononenko and Zorc claim that the systems of rule induction based on rough set theory are not sufficiently compared with other, well known systems of machine learning. Clearly, one can always argue that more comparisons are needed. Some experiments have been in fact performed and more are under way.

In Table 1 some respective results are cited after [13]. In this table LEM2 option of LERS is compared with two other systems of machine learning: AQ15 and C4.5. LEM2 algorithm was enhanced by the new LERS classification scheme [13]. Both AQ15 and C4.5 are among the most popular machine learning systems. AQ15 was developed by R. Michalski [29]. C4.5 is the most advanced system based on ID3 algorithm [41]. As it is clear from the table, all three systems, AQ15, C4.5 and LERS/LEM2 belong to the same category of successful systems. For some data one of these systems is better then the other, but in general, all three of them obviously belong to the same class.

Other comparative studies with well known inductive learning techniques have been performed in [57]. In this study a modified version of the LEM2 algorithm (implemented in system Rough-DAS) has been used for the rule induction phase. In classification tests, an ambiguity in matching objects to rules has been solved by means of a technique based on the valued closeness relation. The details of this technique are presented in [49, 52]. The experiments have been performed using standard tests: ten-fold cross validation and leaving-one-out [60] on some of well known machine learning data sets, e.g., from databases of University of California at Irvine and other data sets coming from rough set community. The system VCRClass has been compared with the system C4.5. Results comparing VCRClass with rule option of C4.5 are given in Table 2. Similarly as in the previously described experiment, both systems produce comparable results.

The most serious methodological error made by Kononenko and Zorc is related to their conclusions drawn from Table 2 in their own paper: "results of RST are poor when compared to Assistant" (see p. 311). Contrary to the claim by Kononenko and Zorc, performance of their own implementation of RST cannot be considered as "poor" when compared to Assistant. Their ad hoc methodology of comparison is based on removal of "differences in the classification accuracy that are less than 4 percent" and then grading the performance by looking at the remaining differences. Obviously, populations are not normal, so t-distribution will not produce valid results. Moreover, samples are not selected in a random way, etc. What should be used to compare RST with Assistant is a standard non-parametric test, e.g., the Wilcoxon matched-pairs signed rank test [17]. Using Wilcoxon test, the critical value of T for the case of seven pairs of accuracies (one of the pairs should be removed because the results are identical) and one-tailed test at the significance level of 5% (see, e.g., [17], p. 721) is equal to 3. The calculated value of T is 10, so Kononenko and Zorc's own evidence does not permit to reject the null hypothesis. Thus, the correct conclusion is that the performance of both classifiers, RST and Assistant, does not differ significantly.

The second criterion, "average importance score", used by Kononenko and Zorc, is not convincing either. The criterion is invented by one of these authors and is not widely used by others, and as such, still requires some independent validation. Besides, their results are drawn from their basic and fundamentally incorrect assumption that there is only one rough-set approach to machine learning. With other machine learning systems, like LERS, RoughDAS, Datalogic results might be quite different.

In addition to the above, the paper by Kononenko and Zorc contains some other misleading and incorrect interpretations of how rough set theory is used with induction techniques. For example, in presenting interpretation of so called "learning algorithm" (see Subsection 2.3 of their paper), the authors claim that "to generate a set of decision rules a subset P of attributes must be selected". This, and their other remarks might lead to the false conclusion that attribute reduction is one of essential steps of the rough set approach to machine learning. The reduction of attributes is not a general part of the rule induction algorithms based on rough sets but is sometimes used to for the preliminary data analysis. Thus, it is only an option which may be used in data preprocessing stage before the actual rule induction.

Another misleading comment is contained in Subsection 3.2 of the paper by Kononenko and Zorc. The authors claim that "Rough set theory can deal with discrete attributes only ... there is no obvious way how to deal with incomplete or noisy data". In fact, induction systems based on rough sets can quite well handle continuous attributes, conflicting examples, or missing attribute values. For instance, in the book [47] which is cited by Kononenko and Zorc, there is a chapter by [23] where a comprehensive approach to handle continuous attributes is introduced. Another approach to discretization of continuous attributes has been introduced by Grzymala - Busse and other authors (see, e.g., [2]). Continuous attribute handling is also a part of Datalogic and KDD-R systems [66].

Moreover, currently at least few authors are introducing other approaches to create rough approximations which are based on similarity relation instead of strict indiscernibility of objects (see, e.g. [54]). In these proposals continuous attributes may be directly handled in the rough set operations and rule induction techniques without any prior discretizations.

In the case of incomplete data (missing attribute values) Kononenko and Zorc suggest that in rough set theory "they are defined as additional values". This is again an incorrect statement. There are many approaches to handle this problem developed within the context of rough sets. For instance in the paper [10] the approach of substituting missing values by a subset of possible values is introduced. Also, in [53] yet other approaches are presented, where a distribution of possible values or fuzzy membership measures are taken into account. On the other hand, systems Datalogic and KDD-R discover rules from data with missing values without any substitutions.

Extensions of the theory of rough sets, and in particular the variable precision model, have been developed relatively long time ago to deal with some of the limitations of the original rough set model in the context of experimental data analysis applications, in particular to use distribution information in the boundary area of the rough set. These extensions appear to be unknown to the authors of the paper as the absence of the set boundary area distribution information in the original model is cited as its drawback. However, this distribution information can only be used if it is reliable, that is, if there a basis to assert that the probability estimates computed from data reflect real probabilities of the application domain, a situation which does not occur very often in real data. Also, in many problems, where the domain is completely specified, for example for digital logic synthesis or control algorithm derivation from system state vectors, the key issue is in answering the question whether deterministic control rules can be constructed for all inputs rather than worrying about the nature of the non-determinism in the boundary area since its very presence makes it impossible to design a deterministic controller anyway.

3 Final Remarks

As we indicated earlier, the aim of this note is to correct the distorted view of rough sets in the context of machine learning applications as presented by Kononenko and Zorc in their paper *Critical Analysis of Rough Sets Approach to Machine Learning.* The comprehensive coverage of the subject of the rough set approach to machine learning would require probably a series of articles dealing with different algorithms, data preprocessing techniques, experimental methodologies, etc., and is definitely beyond the scope of this note. The paper of Kononenko and Zorc just touched this issue while introducing many inaccuracies, untrue claims, and unjustified conclusions. Since for some readers of *Informatica* this may be the first contact with the idea of rough sets we thought that it is essential to present the true image of the role of rough sets in the context of machine learning, at least by responding to the inaccuracies present in the above mentioned article. There is strong scientific evidence and consensus among researchers who studied the theory of rough sets that it is a valuable mathematical model continually contributing to the progress of machine learning, data mining and other areas of Computer Science and Engineering. On the other hand, the paper by Kononenko and Zorc, strongly biased against rough set theory, failed in presenting rough set approach to machine learning.

Evaluation of usefulness of rough set theory in machine learning should be based on the widely accepted standards. Solid exhaustive research should be involved. Besides, conclusions should be drawn on known facts and only facts as contained, for example, in the cited works on the rough set theory and applications. Unfortunately, the analysis presented by Kononenko and Zorc in their article does not even approach this standard.

References

[1] Chan C. C. and Grzymala-Busse J. W., On the two local inductive algorithms: PRISM and LEM2. *Foundations of Computing and Decision Sciences* vol. 19, no. 4, 1994, pp. 185–204.

[2] Chmielewski M. R. and Grzymala-Busse J. W., Global discretization of continuous attributes as preprocessing for machine learning. *Proc. of the 3-rd Int. Workshop on Rough Sets and Soft Computing*, San Jose, CA, November 10 -12, 1994, pp. 474–480. Also in *Soft Computing: Rough Sets, Fuzzy Logic, Neural Networks, Uncertainty Management, Knowledge Discovery*, T. Y. Lin and A. M. Wilderberger, (eds.) Simulation Councils, Inc., 1995, pp. 294–297.

[3] Czyzewski A. and Kaczmarek A., Speech-independent recognition of isolated words using rough sets. *Proc. of the 2nd Annual Joint Conference on Information Sciences*, JCIS'95, Wrightsville Beach, North Carolina, Sept. 28–Oct. 1, 1995, pp. 397–400.

[4] Dubois D. and Prade H., Putting rough sets and fuzzy sets together, In Slowinski R. (ed.) *Intelligent Decision Support. Handbook of Applications and Advances of the Rough Sets Theory*, Kluwer Academic Publishers, 1992, pp. 203–232.

[5] Farrinas del Cerro and Prade H., Rough sets, twofold fuzzy sets and modal logic. In Nola A. D. (ed.) *The mathematics of fuzzy systems*,Verlag TUG Rheinland, 1986, pp. 103–120.

[6] Fayyad U. and Uthurusamy R., (eds.) *Proceedings of the First International Conference on Knowledge Discovery and Data Mining*, Montreal, Canada, 1995, AAAI Press, Menlo Park, CA.

[7] Golan R. and Ziarko W., A Methodology for stock market analysis utilizing rough set theory. *Proceedings of IEEE/IAFE 1995 Conference on Computational Intelligence in Financial Engineering*, New York City, April 9–11, 1995, pp. 32–40.

[8] Gruszecki G., Slowinski R., and Stefanowski J., RoughDAS - Rough Sets based Data Analysis System - User guide, APRO Inc., Poznan - Warsaw, 1992.

[9] Grzymala-Busse D. M. and Grzymala-Busse J. W., The usefulness of machine learning approach to knowledge acquisition. *Computational Intelligence* 11, 1995, pp. 268–279.

[10] Grzymala-Busse J. W., On the unknown attribute values in learning from examples. *Proc. of Int. Symp. on Methodologies for Intelligent Systems*, 1991, pp. 368–377.

[11] Grzymala-Busse J. W., LERS - A system for learning from examples based on rough sets. In Slowinski R. (ed.), *Intelligent Decision Support. Handbook of Applications and Advances of the Rough Sets Theory*, Kluwer Academic Publishers, 1992, pp. 3–18.

[12] Grzymala-Busse J. W., ESEP: An expert system for environmental protection. *Proc.*

of the RKSD-93, International Workshop on Rough Sets and Knowledge Discovery, Banff, Alberta, Canada, October 12–15, 1993, pp. 499–508. Also in Rough Sets, Fuzzy Sets and Knowledge Discovery, Ziarko W. P (ed.), Springer-Verlag, 1994, pp. 466–473.

[13] Grzymala-Busse J. W., Managing uncertainty in machine learning from examples. In Dabrowski M, Michalski R., Ras Z. (eds.) *Proceedings of 3rd Int. Symp. on Intelligent Systems*, Wigry, Poland, IPI PAN Press, Warszawa, 1994, pp. 70–84.

[14] Grzymala-Busse J.W., Rough Sets. *Advances in Imaging and Electron Physics*, 94, 1995, pp. 151–195.

[15] Grzymala-Busse J. W. and Woolery, L., Improving prediction of preterm birth using a new classification scheme and rule induction. *Proc. of the 18-th Annual Symposium on Computer Applications in Medical Care (SCAMC)*, Washington, DC, November 5–9, 1994, pp. 730–734.

[16] Gunn J. and Grzymala-Busse J. W., Global temperature stability by rule induction: An interdisciplinary bridge. *Human Ecology* 22, 1994, pp. 59–81.

[17] Hamburg M., *Statistical Analysis for Decision Making.* Harcourt Brace Jovanovich Inc., Third Edition, 1983.

[18] Hu X., Cercone N., and Han J., An attribute-oriented rough set approach for knowledge discovery in databases. In Ziarko W. P., (ed.), *Rough Sets, Fuzzy Sets and Knowledge Discovery*, Springer-Verlag, 1994, pp. 63–73.

[19] Jelonek J., Krawiec K., Slowinski R., Szymas J., Rough set reduction of features for picture-based reasoning. In Lin T. Y. and Wildberger A. (eds.) *Soft Computing: Rough Sets, Fuzzy Logic, Neural Networks, Uncertainty Management, Knowledge Discovery*, Simulation Councils, Inc., San Diego CA 1995, pp. 89–92.

[20] Kononenko I., Zorc S., Critical analysis of rough sets approach to machine learning. *Informatica* 18, 1994, pp. 305–313.

[21] Krysinski J., Rough set approach to the analysis of the structure activity relationship of quaternary imidazolium compounds. *Arzneim. Forsch*, 40, 1990, pp. 795–799.

[22] Lau S., Image segmentation based on indiscernibility relation. In Ziarko W. P., (ed.), *Rough Sets, Fuzzy Sets and Knowledge Discovery*, Springer-Verlag, 1994, pp. 395–402.

[23] Lenarcik A., Piasta Z., Discretization of condition space. In Slowinski R. (ed.) *Intelligent Decision Support. Handbook of Applications and Advances of Rough Set Theory.* Kluwer Academic Publishers, 1992, pp. 373–390.

[24] Lin T. Y. (ed.), *Proceedings of the 3rd Int. Workshop on Rough Sets and Soft Computing*, San Jose, CA, 1994.

[25] Lin T. Y. (ed.), *Proceedings of the Int. Workshop on Rough Sets and Data Mining, ACM National Conference*, Nashville, Tenn., 1995.

[26] Lin T. Y. and Wildberger A. (eds.), *Soft Computing: Rough Sets, Fuzzy Logic, Neural Networks, Uncertainty Management, Knowledge Discovery*, Simulation Councils, Inc., San Diego CA, 1995.

[27] Lingras P. and Yao Y. Y., Belief functions in rough set models. *Proc. of the 2nd Annual Joint Conference on Information Sciences*, JCIS'95, Wrightsville Beach, North Carolina, Sept. 28-Oct. 1, 1995, pp. 190–193.

[28] Luba T. and Rybnik J., Algorithmic approach to discernibility function with respect to attributes and objects reduction. *Foundations of Computing and Decision Sciences*, vol. 18, no. 3-4, 1993, pp. 241–259.

[29] Michalski R. S., Mozetic I., Hong J., and Lavrac N., The multi-purpose incremental learning system AQ15 and its testing application to three medical domains. *Proc. of the 5th Nat. Conf. on AI*, 1986, pp. 1041–1045.

[30] Moradi H., Grzymala-Busse J. W., and Roberts J. A., Entropy of English text: Experiments with humans and a machine learning system based on rough sets. *Proc. of the 2nd Annual Joint Conference on Information*

Sciences, JCIS'95, Wrightsville Beach, North Carolina, Sept. 28-Oct. 1, 1995, pp. 87–88.

[31] Nakamura A. , On a multi-modal logic based on the graded classification. *Foundations of Computing and Decision Sciences*, vol. 18, no. 3-4, 1993, pp. 275–292.

[32] Nowicki R., Slowinski R. and Stefanowski J., Rough sets analysis of diagnostic capacity of vibroacoustic symptoms. *Computers and Mathematics with Applications*, vol. 24 no. 7, 1992, pp. 109-123.

[33] Pawlak Z., *Rough sets. Theoretical Aspects of Reasoning about Knowledge.* Kluwer Academic Publishers, Dordrecht/ Boston/ London, 1991.

[34] Pawlak Z., Grzymala-Busse J., Slowinski R., Ziarko, W., Rough sets. *Communications of the ACM*, vol. 38, no. 11, 1995, pp. 89-95.

[35] Pawlak Z., Slowinski K., Slowinski R., Rough classification of patients after highly selected vagotomy for duodenal ulcer. *International J. Man-Machine Studies*, 24, 1986, pp. 413–433.

[36] Pawlak Z., Slowinski R., Decision analysis using rough sets. Presented at *13th World Conference on Operations Research*, IFORS'93, Lisbon, Portugal, July 12-16, 1993. Also in *International Transactions in Operational Research*, 1, 1994, pp. 107–114.

[37] Pawlak Z., and Slowinski R., Rough set approach to multi- attribute decision analysis. Invited Review in *European Journal of Operational Research*, 72, 1994, 443-459.

[38] Piasta Z., A rough-set technology in market analysis. *Proc. of the RKSD-93, International Workshop on Rough Sets and Knowledge Discovery*, Banff, Alberta, Canada, October 12-15, 1993, pp. 455–464.

[39] Piatetsky-Shapiro G., An overview of knowledge discovery in databases: recent progress and challenges. In Ziarko W.P., (ed.) *Rough Sets, Fuzzy Sets and Knowledge Discovery*, Springer Verlag, 1994, pp. 1–10.

[40] Plonka L. and Mrozek A., Rule-based stabilization of the inverted pendulum. *Computational Intelligence: An International Journal*, vol. 11, no. 2, 1995, pp. 348–356.

[41] Quinlan J. R., *C4.5: Programs for Machine Learning.* Morgan Kaufmann, San Mateo CA, 1993.

[42] Shan N. and Ziarko W., Data-based acquisition and incremental modification of classification rules. *Computational Intelligence: An International Journal*, vol. 11, no. 2, 1995, pp. 357–370.

[43] Skowron A., Boolean reasoning for decision rules generation. In Komorowski J., Ras Z. (des.) *Methodologies for Intelligent Systems*, LNAI 689, Springer-Verlag, Berlin, 1993, pp. 295–305.

[44] Skowron A. and Grzymala-Busse J. W., From rough set theory to evidence theory. In Federizzi M.W., Kacprzyk J., Yager R. (eds.), *Advances in Dempster-Shafer Theory of Evidence*, John Wiley and Sons, New York, 1993, pp. 193–236.

[45] Skowron A. and Rauszer C., The discernibility matrices and functions in information systems. In Slowinski R. (ed.), *Intelligent Decision Support. Handbook of Applications and Advances of Rough Set Theory.* Kluwer Academic Publishers, Dordrecht/ Boston/ London, 1992, 331–362 .

[46] Slowinski K. and Sanossy Sharif E., Rough set approach to analysis of data of diagnostic peritoneal lavage applied for multiple injuries patients. In Ziarko W. (ed.), *Rough Sets, Fuzzy Sets and Knowledge Discovery*, Springer-Verlag, 1994, pp. 420–425.

[47] Slowinski R. (ed.), *Intelligent Decision Support. Handbook of Applications and Advances of the Rough Sets Theory.* Kluwer Academic Publishers, 1992.

[48] Slowinski R., Rough set approach to decision analysis. *AI Expert*, March 1995, pp. 19-25.

[49] Slowinski R., Rough set learning of preferential attitude in multi-criteria decision making. In Komorowski J., Ras Z., (eds.) *Method-*

ologies for Intelligent Systems, LNAI 689, Springer-Verlag, 1993, pp. 642–651.

[50] Slowinski R., Stefanowski J. (eds.), *Proceedings of the 1st International Workshop on Rough Sets*, Kiekrz-Poznan, Poland September 1992.

[51] Slowinski R., Stefanowski J. (eds.), Special Issue on Rough Sets State of the Art and Perspectives, *Foundations of Computing and Decision Sciences*, vol. 18, no. 3-4, 1993.

[52] Slowinski R., Stefanowski J., Rough classification with valued closeness relation. In Diday E. (ed.) *New Approaches in Classification and Data Analysis, Studies in Classification, Data Analysis and Knowledge Organisation*, Springer Verlag, 1994, pp. 482-489.

[53] Slowinski R., Stefanowski J., Handling various types of uncertainty in the rough set approach. In Ziarko W. (ed.) *Rough Sets, Fuzzy Sets and Knowledge Discovery*, Springer-Verlag, 1994, pp. 366–376.

[54] Slowinski R., Vanderpooten D., Similarity relation as a basis for rough approximations, ICS Research Report 53/95, Institute of Computer Science, Warsaw University of Technology, (1995). Also accepted to Wang P. (ed.) *Advances in Information Sciences*, vol. IV.

[55] Slowinski R., Zopounidis C., Applications of the rough set approach to evaluation of bankruptcy risk, *Intelligent Systems in Accounting, Finance and Management*, vol. 4, 1995, pp. 27–41.

[56] Stefanowski J., Classification support based on the rough sets. *Foundations of Computing and Decision Sciences*, vol. 18, no. 3-4, 1993, pp. 371-380.

[57] Stefanowski J., Using valued closeness relation in classification support of new objects. In Lin T. Y., Wildberger (eds.) *Soft computing: rough sets, fuzzy logic, neural networks uncertainty management, knowledge discovery*, Simulation Councils Inc., San Diego CA, 1995, pp. 324–327.

[58] Stefanowski J. and Vanderpooten. D., A general two-stage approach for inducing rules from examples. In Ziarko W. (ed.) *Rough Sets, Fuzzy Sets and Knowledge Discovery*, Springer-Verlag, 1994, pp. 317–326.

[59] Szladow A., Datalogic/R for databases mining and decision support. *Proc. of 2nd Int. workshop on rough sets and knowledge discovery, RSKD-93, Banff, Canada*, 1993, pp. 511–513.

[60] Weiss S. M. and Kulikowski C.A., *Computer Systems That Learn: Classification and Prediction Methods from Statistics, Neural Nets, Machine Learning and Expert Systems*, Morgan Kaufmann, 1991.

[61] Wong S.K.M., Ziarko W. and Ye Li W., Comparison of rough set and statistical methods in inductive learning. *Int. Journal of Man-machine Studies*, vol. 24, 1986, pp. 53–72.

[62] Wong S.K.M., Ziarko W., A machine learning approach to information retrieval. *Proc. of ACM Conference on Research and Development in Information Retrieval*, Pisa, Italy, September 1986, pp. 228–233.

[63] Woolery L., Grzymala-Busse J., Summers S., and Budihardjo A., The use of machine learning program LERS_LB 2.5 in knowledge acquisition for expert system development in nursing. *Computers in Nursing* 9, 1991, pp. 227–234.

[64] Ziarko W., Variable precision rough sets model. *Journal of Computer and Systems Sciences*, vol. 46. no. 1, 1993, pp. 39–59.

[65] Ziarko W.(ed.), *Rough Sets, Fuzzy Sets and Knowledge Discovery*, Springer-Verlag, 1994.

[66] Ziarko, W. and Shan, N., KDD-R: A comprehensive system for knowledge discovery in databases using rough sets. In Lin T. Y, Wildberg A.M., editors, *Soft Computing. rough sets, fuzzy logic, neural networks uncertainty management, knowledge discovery*, San Jose, CA., USA, Simulation Council Inc., San Diego, 1994, pp. 93–96.

[67] Ziarko W.(ed.), Special Issue on Rough Sets and Knowledge Discovery. *Computational*

Intelligence: An International Journal, vol. 11, no. 2, 1995.

On Facts Versus Misconceptions about Rough Sets

Igor Kononenko
University of Ljubljana
Faculty of Computer and Information Science
Tržaška 25, SI-1000 Ljubljana, Slovenia
E-mail: igor.kononenko@fri.uni-lj.si

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This note is a response to the paper Rough Sets: Facts Versus Misconceptions *by J.Grzymala-Busse, J.Stefanowski and W. Ziarko, Informatica, this volume, which is in turn the response to the paper (Kononenko and Zorc, 1994). I clarify some points from our original paper that were mistakenly interpreted by Grzymala-Busse et al. and stress points from our original paper that were ignored by Grzymala-Busse et al. I conclude that with additions to the Rough Sets theory one can achieve good performance, which is however not due to Rough Sets but due to the additions, and that the use of Rough Sets is an unnecessary burden for machine learning algorithms.*

1 Introduction

In the paper (Kononenko and Zorc, 1994) we critically analyzed the Rough Sets Theory (RST) approach to machine learning (ML). We analyzed the following drawbacks of the RST approach to machine learning:

- complicated formalization of rather trivial notions and sometimes strange terminology that confuses the point,
- inflexibility of the knowledge representation,
- ad-hoc solutions, and
- comparison of the RST approach to machine learning with other approaches.

We concluded:

"*... It seems that many authors have no overview of the work that is going on in machine learning and that may be the reason for many reinventings and also plenty of ad-hoc solutions. ... Complicated formalization in RST adds confusion with numerous new notions and unusual terminology that prevents global overview of the RST and prevents systematic analysis. ... The problems with noise and incomplete data disables RST from providing efficient solutions for complex real-world problems.*"

Grzymala-Busse et al. (this volume) tried to "correct the inaccuracies and respond to unfounded claims" in our paper. In this note I clarify some points from our original paper that were mistakenly interpreted by Grzymala-Busse et al. and stress points from our original paper that were ignored by Grzymala-Busse et al.

2 Experimental comparison in (Kononenko and Zorc, 1994)

In the paper (Kononenko and Zorc, 1994) we compared the performance of one RST-based algorithm for inducing decision rules with one classical algorithm for generating decision trees called Assistant (Cestnik et al., 1987) and the naive Bayesian classifier. We reproduce the results in Tables 1 (classification accuracy) and 2 (information score, (Kononenko and Bratko, 1991)).

In (Kononenko and Zorc, 1994) we have interpreted the results as follows:

"*All differences in the classification accuracy (Table 1) that are less than 4 % are*

Table 1: Comparison of the classification accuracy (%) of different classifiers on various data sets.

domain	Assistant	Bayes	RST
primary tumor	44	50	35
breast cancer	77	79	80
thyroid diseases	73	72	61
rheumatology	65	69	66
hepatitis	82	87	81
lymphography	79	84	77
criminology	61	61	63
fresh concrete	61	63	61

Table 2: Comparison of the average information score (bit) of different classifiers on various data sets.

domain	Assistant	Bayes	RST
primary tumor	1.38	1.57	0.96
breast cancer	0.07	0.18	-0.04
thyroid diseases	0.87	0.85	0.46
rheumatology	0.46	0.58	0.16
hepatitis	0.15	0.42	0.12
lymphography	0.67	0.83	0.51
criminology	0.06	0.27	0.03
fresh concrete	0.70	0.89	0.59

statistically insignificant (confidence level is 0.99 using two-tailed t-test). Other differences are significant. However, note that for breast cancer, rheumatology, and criminology, where the differences are the lowest, the classification accuracy is practically equal to the proportion of the majority class. For those data sets the information score is a better measure. The majority of differences in information score (Table 2) are statistically significant (the exceptions are the differences between Assistant and RST in hepatitis and criminology)."

However, Grzymala-Busse et al. comment:

"Their ad hoc methodology of comparison is based on removal of "differences in the classification accuracy that are less than 4 percent" and then grading the performance by looking at the remaining differences. Obviously, populations are not normal, so t-distribution will not produce valid results. Moreover, samples are not selected in a random way, etc. What should be used to compare RST with Assistant is a standard non-parametric test, e.g., the Wilcoxon matched-pairs signed rank test. Using Wilcoxon test, the critical value of T for the case of seven pairs of accuracies (one of the pairs should be removed because the results are identical) and one-tailed test at the significance level of 5% is equal to 3. The calculated value of T is 10, so Kononenko and Zorc's own evidence does not permit to reject the null hypothesis. Thus, the correct conclusion is that the performance of both classifiers, RST and Assistant, does not differ significantly.

The second criterion, "average importance score", used by Kononenko and Zorc, is not convincing either. The criterion is invented by one of these authors and is not widely used by others, and as such, still requires some independent validation."

The above discussion is meaningless. Four points need clarification:

1. We didn't compare the average performance of Assistant with the average performance of the RST algorithms in all domains as such comparison doesn't make sense at all. Obviously one percent in one domain may be a significant improvement while 3 percents in other domain may not be very significant, especially if the deviation of the performance is higher than 3 percents in that domain. Comparing the average performance in various domains is missleading and can easily lead to wrong conclusions. What we have compared is the perfomance of two algorithms on each domain separately.

2. When comparing the performance of two algorithms in one domain, we conducted 10 runs with different training/testing splits. Although we presented only the average results, for evaluating the significance of the difference we, of course, used 10 pairs of results to test the significance level. It turned out, as we stated in our discussion, that all differences in the classification accuracy in Table 1 that are less than 4 % are statistically insignificant and the other differences are significant. The use of 4 % in this statement is merely for brevity reasons. So we didn't use

ad-hoc threshold of 4 %, as Grzymala-Busse et al. wrongly concluded.

3. The average information score has nice properties (see (Kononenko and Bratko, 1991)) that allows it to appropriately deal with probabilistic answers and to take into account the prior probabilities of classes. Although in the majority of experiments the classification accuracy and the information score are highly correlated (which is the main reason why so few other authors use information score, personal communication with many authors from ML community), they contain different messages for the user. The former states merely the percentage of correct answers while the latter provides the estimate of the average information contained in the classifiers answers and in domains with high variances of prior probabilities of classes this may be of significant value (Kononenko and Bratko, 1991). Still, however, there are some authors that cite and/or use this measure (e.g. Bailey and Elkan, 1993; Brazdil et al., 1994; Bruha and Kockova, 1993; Eisenstein and Alemi, 1994; Fürnkranz, 1994; Kodratoff et al., 1994; Michie et al. 1994; Moustakis, 1995; Reich, 1995; Tirri et al., 1996; Zheng, 1993), including even, surprisingly, Grzymala-Busse (1992).

4. In our paper (Kononenko and Zorc, 1994) we give the best results for the RST-based algorithm where we tried different values of the parameter α for the majority class limit. For other algorithms the default values of all parameters were used. Therefore, the results in Tables 1 and 2 are an *overestimation* of the performance of the RST-based algorithm. This fact was ignored by Grzymala-Busse et al.

3 Drawbacks of the RST approach to ML

In this section we stress the drawbacks of the RST as described in (Kononenko and Zorc, 1994):

The lack of experimental comparison: In the previous section we clarified our experimental comparison of one RST-based machine learning algorithm. In our previous paper we claimed that too few experimental evaluation of the RST approach to machine learning exists. Grzymala-Busse et al. disclaim this fact by citing 19 references that appeared later or the same year as our paper. One certainly should look at all those references, however, this cannot serve as argumentation against claims about state-of-the-art of the paper that appeared in 1994. With modifications/extentions of the RST approach to machine learning it is obvious that one can achieve good performance. However, this fact is obvious also for any approach to machine learning.

Complicated formalization: of rather trivial notions and sometimes strange terminology that confuses the point clearly indicates that the RST is an unnecessary burden for the machine learning algorithms. Skipping the RST staff from the RST-based machine learning algorithms would make the algorithms more simple and more readable and would make algorithms more easily extensible to deal with noise and incomplete data.

Grzymala-Busse et al. fail to comment this issue in their paper as well as they fail to comment the definition of complete independence of two attributes X and Y (Pawlak et al., 1988):

$$H(Y|X) = \log m$$

where m is the number of values of attribute Y.

Inflexibility of the knowledge representation: of the RST approach to machine learning was recently overcome in a bunch of different ways by extending the basic RST apporach by more or less ad-hoc solutions. Therefore, the same argument applies for this issues as for the experimental comparison: With modifications/extentions of the RST approach to machine learning it is obvious that one can obtain more flexible knowledge representation. However, this fact is obvious also for any approach to machine learning. Again, the RST approach is an unnecessary burden that can be easily skipped.

Ad-hoc solutions: The conclusions from our original paper are still valid: Instead of using well known results from the probability theory and the information theory, authors from the RST community often use ad-hoc definitions and solutions. There is plenty of parameters and thresholds with poor theoretical background. The same methodology is used also in the recent extentions of the RST approach to ML.

4 Conclusion

From the discussion above I conclude that with additions to the Rough Sets theory one can certainly achieve good performance. However, good performance of such systems is not due to the Rough Sets Theory but due to the additions, and that the use of Rough Sets is an unnecessary burden for machine learning algorithms. Therefore, of conclusions from our original paper only the latter ("The problems with noise and incomplete data disables RST from providing efficient solutions for complex real-world problems.") was invalidated by Grzymala-Busse et al.

References

[1] Bailey T.M., Elkan C. (1993) Estimating accuracy of learned concepts, *Proc. Int. Joint Conf. on Artificial Intelligence IJCAI-93*, pp.895-900.

[2] Brazdil P., Gama J., Henery B. (1994) Characterizing the applicability of classification algorithms using meta-level learning. *Proc. Eurp. Conf. on Machine Learning ECML-94*, Catania, April 1994, pp. 83-102.

[3] Bruha I., Kockova S. (1993) Quality of decision rules: empirical and statistical approaches. *Informatica*, 17:233-243.

[4] Eisenstein E.L., Alemi F.(1994) An Evaluation of Factors Influencing Bayesian Learning- Systems, *J. of the American Medical Informatics Association*, 1:72-284.

[5] Fürnkranz J. (1994) Top down pruning in relational learning, *Proc. Europ. Conf. on Artificial Intelligence ECAI-94*, Amsterdam. pp.453-457.

[6] Grzymala-Busse J.W. (1992) Lers- a system for learning from examples based on rough sets. In. R.Slowinski (ed.) *Intelligent Decision Support: Handbook of Applications and Advances of the Rough Sets Theory*, Kluwer Academic Publ.

[7] Grzymala-Busse J.W., Stefanowski J. and Ziarko W. (1996) Rough Sets: Facts Versus Misconceptions, *Informatica*, this volume.

[8] Kodratoff Y., Moustakis V., Graner N. (1994) Can machine learning solve my problem, *Applied Artificial Intelligence*, 8:1-31.

[9] Kononenko I. and Bratko I. (1991) Information based evaluation criterion for classifier's performance, *Machine Learning Journal*, 6:67-80.

[10] Kononenko I., Zorc S. (1994) A critical analysis of rough sets approach to machine learning, *Informatica*, 18:305-313

[11] Michie D., Spiegelhalter D.J., Taylor C.C. (eds.) (1994) *Machine learning, neural and statistical classification*, Ellis Horwood.

[12] Moustakis V.S. (1995) CEG - A case-based decision modeling architecture, *European J. of Operational Research*, 84:170-191.

[13] Pawlak Z., Wong S.K.M., Ziarko W. (1988) Rough sets: probabilistic versus deterministic approach. *Int. J. Man-Machine Studies*, 29: 81-95.

[14] Reich Y. (1995) Measuring the value of knowledge, *Int. J. of Human-Computer Studies*, 42:3-30.

[15] Tirri H., Kontkanen P., Myllymaki P. (1996) Probabilistic instance-based learning, *Proc. Int. Conf. on Machine Learning ICML-96*, Bari, Italy, July 1996, pp.507-515.

[16] Zheng Z. (1993) A benchmark for classifier learning, *Proc. Australian Joint Conf. on AI*, 16-19. Nov. 1993.

Application of Neural Networks to Nuclear Power Plants in Korea

Se Woo Cheon
Korea Atomic Energy Research Institute
Yu Song P.O. Box 105, Taejon 305-600, Korea
Phone: +82 42 868 8869, Fax: +82 42 868 8357
E-mail: swcheon@nanum.kaeri.re.kr

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This paper introduces an overview of neural network applications for nuclear power plants in Korea. Neural networks have been applied to various fields of nuclear power plants since early 1990s. The fields of applications can be categorized into two areas. One is plant diagnostics based on the pattern recognition of input symptoms, which includes transient identification and multiple alarm diagnosis. The other is modeling of systems with interpretation of input-output relationships, which includes the prediction of plant parameters, the prediction of signal trend, and signal validation. Most neural networks were based on the backpropagation network model.

1 Introduction

In the operation of a nuclear power plant, a large number of process parameters and systems interactions poses difficulties for operators, particularly during abnormal operation or emergencies.

To help operators in effectively maintaining plant safety and enhancing plant availability, operator support systems that employ the techniques of system modeling and expert systems have been developed in Korea (Cheon 1996).

The neural network, that is another candidate technique to enhance the capability of the operator support systems, offers a method of implementing real-time monitoring and diagnostics in nuclear power plants. Neural networks show great promise for use in environments in which robust, fault-tolerant pattern recognition is necessary, and in which the incoming data may be distorted or noisy.

A number of neural network applications for nuclear power plants have been reported since a decade. These include diagnostics (Guo & Uhrig 1992; Parlos et al. 1994; Tsai & Chou 1996), signal validation (Upadhyaya & Eryurek 1992; Fantoni & Mazzola 1996), control (Jous & Williams 1990; Bakal et al. 1995), plant state identification (Bartlett & Uhrig 1992; Tsoukalas 1994), prediction of plant parameters (Sofa et al. 1990), and optimization (Fukuzaki et al. 1992).

In Korea, a number of studies on the application of neural networks have been performed since early 1990s. The fields of applications can be categorized into two areas. One is plant diagnostics based on the pattern recognition of input symptoms, which includes transient identification and multiple alarm diagnosis. The other is modeling of systems with interpretation of input-output relationships, which includes the prediction of plant parameters, the prediction of signal trend, and signal validation. Most neural networks were based on the backpropagation network model (Rumelhart & McClelland 1987).

This paper describes the research activities in Korea.

2 Application of Neural Networks to Nuclear Power Plants

2.1 Transient identification

When a transient disturbance occurs in a plant, sensor outputs or instrument readings undergo a transient and form a different symptom pattern that represents a different plant state. The fact that the symptom pattern is different for any condition is sufficient to provide a basis for identifying the transient behavior. Thus, this behavior can be easily incorporated into a neural network.

Cheon & Chang (1993a) introduced the feasibility of using a neural network for transient identification.

The implemented network was a three-layer feedforward network based on a modified backpropagation model, where the input layer consists of 24 sensor input nodes, a hidden layer consists of 17 nodes, and an output layer consists of 14-class transient identification nodes. The input values are various parameter trends (increasing/unchanging/decreasing), valve position (open/closed), pump operating state (operating/stopped) and alarm data (on/off).

The acquisition of the training data can be made possible by using actual plant data and/or the results of computer simulation codes. In this way, the transient behavior of sensors and alarms can be transformed into a transient data template. To construct the template, the approach was based on the conversion of raw symptom data to qualitative relationships and on the mapping of these relationships to transient conditions. That is, the analog data is qualitatively divided into three categories; 1, 0, and -1 corresponds to the trends of increasing, unchanging and decreasing, respectively. For binary on/off type data, 1 and 0 represents on and off, respectively.

After the network has been fully trained, the transient identification is simply a matter of presenting plant symptoms to the input nodes and comparing the activation values at the output nodes. In other words, a transient can be diagnosed when the output node pertinent to the transient is represented by a significant high activation value (close to +1) for a given symptom vector.

The network was trained until the error in the weights between successive iterations was less than a specific minimum value. Total 29,431 training cycles were required to achieve 0.1% root mean squared (RMS) output error.

They demonstrated the performance of the trained neural network in the cases of untrained, incomplete, and sensor-failed symptoms. The results showed that the network was able to identify an appropriate transient with RMS errors less than 3.14% in all cases. Also, multiple transients were simultaneously identified with a given symptom vector.

2.2 Multiple alarm diagnosis

The purpose of multiple alarm diagnosis is to give operators the correct information and perception of the malfunction present in a plant. The operators should comprehend a malfunction in real time by quickly analyzing a set of multiple alarms. This task can be also viewed as a form of pattern recognition.

The diagnosis of multiple alarms by Cheon et al. (1993b) was approached from a pattern-matching perspective in that an input pattern was constructed from alarm symptoms and this pattern was matched to the appropriate output pattern that is corresponding to the fault occurred.

The target domain for multiple alarm diagnosis was the reactor coolant pump system at Kori-2 nuclear power plant, where 9 faults were related to 12 alarms. Total 41 alarm sets, where each alarm set corresponds to one of the possible faults, can be derived from the analysis of a cause-consequence diagram. The training data were easily implemented from those alarm sets by encoding 1's for active alarms (on state) and 0's for inactive alarms (off state).

In the implemented backpropagation network, an input layer had 12 alarm input nodes, a hidden layer had 8 nodes, and an output layer had 9 fault identification nodes. Total 5,875 training cycles were required to get a mean square error of 0.01%.

They tested the recall operation for five cases; single alarm pattern, untrained alarm pattern, incomplete/sensor-failed symptoms, multiple fault identification, and time-varying alarm patterns. Their results showed that the trained network was able to diagnose the fault of multiple alarms well in all cases. They demonstrated that the neural network trained to identify a single fault was also used to identify simultaneous multiple faults.

2.3 Prediction of thermal power

Traditionally, thermal power in nuclear power plants can be predicted using either physical or empirical models. However, it is difficult to accurately measure thermal power due to the uncertainty associated with large-scale flow measurement devices.

Roh et al. (1991a & 1991b) proposed the feasibility of using neural networks in thermal power measurement systems. The proposed system had two signal processing modules, one for input preprocessing using a modified parity space algorithm and the other for power prediction using two backpropagation neural networks.

The parity space algorithm was based on the recognition of inconsistencies among the redundant measurement values from multi channels; it generates the most consistent value by eliminating any fault signal exceeding the allowable error bounds of the parity space.

For the power prediction module, two networks were constructed for the prediction of two-type power levels; one from a nuclear instrumentation system (i.e., reactor power in the primary system) and the other from steam generators (i.e., thermal power in the secondary system).

In the first network, the input layer had four nodes (i.e., reactor coolant system average temperature, reactor coolant system reference temperature, delta temperature and cold-leg temperature) and the output layer had one node corresponding to the first power level. In the second network, the input layer had six nodes (i.e., steam pressure, main feedwater flow rate, main feedwater temperature, turbine impulse pressure, main feedwater pressure, and steam generator water level).

They demonstrated the performance of the system with several recall cases such as untrained input patterns, random noisy inputs, and lack of input parameters. The results showed that the system was able to predict two power levels reasonably with error deviations less than 2.3% in all cases.

2.4 Prediction of thermal margin

In a pressurized-water-reactor (PWR) type reactor core, one of the key safety parameters is the departure from nucleate boiling ratio (DNBR). This is defined as the ratio of the critical heat flux to the current peak heat flux, given the same thermal hydraulic conditions.

DNBR is used to estimate the core thermal margin, defined as the difference between the predicted (minimum) DNBR and the limiting DNBR. During normal operation, appropriate thermal margin should be continuously monitored for the protection of the reactor core.

DNBR is not directly measurable but derived from the calculation results of a thermal hydraulic computer code, given the inputs of several core related parameters. Since use of the computer code involves rather complex calculations with extensive data storage, some simplification for the calculation model should be required for on-line DNBR monitoring.

On-line estimation of thermal margin by Kim et al. (1992) was approached to train a backpropagation neural network to map the plant variables being monitored to the DNBR that was calculated by the computer code COBRA.

The major parameters affecting the DNBR are core inlet temperature, core power (or heat flux), enthalpy rise peaking factor, core inlet flow rate, and reactor coolant system pressure. Hence, the input layer had five nodes corresponding to these parameters. The output layer had a single node representing the predicted DNBR value.

The DNBR results, predicted from the network using untrained input data, agreed with those obtained from COBRA calculations within 2.5% error in virtually all cases.

2.5 Prediction of reactor core parameters

In a PWR-type nuclear reactor, optimal fuel reloading has significant meanings in both safety and economic aspects. When one fuel cycle has been finished, about one-thirds of the total number of fuel assemblies should be replaced by fresh fuel assemblies, and the reactor core parameters, such as the local power peaking factor, the maximum burnup, and the effective multiplication factor, should be estimated using a computer code package.

After reloading of the fresh fuel assemblies, the local power peaking factor and the maximum burnup should be kept lower than the predetermined values to maintain the integrity of fuel assemblies. Also, the effective multiplication factor should be maximized to extract maximum energy from fuel assemblies.

Kim et al. (1993a) proposed the feasibility of using neural networks to predict the reactor core parameters at the beginning of cycle condition for a given fuel loading pattern.

They constructed two backpropagation networks for the prediction of two parameters; one for the local power peaking factor and the other for the maximum value of the effective multiplication factor. Each network had 20 input nodes, 500 hidden nodes and 18 output nodes. The training data for these two parameters were obtained from the results of the CITATION computer code. In this way, over 1,000 different training data patterns were generated randomly.

To test the recall performance of the trained network, 100 untrained loading patterns were generated randomly. In the prediction of the local power peaking factor, the output values for the 90% of the untrained loading patterns were successfully predicted within 6.0% error, and the maximum and average prediction errors were 7.8% and 2.9%, respectively. The recall time of the network was about 700 times faster than the calculation time of the CITATION code. Hence, using the neural networks, the fuel reloading time can be reduced considerably.

2.6 Prediction of critical heat flux

The critical heat flux (CHF) is one of the important design factors to extract maximum thermal power from nuclear reactors without the risk of fuel burnout.

Traditionally, the CHF was estimated by experiments or statistically analyzing the look-up tables prepared from experiments.

Moon & Chang (1994) proposed the prediction method of the CHF, based on the fuzzy clustering and backpropagation neural networks.

Using fuzzy *c*-means clustering, experimental CHF data can be divided into four data groups, each group has characteristic data ranges and its physical meanings. These partitioned data can be used to investigate CHF mechanisms according to the experimental conditions.

The CHF data in each group were trained in a backpropagation neural network to predict the CHF. The RMS errors of the prediction results were less than 20% except for the data group 4.

They compared the prediction results by using seven different conventional methods with the result from the neural networks. They showed that the neural networks were able to predict the CHF better than any other conventional correlation. This method can be used for numerous two phase flow phenomena, heat transfer and flow mechanics.

2.7 Prediction of signal trend

Signal prediction is to estimate the signal values to be detected in the near future by using the last available measurement data. Traditionally, signal prediction can be accomplished using the measurement data and the physical model of a system. However, it is difficult to set up all required physical models for many systems in nuclear power plants.

The possibility of using a neural network for predicting the signal trend of a plant parameter was demonstrated by Kim et al. (1993b). The target signal for prediction is the steam generator water level that is one of the important parameters for plant operation and is difficult to detect accurately.

The basic idea is the auto-regressive (AR) method that is a powerful representation technique for linear systems. The implemented network was a three layer backpropagation network. The number of nodes for the input, hidden and output layers were nine, ninety and eight, respectively.

They demonstrated the signal prediction capability of the neural network by simulating one of steam generator transients. The simulation results showed that the predicted trend (i.e., increasing, decreasing or steady) of the steam generator water level followed the actual trend of the signal well. Although the detected signal had noise, the result followed the actual trend of the signal.

2.8 Signal validation

In nuclear power plants, sensor outputs from many different channels are used in control systems, protection systems, and plant-wide monitoring systems. It is necessary to validate these sensor outputs to increase the reliability of operator decision and improve plant productivity.

Work by Oh et al. (1995) was the signal validation of the pressurizer water level, where they used the backpropagation network model and a generalized consistency checking method. A neural network was used as an estimator of sensor signal validation, instead of a physical model. The generalized consistency checking method was used to detect inconsistencies among redundant sensors.

For signal validation, the input layer of the neural network had four input nodes (i.e., reactor power, pressurizer pressure, and both hot- & cold-leg temperatures), and the output layer had just one node for the estimation of the pressurizer water level.

In the case of trained input signals, the neural network estimated the pressurizer level signal with standard deviations less than 0.17% during the transient condition of a safety injection accident. They also showed that the estimated value was not greatly affected by noisy sensor inputs.

3 Conclusions

This paper has surveyed a number of studies on the neural network applications to the operation of nuclear power plants in Korea. Although much works have been performed at the feasibility stage, those applications may be the potential for actual implementation.

The neural network approach has powerful advantages such as short knowledge acquisition time, fast execution time, robustness to noisy input signals, and general mapping capability. Especially this approach is most appropriate for the pattern recognition problems in environments where plant actual data are abundant and noisy.

To combine the advantages of both conventional expert systems and neural networks synergistically, the technique of hybrid systems may be required to the development of more enhanced operator support systems. For example, a neural network module preprocesses and analyzes raw input data, and its output is used as input to an expert system module.

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References

[1] Bakal, B., Adali, T., Fakory, R., Sonmez, M. K. & Tsaoi, O. (1995) Neural Network Simulation of Real Time Core Neutronic Model. *Proceedings of the SCS Simulation Multiconference*, Phoenix, AZ, USA.

[2] Bartlett, E. B. & Uhrig, R. E. (1992) Nuclear Power Plant Status Diagnostics Using an Artificial Neural Network. *Nuclear Technology*, 97, p. 272–281.

[3] Basu, A. & Bartlett, E. B. (1994) Detecting Faults in a Nuclear Power Plant by Using Dynamic Node Architecture Artificial Neural Networks. *Nuclear Science and Engineering*, 116.

[4] Cheon, S. W. (1996) Development of Expert Systems for Nuclear Power Plants in Korea. *Informatica*, 20, 2, p. 203–209.

[5] Cheon, S. W. & Chang, S. H. (1993a) Application of Neural Networks to Connectionist Expert System for Transient Identification in Nuclear Power Plants. *Nuclear Technology*, 102, 2, p. 177–191.

[6] Cheon, S. W., Chang, S. H., Chung, H. Y. & Bien, Z. N. (1993b) Application of Neural Networks to Multiple Alarm Processing and Diagnosis in Nuclear Power Plants. *IEEE Transactions on Nuclear Science*, 40, 1, p. 11–20.

[7] Fantoni, P. F. & Mazzola, A. (1996) Multiple-Failure Signal Validation in Nuclear Power Plants Using Artificial Neural Networks. *Nuclear Technology*, 113, 3.

[8] Fukuzaki, T., Ohga, Y. & Kobayashi, Y. (1992) Feasibility Studies on Applying Neural Network Techniques in Nuclear Power Plants. *Proceedings of the OECD-NEA/IAEA International Symposium on NPP Instrumentation and Control*, Tokyo, Japan.

[9] Guo, Z. & Uhrig, R. E. (1992) Use of Artificial Neural Networks to Analyze Nuclear Power Plant Performance. *Nuclear Technology*, 99, p. 36–42.

[10] Jouse, W. C. & Williams, J. G. (1990) Neural Control of Temperature and Pressure During PWR Start-up. *American Nuclear Society*

Transactions, 61, Nashville, TN, USA., p. 219–220.

[11] Kim, H. K. , Lee, S. H. & Chang, S. H. (1992) Neural Network Model for On-Line Thermal Margin Estimation of a Nuclear Power Plant. *Proceedings of the 2nd International Forum on Expert Systems and Computer Simulation in Energy Engineering*, Erlangen, Germany.

[12] Kim, H. G., Chang, S. H. & Lee, B. H. (1993a) Optimal Fuel Loading Pattern Design Using an Artificial Neural Network and a Fuzzy Rule-Based System. *Nuclear Science and Engineering*, 115, p. 152–163.

[13] Kim, W. J., Chang, S. H. & Lee, B. H. (1993b) Application of Neural Networks to Signal Prediction in Nuclear Power Plant. *IEEE Transactions on Nuclear Science*, 40, 5, p. 1337–1341.

[14] Moon, S. K. & Chang, S. H. (1994) Classification and prediction of the critical heat flux using fuzzy theory and artificial neural networks. *Nuclear Engineering and Design*, 150, p. 151–161.

[15] Oh, S. H., Kim, D. I., Chung, Y. H., Zoo, O. P., Yun, W. Y. & Kim, K. J. (1995) Sensor Signal Validation Method of Nuclear Power Plant Using the Neural Network and the Inconsistency Index. *Proceedings of the Topical Meeting in Computer-Based Human Support Systems: Technology, Methods, and Future*, American Nuclear Society, Philadelphia, USA, p. 459–466

[16] Parlos, A. G., Muthusami, J. & Atiya, A. F. (1994) Incipient Fault Detection and Identification in Progress Systems Using Accelerated Neural Network Learning. *Nuclear Technology*, 105, p. 145.

[17] Roh, M. S., Cheon, S. W. & Chang, S. H. (1991a) Thermal Power Prediction in Nuclear Power Plant Using Neural Network and Parity Space Model. *IEEE Transactions on Nuclear Science*, 38, 2, p. 866–872.

[18] Roh, M. S., Cheon, S. W. & Chang, S. H. (1991b) Power Prediction in Nuclear Power Plants Using a Back-propagation Learning Neural Network. *Nuclear Technology*, 94, p. 270–278.

[19] Rumelhart, D. E. & McClelland, J. L. (1987) Parallel Distributed Processing: Explorations in the Microstructure of Cognition. *The MIT Press*, Cambridge, MA, USA.

[20] Sofa, T., Eryurek, E., Uhrig, R. E., Dodds, H. L. & Cook, D. H. (1990) Estimation of HFIR Core Flow Rate Using a Back Propagation Network. *American Nuclear Society Transactions*, 61, Nashville, TN, USA.

[21] Tsai, T. M. & Chou, H. P. (1996) Recurrent Neural Network for Fault Detection and Isolation. *Proceedings of the 1996 American Nuclear Society International Topical Meeting on Nuclear Plant Instrumentation, Control, and Human-Machine Interface Technologies*, Pennsylvania, USA, p. 921–926.

[22] Tsoukalas, L. H. (1994) Virtual Measurement and Prediction in Human-Centered Automation. *Proceedings of the Topical Meeting on Computer-Based Human Support Systems: Technology, Methods, and Future*, the American Nuclear Society's Human Factors Division, Philadelphia, Pennsylvania, USA., p. 235–241.

[23] Upadhyaya, B. R. & Eryurek, E. (1992) Application of Neural Networks for Sensor Validation and Plant Monitoring. *Nuclear Technology*, 97, 2, p. 170–176.

$\Pi\acute{o}\lambda\varepsilon\mu o\varsigma$[1] of Consciousness

The Informational in the Conscious Mind

A short counter-essay with a commentary to a book

All essential philosophical questioning is necessarily untimely. This is so because philosophy is always projected far in advance of its time, or because it connects the present with its antecedent, with what initially *was. Philosophy always remains a knowledge which not only cannot be adjusted to a given epoch but on the contrary imposes its measure upon its epoch.*

—Martin Heidegger [3] p. 8

The Conscious Mind by David J. Chalmers[2] represents one of the rare new challenges in the study of consciousness which may concern computer scientists, AI scientists, and information scientists—the last ones in a particular way and much more than the other twos! Certainly, it may concern quite another profiles of scientists too, especially quantum theorists and philosophers, declining from the firm tradition of different physicists and philosophers schools worldwide. However, an adequately educated German would say, that *im großen und ganzen,*[3] the Chalmers' book is a consequence of the Australo-Anglo-American philosophical tradition[4] (a priori intension). Dealing with such a philosophical text, a European feels clearly how only very small disciplinary compromises within the firm tradition are possible: and Chalmers' essay just confirms such a 'microscopic' (if at all deliberate) informational compromise.

The undersigned will take the position to polemize merely with the part of the Chalmers' essay concerning the informational, how the informational is coming into the discourse of the physical and the phenomenal (experiential, psychological) of the conscious mind. Maybe he is wrong in the feeling, that the compromise between the physical and the phenomenal of the conscious mind lies in the informational. It appears a bit problematic to discuss the subject of the informational within the consciousness phenomenalism in the context of the predominantly traditionally conceptualized philosophical text—but let him try to do it anyhow.

An Initial Argument

A critical reader may argue that it is impossible to discuss a subject matter separately from the complete text of the Chalmers' book. Philosophically, the phenomenon of consciousness is a philosophical problem which can be hold within the usual common horizons of, for instance, cognitive science, psychology, mind theory, and other philosophically correlated scientific disciplines. Consciousness can certainly be studied from the biological point of view where neuroscience and neuropsychology can perform the study of the commonly related points. Consciousness can be grasped also as a biophysical or even pure physical phenomenon where the theoretical physics, especially quantum theory, could be helpful.

The informational view of consciousness does not fit traditionally the enumerated aspects: the philosophical, biological, neuroscientific, and physical. To be more precise: information is certainly taken as something most natural appearing in the mentioned scientific aspects. On the other hand, there does not exist a serious, fundamental, and thorough philosophy of information as a dynamic (live, emerging, arising, and especially cir-

[1]The Greek $\pi\acute{o}\lambda\varepsilon\mu o\varsigma$ has the meaning of dis-play, ex--hibition; its ancient meaning includes the conflict which sets (Being) apart, with setting up, raising, and erection; metaphorically, it has the meaning of the swarm of fight or the storm of battle. The so-called hard-problem of consciousness now begins to fall into the polemical context.

[2]CHALMERS, D.J. 1996. The Conscious Mind. Oxford University Press. New York.

[3]'*In general*' (or *im Grunde*) does not correspond felicitously the German phrase, which has in mind the size and the entirety of the book.

[4]D.J. Chalmers was born in Sydney, Australia, he has been a Rhodes Scholar at the University in Oxford, and now is a professor of philosophy at the University of California, Santa Cruz.

cular[5]) phenomenon yet, which would stay on its own informationally founded principles. It is astonishing how the dynamic nature of information was usually reduced into the framework of data, data processing, static information, information processing, and the like. Does consciousness represent that sort of exception where information emerges together with it as a dynamic concept, process and, lastly, phenomenalism?

The argument is that the conscious mind comes into the foreground of the scientific attention as an informational phenomenon par excellence. The informational theory of consciousness can be construed on common informational principles, where conscious mind is structured and organized as a particular informational system of the universe—within the so-called *informational space.* Under the sufficiently wide conceptualized principles, this kind of space can cover the humanly conceptualized physical space and, certainly, the phenomenal space of any kind. But let us discuss these possibilities in a separate paragraph.

Some Essential Chalmers' Arguments and Doubts

To reach a sufficiently actual polemic concerning the conscious phenomena, we must first discuss and interpret Chalmers' arguments, beginning by Section 8 of his book, entitled *Consciousness and Information: Some Speculation.* Up to this point we must construct a small dictionary of the most essential Chalmers' terms to maintain the discussion as intelligible as possible. We must not forget the titles of the subsections which bring some pre-understanding into the discourse concerning consciousness and information. The subtitles are: 1. Toward a fundamental theory; 2. Aspects of information (physically realized information, phenomenally realized information, the double aspect principle); 3. Some supporting arguments (explaining phenomenal judgements); 4. Is experience ubiquitous? (what is like to be a thermostat? whither panpsychism? constraining the double-aspect principle); 5. The metaphysics of information (it from bit, grounding information in phenomenology, what about macroscopic phenomenology?); 6. Open questions.

How to construe a fundamental theory of consciousness? Chalmers begins with three principles which are according to his belief neither plausible nor fundamental, but they constrain the form of any correct consciousness theory. The most problematic among these principles is the principle of organizational invariance[6]. What has Chalmers in mind by the principle of organizational invariance?

Let us take two (living) systems that have the same fine-grained functional organization (a functional organization of a system which is fine enough to determine behavioral capacities). As a consequence, they will have qualitatively identical experiences. In this way, consciousness is an organizationally invariant experience (pp. 248–249). ..."if one system with fine-grained functional organization F has a certain sort of conscious experience, then any system with organization F has those experiences." (P. 274) However, the three principles do not give the answers to some fundamental questions: What kind of organization could constitute the conscious experience[7]? Which is the step of organizational simplicity by which the experience vanishes? This question concerns the border between conscious

[5]Circular informing of informational entities represents a kind of *questioning,* where some questions arise and have to be answered over and over again, cyclically improving the subject of questioning. In this respect, questioning belongs to the phenomenon (or mechanism) of informational decomposition of entities, especially to the intrinsic or metaphysicalistic ways of informational decomposition. Besides, circular informing can be grasped as the most natural form of the physical existence (lasting with minor, reductive, non-essential changes; inertia; perseverance; etc.) of things, processes, and phenomena.

[6]Invariance means the quality or state of being constant, for example, unchanged by specified mathematical or physical operations or transformations. The living phenomena—and consciousness is one of them—are, on the contrary, not only variant (variable, deviating) but also emerging, arising, spontaneous, and the like when the new conscious information is coming into existence. Several initial consciousness-like models (which are meant to emerge and develop circularly and spontaneously in their graphical and formal presentation) are formalized and discussed in [13]. This kind of organizational variance concerns just the informational systems (systems of circular informational formulas) representing the initial models. But, in philosophy, Being (of something) is that which never changes.

[7]One of the answers to this question is that the system organization must be informationally circularly structured, that is physically circularly realized (existent), e.g., in the form of circularly meshed neuronal nets in which informational phenomena (phenomenal entities) can appear, emerge, arise, and vanish physically.

and unconscious processes. Without phenomenal circularity, consciousness could not exist. Consciousness is, for example, closely tied to the phenomenon of memory. The majority of readership will agree that the dynamic property of memorizing concerns the circular physical and phenomenal organization. On the other side, experience can simply come to an end because of the insufficiency of outer an intrinsic stimuli concerning something conscious (the process of forgetting). The next question is (pp. 276–277) how can a specific character of experience be predicted from its physical basis? Prediction presupposes that what Chalmers calls the invariant organization (of the physical structure). In philosophy, that is, in the domain of experience (of the phenomenal), intention might be the adequate term, representing a kind of (informational) inertness (similar to the physical inertia, or a kind of system perseverance, equilibrium, stability).

The final theory of consciousness would need a set of psychophysical laws analogously fundamental to fundamental laws of physics. Is it really a necessity, or something different has to be invented to have the retrograde impact on the existing fundamental physical laws? The most problematic point of any physical law is that it is invariant. Through the cultural and especially technological (scientific) development of the conscious mind, physical laws have been changed, innovated, improved, and also developed from different points of views. Can consciousness really have a kind of its own mass, energy, inertia, charge, gravity, relativity, electromagnetism, and the other physics-like laws to become a scientific discipline, and thus to remain within the horizons and technical frameworks of the traditional science and the western philosophical thought?

A Short Dictionary of the Most Frequently Used Terms

coherence principle: connects consciousness to awareness (global availability);

consciousness: is emergent in a stronger sense [1]; the strong variety of emergence requires new fundamental laws in order that the emergent properties emerge (pp. 129–130);

connection between experience, information, and intrinsic properties of the physical;

double-aspect principle: represents a crucial link between the physical and the phenomenal; whenever an information space is realized phenomenally, the same space is realized physically;

information: is realized in phenomenology; information is a link between the physical and the phenomenal; it is fundamental by itself;

information space: is an abstract space consisting of a number of information states; lastly, the concept approaches that of Hilbert space [6];

information state: is realized in the experience's physical substrate; within Chalmers' proposal, such a state could be a sequence of bits;

principle of organizational invariance: means a fine-grained functional organization causing the same kinds of system experiences;

principle of structural coherence: connects the structure of consciousness to the structure of awareness;

psychophysical laws: connections between consciousness and physical processes;

states of experience: fall into information spaces in a natural way

Information as an Aspect toward a Fundamental Theory

Information should be one of the fundamental aspects of the new theory proposed by Chalmers. Chalmers turns to the concept of information invented by Shannon[8] (1948). He slightly adapts and develops the Shannon's idea.

Shannon developed a syntactic (formally primitive) notion of information, leaving its semantic subject as information about something untouched. The bit is the basic information particle which can carry information (0 or 1). Bits can be composed into messages as sequences (concatenations) of bits (information states). A state can be differently interpreted within different information spaces. Number of possible states constitutes a space and enables a basic structure of differences between states. To distinguish differences between states is the crucial relation of the space. If the sequence of bits has a length m, the number of the possible different occurrences

[8] SHANNON, C.E. 1948. A Mathematical Theory of Communication. Bell System Technical Journal **27:** 379–423.

is 2^m.[9]

In the widening of the concept, Chalmers allows a more complex difference structure between states and also an internal structure of the states[10]. Complexity can be increased by choosing the basis b of a system $b > 2$ (e.g., $b = 3, 4, \ldots$). Lastly, continuous information spaces can be introduced whose states are within an interval of continuous real numbers. In such a space the structure corresponds to the topology of the continuum (adjectives like close, closer, distant, etc. can come into the discourse of the relations of states.) And certainly spaces can be multidimensional[11].

An information state can also have a continuous internal structure, which would mean an infinite number of 'values' (e.g., meanings, interpretation possibilities). An information space could have *two* sorts of structure: internal structure of a state, and each state element can belong to a subspace with a topological difference structure[12]. The first structure is combinatorial (number of states) and the second one relational (differences between the state elements).

Chalmers says that much of the time, a subspace will have the same relational structure (probably, a kind of intentionality). But, this kind of space does not incorporate anything semantical (e.g., in the sense of Dretske[13] or Barwise and Perry[14]). Chalmers stresses that it might be possible to associate a semantic content with each information state. In this way, the information part, connecting the physical part and the phenomenal part within a unique fundamental theory of consciousness is a new, possibly a mathematical construct of the combinatorial and relational formalistic nature. How could it happen that nobody prior to Chalmers came to the idea of a particular mathematical theory of information[15]?

Information in the Physical and Phenomenal World

Let us begin by Bateson:[16] information is a *difference that makes a difference.* This slogan reminds on 'something being something', on a circular structure (difference that makes difference, consciousness that makes consciousness, or informational metaphysicalism in the terms of the undersigned [7, 9, 13, 15, 16]).

"Physical states will correspond to information states according to their effects on the causal pathway" (p. 281). But information can also be found in phenomenology (p. 284). States of experience fall into information spaces. Whenever an information space is realized phenomenally, the same information space can be realized physically[17]. What is the ontology of such a view? Are the physical, the phenomenal, or both, ontologically dependent on the informational? We see how information, in its complexity, is not comparable with primitive features of the physical world (mass, charge, and so on). Is there a way of seeing information itself as fundamental (p. 287)?

Only a Call for the New Sort of Reductionism?

The undersigned would heavily believe that phenomenalism (not phenomenology) of the informational could be narrowed into a kind of new reductionism—the so-called organizational invariance[18]. Information systems which are observed

[9]So far, there is nothing new for a basically educated computer user.

[10]On this way, one slightly arrives to the concepts of, for example, relational databases or structured programming in general.

[11]So far, this concept remains within the geometry of Hilbert spaces [6].

[12]This concept does now, to some extent, approach to the undersigned concept of informational entity in respect of the infinite number of possibilities of the emerging of the entity. The undersigned will present his concept of the informational space in the shortest possible way in the continuation of this counter-essay.

[13]DRETSKE, F.I. 1981. Knowledge and the Flow of Information. MIT Press. Cambridge, MA.

[14]BARWISE, J. & J. PERRY. 1983. Situations and Attitudes. MIT Press. Cambridge, MA.

[15]The question remains if any traditional mathematical theory could come closer to the nature of the self-organized, developing, autopoietically structured concept of informational entities.

[16]BATESON, G. 1972. Steps to an Ecology of Mind. Chandler. San Francisco, CA.

[17]The problem may emerge if we do not know (yet) exactly how to realize such a transformation or connection, respectively.

[18]A sort of organizational invariance could only be very schematic, that is, artificial, as an advice to the general structure (dynamics) of organization. The undersigned has proposed a standardized form of metaphysicalistic organization in the form (of a circular sequence) of intentional informing, counterinforming, and informational embedding within an informational entity—not only the consciousness one [7, 9, 13]. Physically, a kind of instantaneous organi-

within the living world live together with their owners, and behave together with them variably. What could be organizationally invariant in the fundamental laws of consciousness is a sort of initial schematism (imprints, initial systems, informational graphs [16]) which already developed into a more complex conscious organization, or is on the way to the consciousness vanishing—approaching the state of unconsciousness or something else.

It is important to stress that the informational, irrespective of its embedding within the physical and phenomenal, behaves phenomenalistically. For instance, for an arbitrary observer, consciousness $\mathfrak{z}$ informs (operator $\models$, as a general, not particularized yet, joker of consciousness informing) the observer about its phenomenalizing (symbolically, $\mathfrak{z} \models$). As a higher informational function, consciousness $\mathfrak{z}$ can be informed according to its informational capabilities intrinsically and environmentally (in general, symbolically, $\models \mathfrak{z}$). So far, there is no reductionism in these two principles (externalism and internalism of consciousness $\mathfrak{z}$, respectively).

The openness (emptiness on the one side of the operator $\models$) of consciousness $\mathfrak{z}$ to experience, memory, emotion, etc., that is, to *itself,* as well as to the environmental impacts, is formally expressed by its externalism ($\mathfrak{z} \models$) and its internalism ($\models \mathfrak{z}$). The openness of consciousness to itself is called consciousness *metaphysicalism* and expressed formally by $\mathfrak{z} \models \mathfrak{z}$. Metaphysicalism of consciousness brings the necessary (organizationally invariant) circularity as a basis of the experienced, rooting in the learned, memorized, emotionalized, etc. Metaphysicalism of consciousness is a consequence of its externalism and internalism [11]. At the end, phenomenalism of consciousness brings in the foreground the parallelism of externalism, internalism, and metaphysicalism in the possible forms of a formal expression, for example,

$$\mathfrak{z} \rightleftharpoons \begin{pmatrix} \mathfrak{z} \models; \\ \models \mathfrak{z} \end{pmatrix} \quad \text{or} \quad \mathfrak{z} \rightleftharpoons \begin{pmatrix} \mathfrak{z} \models; \\ \models \mathfrak{z}\,; \\ \mathfrak{z} \models \mathfrak{z} \end{pmatrix}$$

zational invariance could root in the current existence and in the connections of a living neuronal net, which structure together with neurons arose out of the concrete experiences (for example, the learned songs of a canary are fixed by the concrete connections of the emerged neurons for a specific song).

as the consequence of the first formula. These formulas serve as initial formulas for further decomposition of consciousness $\mathfrak{z}$.

As Chalmers stresses there is no a firm evidence that information is the link between physical processes and conscious experience (p. 287). A sort of supporting consideration is that the same informational spaces are realized physically and phenomenally. Such a double-aspect of information is compatible with the discussed psychophysical principles, especially with those of structural coherence and organizational invariance. The structure of experience can be seen as a phenomenally realized information space, while the structure of awareness is a kind of physically realized information space. This speaks in favor for the development of the really powerful theory of the informational space, which would exceed the formalism of, for instance, the Hilbert spaces in mathematics, introducing another (additional and different) formal structures, mappings, and transformations (for instance, that of meaning, interpretation between the pure informational and experientially informational space) into the space concept, and especially vectoring informationally the parallelism and simultaneously the metaphysicalism of circularly and intentionally (within spontaneous consideration) of informational entities in general, and consciousness as the physical, informational, and experiential phenomenon in particular.

Physical features that are both organizational invariant and simple enough should constitute the fundament of the consciousness theory. Physically realized information should meet the criteria of invariance and simplicity. In this search, the informational approach to physical laws should be essential (crucial) (p. 288).

Mathematical, Physical, Experiential, and Informational Space

In the title mentioned spaces are more concretely, for example: the Hilbert vector space, quantum field space in physics, yet not determined (or conceptualized) experience space (Chalmers' proposal), and the informational space which could correspond to any other mentioned space as a particularization of a wider conception.

Mathematical spaces are abstract and artificial (constructed by mathematicians on the basis of mathematical principles—axioms and rules of procedure). Hilbert space is one of candidates; it still needs an additional structure, especially if used as a vehicle within the experiential and informational space. The Hilbert space is already a good vehicle in the quantum theory [5], which is one of candidates for the description of the physical in the study of consciousness. In this case, the physical adds to the mathematical a particular semantics of operands and operators.

The undersigned sees, as the title of this paragraph marks, four basic theoretical problems: the mathematical, the physical, the experiential and the informational one. The four spaces, in the context of consciousness have to be compatible. A new mathematical space has to be developed for giving the support and possibilities to the formulation of the physical space (e.g., quantum space, in general). By this, the physical space becomes a real ground for the development of the abstract informational space, which can easily absorb the physical space as an abstract transformation (a mapping of a space into a space). Between the informational and the experiential space, probably, a meaning or an interpretative (concretely semantical) space is necessary, which is a particular (the second one) informational space, considering already the semantics of a particular experience space. This space is then definitely mapped onto the experiential space.

All the mentioned spaces need innovative ('radically' new) concept, innovation, structure, and organizational approach (the organization cannot be usually directly recognized out of the structure of a complex system [16]). The abstract informational space may serve as a paragon for the development of the mentioned physical and experiential space. So, let me list only some initial possibilities of the emerging informational space in the domain of consciousness.

For certain reasons, we introduce a Dirac-like notation for an informational entity (e.g., a vector in the Hilbert space), however, only in the sense of a symbolic likeness, which is neither structural nor contentious[19]. To express the whole possible formal complexity of the informational consciousness $\mathfrak{z}$ in the informational space, we introduce

$$\mathfrak{z} \rightleftharpoons \|\mathfrak{z}\rangle$$

[19]For comparison see Penrose [5] pp. 333–336, or in the pure mathematical sense in [6].

We have to recognize how symbol $\|\mathfrak{z}\rangle$ substantially differs from something, marked by $|\mathfrak{z}\rangle$, which could have sense as an element of the Hilbert space. Symbol (a kind of intentional informational vector) $\|\mathfrak{z}\rangle$ considers a parallel structured space, in which components of $\|\mathfrak{z}\rangle$ inform in parallel. Informational parallelism (e.g., an independent parallel informing of $\mathfrak{z}$'s components) within the $\mathfrak{z}$'s metaphysicalism (complexly interweaved circular connections of components—a structure of informational coherence) represents a kind of orthogonality (in mathematical spaces), and in this sense the left $\|$ in $\|\mathfrak{z}\rangle$ emphasizes this particular informational and, simultaneously, general feature (compared to the mathematical orthogonality)[20].

The Hilbert space H (with a product by a real number λ) is a good mathematical example for the discussion concerning consciousness. What could, for example, represent a real number and the scalar product (x, y) of vectors x and y as a possibility of an informational interpretation? Or, what to do with the laws of the Hilbert space like $(y, x) = (x, y)$; $(x, y + z) = (x, y) + (x, z)$; $(\lambda x, y) = \lambda(x, y)$; and $(x, x) > 0$ for $x \neq 0$ and $(x, x) = 0$ for $x = 0$.

Probably, some reasonable interpretation could be found, but all this would mean an artificial (only mathematically aesthetical) reduction. For this reason, an another mathematical space has to be theorized to make the presentation and description of the specific informational phenomenalism formally possible (and mathematically legal).

Another widening of the parallel vectored informational entity $\|\mathfrak{z}\rangle$ could follow the definition of the form

$$\|\mathfrak{z}\rangle \rightleftharpoons (\mathfrak{z}_0; \mathfrak{z}_1; \cdots; \mathfrak{z}_m)$$

However, this parallel (distributed) structure of $\|\mathfrak{z}\rangle$ does not exhaust its circular serial organization, which can be structured further as

$$ {}_1\|\mathfrak{z}\rangle \rightleftharpoons (((\cdots(\mathfrak{z}_0 \models \mathfrak{z}_1) \models \mathfrak{z}_2) \cdots \models \mathfrak{z}_{m-1}) \models \mathfrak{z}_m)$$

[20]The critical reader might agree that orthogonality is a particular case of informational parallelism, by which components irrespective of their serial informational coupling perform an intrinsic, e.g., metaphysical informing, which certainly can be impacted by the component environment.

where the subscript 1 refers to the other possibilities, that is,

$${}_i\|\mathfrak{z}\rangle;\quad 1 \le i \le \frac{1}{\ell+1}\binom{2\ell}{\ell}$$

of formal (causally dependent) consciousness expression. Number ℓ denotes the length of the serial formula (the number of consecutive binary operators $\models$ in the formula), and i is the consequence of the setting of the parenthesis pairs in the formula.

Further parallelism of consciousness components is possible, for example,

$$\|\mathfrak{z}\rangle \rightleftharpoons (\|\mathfrak{z}_0\rangle; \|\mathfrak{z}_1\rangle; \cdots; \|\mathfrak{z}_m\rangle)$$

and, consequently, for the serial organization,

$${}_1\|\mathfrak{z}\rangle \rightleftharpoons ((\cdots((\|\mathfrak{z}_0\rangle \models \|\mathfrak{z}_1\rangle) \models \|\mathfrak{z}_2\rangle)\cdots \models \|\mathfrak{z}_{m-1}\rangle) \models \|\mathfrak{z}_m\rangle)$$

An additional supplement to the discussed parallelism of consciousness entities and their components could be the informational metaphysicalism (a kind of an intrinsic and loose organizational invariance of the occurring entities and their components). The general and the standardized metaphysicalistic graph together with the formula system was presented in Fig. 7 and Fig. 9, respectively, in [14].

To emphasize both the metaphysicalistic and the parallel organization of consciousness, additionally the superscript μ is used; and expressing the metaphysicalistic parallel (distributed) and serial (metaphysicalistically circular) organization (parallel-serial-circular metaphysicalistic coherence), there is,

$${}^{\mu}\|\mathfrak{z}\rangle \rightleftharpoons ({}^{\mu}\|\mathfrak{z}_0\rangle; {}^{\mu}\|\mathfrak{z}_1\rangle; \cdots; {}^{\mu}\|\mathfrak{z}_m\rangle)$$

$${}^{\mu}_{1}\|\mathfrak{z}\rangle \rightleftharpoons (((\cdots(({}^{\mu}\|\mathfrak{z}_0\rangle \models {}^{\mu}\|\mathfrak{z}_1\rangle) \models {}^{\mu}\|\mathfrak{z}_2\rangle)\cdots \models {}^{\mu}\|\mathfrak{z}_{m-1}\rangle) \models {}^{\mu}\|\mathfrak{z}_m\rangle) \models {}^{\mu}\|\mathfrak{z}_0\rangle)$$

This short discussion should suffice to recognize where the essential problems of the emerging informational space might lurk[21].

[21] The undersigned prepares two papers, entitled *Informational Consciousness* and *Informational Theory of Consciousness,* which are in the final phase; the third one, *Informational Space* is under development, and will predominantly cover the dilemmas listed by Chalmers as well as those of the undersigned.

At last, what has to be said to the problem of the so-called experiential space? This space is a consciousness space and grasps the various sense and mind phenomena, that is, is extremely interdisciplinary. In this context the natural as well as humanistic sciences (philosophies) with their conceptual backgrounds will play their more or less significant roles for long. However, the new informational approach could be crucial not only in the development of the consciousness conceptualism but also for these sciences themselves. Metaphysicalistic organization [13] might be a good (initial) example of the mentioned possibilities.

The Metaphysics of Information

How to understand the view (the double-aspect or any other one) of information? A global answer might be: *The view of information can be understood only informationally.* Why? Understanding as such belongs to informational phenomena, based on experience, that is on consciousness. Somebody might argue that understanding can appear also as an unconscious phenomenon, or at least, to be not in the domain of consciousness. Without information, consciousness would hardly function as a conscious system processes.

This short introduction leads to the problem of informational circularity. Can anybody argue against the experience that information someone understands roots in information gathered and learned in preceding events and happenings? One of the most evident experiences of this sort is the domain of written and spoken language. Writing and speaking means to use words, their informational connections, sentences, etc. to explain and interpret new words, connections, and sentences, to arrive to the 'psychologically satisfactory' understanding, to the subjective feeling of understanding. The background of such understanding is certainly the existing neuronal net (the physical), built up by the previous learning and experience. The consequence is, that understanding information means to inform and to be informed by the other informational constituents.

Information could be grasped as a consequence of the entire physical phenomenalism, which means, within the physics of particles, waves, and other possible physico-mathematical abstract constructs, if possible, confirmed by experiments. Informational metaphysicalism is clearly on the way of such understanding of information by information.

Strong AI is based on mathematical principles and not on informational ones. The second ones could disturb the platonic and rationalistic structure of contemporary mathematics substantially. Machine consciousness based on computers is disputable. The conscious computation and its implementation remains an unanswered question of the contemporary computer science and AI. Brain is not a computer system, it is self-organized (spontaneous), autopoietic, and simultaneously sensitive for the impacts and disturbances of the environment and the like. Computers as systems cannot fulfill these requirements yet. The 'machine' must perform as an informational entity by itself, not only on its physical (hardware) level, but also on the level of its operating system and application programs. These requirements may lead to the concept of an another machine, called the informational machine [10]. Such a machine behaves phenomenalistically, and on the way to it, the new theoretical achievements have to be realized, especially in the domain of the so-called informational space.

Computation of Consciousness?

A new formalism, the strong mathematical one, should enable the computation of consciousness. Chalmers begins with the discussion in this direction by a finite-state automaton (FSA). The older generation of computer scientists may recall that FSA builds the background theory of nowadays computers. Such an automaton is, according to Chalmers, insufficient for the performing of consciousness computation. A combinatorial-state automaton (CSA) is like an FSA, except that its internal states are structured. A state of CSA is a vector $\vec{S}$ and can be infinite (probably, potentially infinite). The components of $\vec{S}$ correspond to the cells in a cellular automaton or the tape squares and head state in a Turing machine (p. 317). Each element s^i, can take on a finite number of values s^i_j, where s^i_j is the jth possible value of the ith element. Inputs and outputs have a similar structure: $\vec{I}$ and $\vec{O}$, respectively. In this sense, a CSA can be represented by an FSA (computational equivalence), but CSA should capture the structure and organization of consciousness (or, generally, a mind). A computer scientist may state that it is nothing profoundly new behind the CSA. All what remains is a kind of mapping the one system onto or into an another one (e.g. beginning by the mapping of the physical system, and so on).

A state of a physical system is decomposed[22] into a vector of substates (e.g., parallelism), and the causal organization of distinct components of the system must be considered (serial-circular organization with different causal possibilities [12]). According to Chalmers, the crucial differences between an FSA and a CSA are the following: (1) CSA is much more constrained; (2) a CSA implementation requires a complex causal interaction among separate parts of the machine; (3) by this, CSA captures the causal organization; (4) CSA can implement both the finite and infinite machines; (5) a CSA can reflect the complex formal organization of computational objects (Turing machines, cellular automata); (6) in the corresponding FSA, much of this structure would be lost[23].

Objections to AI are external and internal. External objections argue: computers follow rules and cannot exhibit creative and flexible behavior [2]; computers could never duplicate human mathematical insight and are limited by Gödel's theorem [4, 5]. Internal objections argue that computers cannot have inner life, experience, and understanding, but only a simulation of mentality.

The bridge between abstract (computational) and concrete (physical, cognitive) is the notion of *implementation* (p. 316): how a physical system realizes a computation and how a computation describes a physical system. The strong AI thesis says that implementation of the appropriate[24] computation suffices for consciousness. In

[22]The word (informational) *decomposition* is used as a central feature in the determination of an intrinsic or metaphysicalistic structure of an informational entity (see, for instance [7, 9, 11, 13, 14]).

[23]The last argument (6) forgets that an FSA could be specialized—especially equipped by hardware and software—to do the same equally satisfactorily as a CSA. This reminds on known (unsolved) problems with only minimally tailored machine philosophy.

[24]The appropriate in this context is crucial, although it is not clearly said what could it mean. An appropriate implementation would mean an appropriate informational machine which could essentially differ (certainly, as an informationally realized supplement) from the today mathematically based concept of a computation.

this context, implementation must not be taken for granted. Searle[25] argues that implementation is observer-relative (and not objective) and depends on an appropriate interpretation.

Chalmers says that he gives account of a single formalism, combinatorial-state automata, which corresponds to the different classes of computations: Turing machines, finite-state automata, Pascal programs, connectionist networks, cellular automata, etc. However, an average computer scientist knows that by an adequate program in any high-level programming language each of these computations, including CSA, can be implemented. The undersigned understands that the strong AI has now to be defended according to the tremendous extent of the human (intellectual), material, and financial investments into the field. The conclusion might be that there are no barriers to the ambitions of AI (p. 331). The external objections are without objective force, and the internal objections can be put by side by Chalmers' analytical arguments. There is hope that an appropriate computation will bring conscious experience with it (p. 331).

The Physical, the Informational, and the Phenomenal as Informational Phenomenalism

At last, after this dispute, it becomes necessary to turn to the metaphysical background of the discussed matters (e.g., in the sense of Heidegger's *Introduction to Metaphysics* [3]). It is significant to stay aware of the contradictions originating already from the Greek ontology (e.g., the apparent opposition of the Parmenides' and Heraclitus' doctrine and other apparent contradictions concerning Being, becoming, appearance, thinking and the ought, coming up as a sort of informational phenomenalism). Informational phenomenalism unites and perplexes apparently the most contradictory items of the ancient and nowadays philosophical investigation, especially in concern to the phenomenon of consciousness.

In the sense of [3], let us turn first to the problem of Being and becoming. By informational terms, becoming means informational arising, embracing everything which concerns the arising metaphorically (see [8], p. 141 or [7]). Thus 'arising' transits into a kind of (updated) informational inferential scheme of the form

arise

---

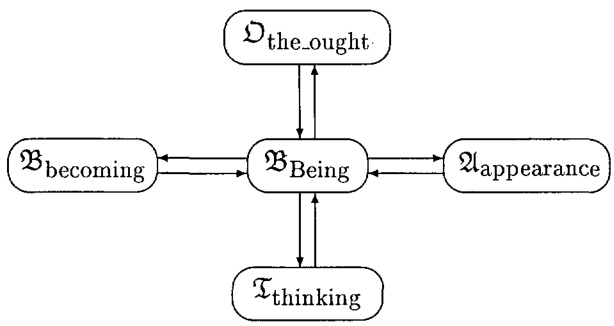
appear, be, become, become_conscious_of, bring_to_the_comprehensional_surface, come_to_presence, come_into_Being, come_into_existence, contradict, counteract, counterinform, create, develop, disclose, disturb, do, emerge, enable, establish, evolve, expose, form, generate, grow, imagine, impact, inform, inform_circularly, inform_spontaneously, innovate, inspire, interpret, make, mutate, oppose, originate, phenomenalize, process, process_anew, produce, set_up, shape, spring_up, understand, unfold, think,

...

This scheme unites that what could be marked as perplexity of the Being and becoming principle, that is,

$$\frac{\text{Parmenides' doctrine}}{\text{Heraclitus' doctrine}} \quad \text{and} \quad \frac{\text{Heraclitus' doctrine}}{\text{Parmenides' doctrine}}$$

in the Greek ontology [3]. But the principle of informational arising brings to the surface also the so-called appearance, thinking, and the ought[26] [3]. First, the appearance sounds in the sense of informingness (externalism of Being) and informedness (internalism of Being). In [3] (p. 196), Heidegger draws a scheme connecting (informationally) the discussed entities. This scheme can be transformed and slightly modified (to meet the informational principles) in the informational graph of the form



Operators (arrows) of the graph are inferential (particularized to $\doteqdot$ out of the general form $\models$). Thus, according to the Parmenides'/Heraclitus' teaching, there is informationally

[25] SEARLE, J.R. 1990. Is the Brain a Digital Computer? Proceedings and the Addresses of the American Philosophical Association **64:** 21–37.

[26] The verb ought expresses duty or moral obligation, and what is correct or naturally expected.

$$\frac{\mathfrak{B}_{\text{Being}}}{\mathfrak{B}_{\text{becoming}}} \quad \text{and} \quad \frac{\mathfrak{B}_{\text{becoming}}}{\mathfrak{B}_{\text{Being}}}$$

As one can see from the graph, the ontological (metaphysical) entities are circularly connected via $\mathfrak{B}_{\text{Being}}$. What could be said about the informational graph by the Chalmers terms? Evidently, Being is a representative of the physical (the Greek $\varphi\acute{\upsilon}\sigma\iota\varsigma$). Undoubtedly, consciousness belongs to thinking, and has its roots in the physical (Being). The phenomenal is constituted by becoming and appearance. The informational, in concern to consciousness, stands somewhere between appearance and thinking. The ought belongs to the physical, but also to the laws of physics thought by man, that is, to consciousness.

The informational in the most general physical and phenomenal sense unites the presented informational graph in its physical and phenomenal entirety. Because of the evident informational circularity, all the entities are not only circularly informationally perplexed but perform (in fact, inform) also in parallel.

A Concluding Commentary

Chalmers' book gives suggestions to the different scientific disciplines. In this short essay the informational view of consciousness-related topics was discussed mainly. The undersigned believes that, for instance, varieties of psychological consciousness (pp. 26–28) may substantially influence the formalistic (theoretically-symbolic) abstract systems formalizing the phenomenon of consciousness, and calling for an another informational system as a CSA in its generality and simultaneously formalistic simplification could offer [13]. It is time to stress that formalism must come closer to the physical situation and the natural phenomenalism of consciousness.

References

[1] Broad, S.C. 1925. Mind and Its Place in Nature. Routledge and Kegan Paul. London.

[2] Dreyfus, H. 1972. What Computers Can't Do. Harper & Row. New York.

[3] Heidegger, M. 1959. An Introduction to Metaphysics. Translated by R. Manheim. Yale University Press. New Haven, CT.

[4] Lucas, J.R. 1961. Minds, Machines and Gödel. Philosophy **36:** 112–127.

[5] Penrose, R. 1989. The Emperor's New Mind. Concerning Computers, Minds and the Laws of Physics. Vintage. London.

[6] Шилов, Г.Е. 1960. Математически˘и анализ. Специальный курс. Государственное издательство физико-математической литературы (Физматгиз). Москва.

[7] Zeleznikar, A.P. 1988. Principles of Information. Cybernetica **31:** 99–122.

[8] Železnikar, A.P. 1990. On the Way to Information. The Slovene Society Informatika. Ljubljana, Slovenia (ISBN 86–901125–1–0).

[9] Železnikar, A.P. 1993. Metaphysicalism of Informing. Informatica **17:** 65–80.

[10] Zeleznikar, A.P. 1995. A Concept of Informational Machine. Cybernetica **38:** 7–36.

[11] Železnikar, A.P. 1995. Elements of Metamathematical and Informational Calculus. Informatica **19:** 345–370.

[12] Železnikar, A.P. 1996. Informational Frames and Gestalts. Informatica **20:** 65–94.

[13] Zeleznikar, A.P. 1996. Organization of Informational Metaphysicalism. Cybernetica **39:** 135–162.

[14] Železnikar, A.P. 1996. Informational Transition of the Form $\alpha \models \beta$ and Its Decomposition. Informatica **20:** 331–358.

[15] Železnikar, A.P. 1996. Zum formellen Verstehen des Informationsphänomenalismus. Grundlagenstudien aus Kybernetik und Geisteswissenschaft/Humankybernetik **37** (in print).

[16] Železnikar, A.P. 1997. Informational Graphs. Informatica **21** (to appear soon).

By *A.P. Železnikar*

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Board of Administration

Email of Prof. Jean Ramaekers, the Editor-in Chief: jra@info.fundp.ac.be

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CYBERNETICA, International Association for Cybernetics, Palais des Expositions, Place André Rijckmans, B - 5000 Namur (Belgium)

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A Look into Cybernetica

Let us make a look into Cybernetica, Vol. 39 (1996) No. 2:

The Sociology of Scientific Knowledge and the Activity of Science; or, Science is a System, too (J.A. KLAASSEN) 77–98;

Cybernetic Interpretation of Thought (S. FIRRAO) 99–112;

A Suggested Correction of the Hendrickson Paradigm: the Hemisphericity and the Brain's Consumption of Energy Factors (U. FIDELMAN) 113–133; and

Organization of Informational Metaphysicalism (A.P. ŽELEZNIKAR) 135–162.

Citations

Let us list some most challenging citations from *Cybernetica* with commentaries which characterize the contents of the journal.

Questions concerning cybernetics, especially the second-order cybernetics, can be the easy, the hard, and the soft ones, pertaining to a wide range of scientific disciplines—from philosophy, special theories to technical solutions.

— **39** (1996) 2, pp. 77–98, *J.A. Klaassen,* The Sociology of Scientific Knowledge and the Activity of Science; or Science is a System, too.

The paper consists of the following sections: 1. The 'problem' with science: the sociologists (78–82); 2. Systemantics: a brief view (82–89); 3. Science and system (90–95); and Conclusion. The paper is presented mainly in a COMMENTARY style of the undersigned.

[P. 77] SSK (the Sociology of Scientific Knowledge) emphasizes the social determination of the scientific enterprise (social influence on the processes of science), aspects of life, and formation of both the practice and products of science. SSK makes scientists the equals of "economists, health policy makers, police officers, legal advocates, weather forecasters, travel agents, car mechanics, or plumbers." It is stressed that the conception of scientific practice propounded by scientists not only differs from but actually conflicts with the description of that practice[1].

[P. 78] Nickless[2] distinguishes "linear, *one-pass*" model from the "*multi-pass*" model. In the first model, a scientist's publication of experimental results is intended to stand on its own, to be solitary and absolute. The multi-pass science, on the other hand, is communal and variable.

[P. 79] If natural philosophy were deductive, there would be no need for any experiments (which merely clarify the deduced phenomena)[3]. A deduction could be carried out in scientific isolation and based on knowledge of all universally true axioms. However, no deductive theory knows (in advance) how its axioms have to be determined[4]. Physics long dominated by axiomatics of Euclidean geometry, and then by Newton's inductivism.

The new non-deductive form of science was introduced by Galileo (in telescopic astronomy), in the form of the cooperative spirit of the new experimentalism, with different observers sharing information about methods and results[5]. Some scientists stressed that nominalism's dependence on induction leading to *generalization* is the primary goal of science. A better way should be to replace the indubitable rationalism with admittedly fallible *hypotheses* within the scientific framework of causalism.

[P. 80] Both Newton as inductivist (e.g. in *Principia*) and the Newton's retroductivist contemporary Huyghens[6] rely heavily on observations[7], and thus the confirmation of hypotheses

[1] GALL, J, 1986. Systemantics: The Underground Text of Systems Lore; How Systems Really Work and Especially How They Fail. Second edition. General Systemantics Press. Ann Arbor, MI.

[2] NICKLES, T. 1992. Good Science as Bad History: From Order of Knowing to Order of Being. *In* E. McMullin, Ed. The Social Dimensions of Science. University of Notre Dame Press. Notre Dame, IN.

[3] COLLINS, H. & T. PINCH. 1993. The Golem: What Everyone Should Know about Science. Cambridge University Press. Cambridge, U.K.

[4] Certainly, we know that axioms of a concrete theory are based on scientists' experiences, that is, in scientifically experienced common human consciousness

[5] MCMULLIN, E. 1992. Introduction: The Social Dimensions of Science. *In* E. McMullin, Ed. The Social Dimension of Science. University of Notre Dame Press. Notre Dame, IN.

[6] sc Hyghens, C. 1690. Treatise on Light.

[7] Observation in the informational sense, as a principle of informedness, relies on the fact that an informational entity can be informed, that is, can have its (own) observing capabilities (impactedness depending on itself and its environment being a valid principle). Informational observing (also physical impactedness of things) as a general phenomenon is probably an infallible (even unerrorneous) principle (one of basic admitted informational axioms).

is possible after intense experimentation and only after repeated observations. *Reliance on experimentation does not obviously remove science from the single-pass model's grasp. The crucial experiment seems to dominate our cultural understanding of scientific practice. But philosophers have long recognized the fallibility of observation*[8].

[Pp. 82–85] Systemantics is a marker for the general systems theory (GST), system science, etc. as a self-contained field of science and engineering. One of the pioneers of this sort of science is Ludwig von Bertalanffy[9]. Today, some people (e.g., Gall[1])argue that GST has been removed from its realworld roots. Systemantics is a deductive discipline: a set of parts co-ordinated to accomplish a set of goals.

The first of axioms Gall lists is the *generalized uncertainty principle* (GUP): "Complex systems exhibit unexpected behavior." By a complex system Gall has in mind a *large, very large*[10], or even *too large* system. A system is complex if it is able to do things humans cannot, or when its by-products become complex (e.g., computer systems doing something we do not expect).

One of the most provoking consequence of GUP is the appearance of "emergent phenomena". The larger the system, the more unexpected behavior it performs, e.g., in the form of an unexpected way of failing. The consequence is: A large system, produced by expanding the dimensions of a smaller system, does not behave like the smaller system. The reality is more complex than it seems[1].

[Pp. 86–87] The central theorem Gall presents is the *operational fallacy*: The system itself does not do what it says it is doing (e.g., the fundamental law of administrative workings, or the real world is what is reported to the system). The *coefficient of fiction* is defined by the ratio $\frac{R_0}{R_s}$, where R_0 is the amount of reality which tails to reach the control unit, and R_s equals the total amount of reality presented to the system[1]. In large systems the coefficient of fiction is high (using highly abstract conceptions).

[Pp. 88–89] There exists a Newtonian law of inertia for systems: A system that performs a certain function or that operates in a certain way will continue to operate in that way regardless of the need or of changed conditions[1]. In this way systems are fallen into a pattern: The system continues to do its own thing, regardless of circumstances (like it has its inner goals). The system behaves as if it has a will to live[1]. The basic axiom of systems function says: Big system either work on their own or they don't. If they don't, you can make them. For Gall, systems are essentially unpredictable: though they tend to operate according to generally understandable rules, they may also break any of those rules at any time.

[P. 90] Science is clearly subject to the GUP; it continually presents unexpected results and shows how reality is much more complicated than we thought. It also operates under the operational fallacy, but is still subject to a measurable coefficient of fiction. Steps of the scientific process are the following:

$$\begin{array}{c}\text{accepted theoretical background}\\ \downarrow\\ \text{experiment}\\ \downarrow\\ \text{interpretation}\\ \downarrow\\ \text{negotiation}\\ \downarrow\\ \text{consensus}\\ \downarrow\\ \text{new theoretical background}\end{array}$$

The accepted theoretical background usually grows. Sentences and hypotheses can be identified to be true only in the context of the other sentences and hypotheses which have already been recognized to be evidently true. On the other side, black boxes are passed down from past scientific endeavors and they represent a high coefficient of fiction. Thus, a background theory has to be questioned over and over again.

Experiment hypotheses opened by past science link theoretical assumptions to experience.

[8]The relativity (individuality) of informational observation (—can observation be something else than an informational phenomenon at all—) is studied meticulously and in detail in ŽELEZNIKAR, A.P. 1996. Informational Transition of the Form $\alpha \models \beta$ and Its Decomposition. Informatica **20:** 331–358, where β is the observer of α, and operator $\models$ is decomposed in its α-belonging and its β-belonging part (operator composition $\models_\alpha \circ \models_\beta$).

[9]VON BERTALANFFY, LUDWIG. 1972. Foreword. *In* Introduction to Systems Philosophy: Toward a New Paradigm of Contemporary Thought. E. Laszlo, Ed. Gordon & Breach. New York.

[10]A system is 'very large' if in some way it beats *me* by its richness and complexity (Ashby).

Through experiments a background theory can be reconsidered. Then, the collected data are interpreted and compared to the predicted consequences. Observation is itself impacted by theoretical assumptions. The interpretive process may begin again if data do not support the conclusion. Experiment and interpretation are subject of GUP.

Negotiation begins by submission of a scientific paper for publication. The question arises: Is the problem intelligible? Finally, consensus can mean the re-design, re-performance, re-interpretation, and re-negotiation of theories, hypotheses, and experiments[11]. The operational fallacy predicts that system of science *does not do what it says it is doing.* At last, a new theoretical background can come to the surface.

— **39** (1996) 2, p. 99–112, *S. Firrao,* Cybernetic Interpretation of Thought.

[P. 99–108] What to say to the cybernetic[12] interpretation of mind? Mind is a dynamic[13] network, a kind of psychic system perceiving by means of a large number of sensory terminals and inducing mental representations. Introductory, Firrao turns to Leibniz' monad and Einstein's conception of time and space (relativity).

The relativistic theory states that transformations of coordinate systems involve changes in forces, masses, velocities, and accelerations. The objective reality is objectively indistinguishable. Different connections of neurons can belong to different (overlapping) networks supporting different kinds of perception (physical and phenomenal situations). The contents of perception is a consequence of the detection of the temporal coordinates (an internal system organization). The perception of motion represents an elementary perceptual act[14].

The brain is a structure for processing the information conveyed by perception. Firrao explains how associations are formed in a multi-level net where a neuron can have thousands of inputs and outputs. What is meant by a cybernetic interpretation of thought after all?

According to Firrao, perceptual processes are various kinds of energy flux (flow), from sensory terminals to the terminal neuronal layer of perceptual memory, and the reconstitution of the sensory information, accompanied by parallel paths and energy flux in the opposite direction. The layer of the terminals of perceptual memories is that in which the flux[15] arriving from the sensory terminals has no degree of freedom as a consequence of having reached a certain critical number of excited input terminals. The reverse flux, starting from a single input terminal, takes on degrees of freedom, limited by the stratification of the paths in terms of rigidity. This freedom manifests itself in the weakest layer of connections situated next to the sensory terminals, called "logical memories". This layer involves a modification of the sensory information, of perception, and constitutes the activity of thought.

The motion of energy fluxes in the cerebral networks is governed by cybernetic guides, definable as "differences in potential[16]", determined through two distinct processes—increase in input potential or decrease in output potential—headed in the directions leading to the discharge of tension (e.g. the "pleasure principle" in psychology). The motion of thought follows this law.

The thought flux of reflected energy encounters the system of channeling forming part of alarm and reassurance memories and draws away from certain directions of motion and closer to others, increases its activity or extinguishes it. Thought is in no way totally guided by the potential differences induced by the alarm and reassurance memories encountered along its path. Residual degrees of freedom exist being analogous to situations found in connections between sensory memories and operative memories. In

[11]In this interplay, the essential roles can be given to the governing scientific 'school', together with its specific reductionism, traditionalism, and bound paradigmatism.

[12]Modern scientific theories develop in the direction of cybernetic systems. Today, cybernetic means self-regulating, self-structuring, and self-organizing; it means cellular, organic, and systemic. Within this sense (second order cybernetics) the cybernetic lays beyond the possibilities of not only artificial intelligence but the exact sciences in general.

[13]It is not said explicitly which sort of dynamics is meant: physical, informational, and/or experiential.

[14]MINSKY, M. 1985. The Society of Mind.

[15]Obviously, the word flux is used as a metaphor for the phenomenal processes in the domain of energy (energies), for example, the informational ones.

[16]E.g., a definition of information might be a difference of differences.

reasoning—understood as a succession of logical steps—a variable relationship between the steps, where the lowering of tension does not happen and those where it does, occurs. One must therefore regard as variable the degree of satisfaction connected with each process of reasoning, definable as the "quantity of certainty" or by the symmetrical concept of the "quantity of doubt".

[Pp. 109–111] Firrao sets down the most general formal system in the following manner. Let T be the global tension of the system. It is a function of tensions belonging to the individual energy fluxes, called impulses $y_1, \ldots, y_n$. These are functions of variables $x_1, \ldots, x_r$ identifying the operative program or the simulated representation of thought. Explicitly, relations

$$y_j = y_j(x_1, \ldots, x_r) \quad \text{for } j = 1, \ldots, n$$

are known, and substituting them in T, there is

$$T = f(x_1, \ldots, x_r) \tag{1}$$

Here, T is a function of independent variables. The minimum conditions of (1) are obtained by solving the system

$$\frac{dT}{dx_m} = 0 \quad \text{for} \quad m = 1, \ldots, r \tag{2}$$

The motion of thought is thus a program seeking the minimum values of a function with more than one variable. This corresponds to the pleasure principle, where the motion of thought proceeds in the direction of a tension drop (negative derivative).

If some of the relations of dependence between impulses and operative variables cannot be made explicit, function (1) becomes

$$T = f(x_1, \ldots, x_r, y_1, \ldots, y_n) \tag{3}$$

If the lack of information as to the relations of dependence between y_j and x_m is not total, and if the information available is in the form of n conditions of constraint to be realized at the minimum point expressed by

$$\varphi_j = f(x_1, \ldots, x_r, y_1, \ldots, y_n) = 0 \quad \text{for } j = 1, \ldots, n \tag{4}$$

the search for the constrained minima of function (3) coincides with the search for the free minima of the function, that is,

$$W = f(x_1, \ldots, x_r, y_1, \ldots, y_n) + \sum_j \alpha_j \varphi_j(x_1, \ldots, x_r, y_1, \ldots, y_n) \tag{5}$$

where α_j are Lagrangian multipliers (real constants).

The presence of impulses displaying a negative gradient of tension even in the presence of a null gradient of global tension obviously indicate the existence of other impulses with a positive gradient, i.e. that the equilibrium achieved at the minimum point is a dynamic equilibrium. System (4) must therefore express the condition that the tension of these impulses diminishes in the absolute minimum, and this condition is obviously fulfilled if one imposes the condition that the tension of these impulses is actually zero in the absolute minimum. Thus, considering (4), there is

$$y_j(x_1, \ldots, x_r) = 0 \quad \text{for} \quad j = 1, \ldots, n \tag{6}$$

and, consequently, (5) becomes

$$W = f(x_1, \ldots, x_r, y_1, \ldots, y_n) + \sum_j \alpha_j \varphi_j(x_1, \ldots, x_r) \tag{7}$$

The search for the absolute minimum of (3) can the be carried out as a search for the minimum of function (7).

— **39** (1996) 2, p. 99–112, *U. Fidelman*, A Suggested Correction of the Hendrickson Paradigm: The Hemisphericity and the Brain's Consumption of Energy Factors.

[Pp. 113–115] According to the Hendrickson paradigm of intelligence[17] it is expected that the string and amplitude measures of averaged evoked potentials are positively correlated with IQ. High

[17] HENDRICKSON, D.E. & A.E. HENDRICKSON. 1980. The Biological Basis for Individual Difference in Intelligence. Personality and Individual Differences **1:** 3–33.

HENDRICKSON, D.E. & A.E. HENDRICKSON. 1982. The Biological Basis of Intelligence. *In* A Model of Intelligence. H.J. Eyseneck, Ed. Springer Verlag. New York.

intelligence is related to a small probability of transmission errors in the brain, particularly in the synapses. The Hendricksons' experiments show that these correlations are sometimes significantly positive, sometimes significantly negative, and sometimes not significant. Fidelman suggests an explanation of the situation by the paradigm of Haier et al.[18] according to which intelligent brains consume less energy, by the difference in the consumption of energy by left-hemispheric and right-hemispheric brains, and by hemisphericity-related individual differences in the conductivity of the corpus callosum. Jensen[19] suggests that intelligence is related to the myelination of the axons and to the length of the oscillation between the excitatory and refractory phases of the neurons.

According to Miller[20] there is a limitation on the amount of data that the brain can handle simultaneously. The maximal number varies between 5 and 9, and the average maximal number of simultaneously processed data is 7. At an greater number, the brain synthesizes data into "chunks"[21]. Chunks are processed as new individual data and, in this way, chunks of chunks are synthesized, and more and more complicated cognitive structures can come into existence.

Levy-Agresti & Sperry[22] suggested that the left cerebral hemisphere is specialized in the analytic processing of individual details, while the right hemisphere is specialized in the synthesis of new wholes out of individual details. From this model it is possible to infer that the processing of individual data is performed analytically by the left hemisphere. These data are transmitted to the right hemisphere, where they are synthesized into Miller's chunks. New chunks are transmitted back to the left hemisphere where processed analytically as individual data, and so forth. The size of Miller's chunks is determined by the synthesizing power of the right hemisphere. The brain possessing an efficient right hemisphere needs a smaller number of inter-hemispheric transmissions in order to process data. According to Fidelman[23] a brain with a larger maximal size of Miller's chunk needs a smaller number of both analytical and synthetical data processings, since the number of chunks that have to be reprocessed analytically is smaller (this means also smaller consumption of energy).

In Papçun et al.[24] there is evidence relating Miller's chunking theory to the theory of Levy-Agresti & Sperry. Subjects who did not know the Morse code had a left ear (right-hemispheric) superiority in the perception of more than seven dots and dashes, and right-ear (left-hemispheric) superiority when the number of dots and dashes was seven or less. The efficiency of the inter-hemispheric commissures determines the ability of the brain to co-operate between the hemispheric mechanisms, which are related to special abilities of intelligence. The conclusion is that left hemispheric analytical brains is related to a larger g (factor of general intelligence), while synthetical right hemispheric brain is related to a smaller g.

[Pp. 116–124] Concerning the hemispheric consumption of energy, the following can be stated. (1) The energy consumption of a single left-hemispheric neuron for a single firing is, averagely, larger than that of a single right-hemispheric neuron. (2) Left-hemispheric neurons fire, averagely, more shots per unit time (synchronically) than the right-hemispheric neurons. (3) There are more neurons and more connections between neurons in the left hemisphere than in the right one.

[18] HAIER, R.J., B.V. SIEGEL, K.H. NUECHTERLINE, E. HAZLETT, J.C. WU, J. PEAK, H.L. BROWNING & M.S. BUSCHBAUM. 1988. Cortical Glucose Metabolism Rate Correlate of Abstract Reasoning and Attention Studied with Positronic Emission Tomography. Intelligence **12:** 199–217.

HAIER, R.J., B.V. SIEGEL, C. TANG, L. ABEL & M.S. BUSCHBAUM. 1992. Intelligence and Changes in Regional Cerebral Glucose Metabolic Rate Following Learning. Intelligence **16:** 415–426.

[19] JENSEN, A.R. 1992. The Importance of intraindividual Variance in Reaction Time. Personality and Individual Differences **13:** 869–881.

[20] MILLER, G.A. 1956. The Magical Number Seven Plus or Minus Two: Some Limiting on Our Capacity for Processing Information. Psychological Review **63:** 81–97.

[21] In this context, chunk means a substantial amount of data, an informational lump, cut-off or shortcut information.

[22] LEVY-AGRESTI, J. & R.W. SPERRY. 1968. Differential Perceptual Capacities in Major and Minor Hemispheres. National Academy of Sciences of the United States of America. Proceedings. Biological Sciences **6:** 1151.

[23] FIDELMAN, U. 1992. The "Unmeasure" of Man: The Non-Generality of General Intelligence. Methodology and Science **25:** 11–36.

[24] PAPÇUN, G., S. KRASHEN, D. TERBEEK, R. REMINGTON & R. HARSHMAN. 1974. Is the Left Hemisphere Specialized for Speech, Language, and/or Something Else? Journal of the Acoustical Society of America **55:** 319–327.

Therefore more neurons and more neural connections participate synchronically in the processing of data by the left hemisphere than by the right hemisphere.

Further, Fidelman discusses a unified paradigm of intelligence by the three characteristic samples: the left-hemispheric, the right-hemispheric, and the balanced sample. He shows how Miller's chunks relate the IQ tests, for instance, showing the number of cerebral operations while processing "block design" matrices. He tries to explain how left—and the right—hemispheric samples are possible.

— **39** (1996) 2, p. 135–162, *A.P. Zeleznikar*, Organization of Informational Metaphysicalism.

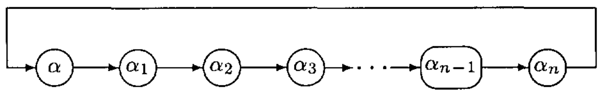
[Pp. 135] Metaphysicalistic organization of informational entities can be shown clearly by examples using informational graphs together with the formalism of informational formula systems and phenomenal cases in the domain of psychology, understanding, and management. For this purpose of evident presentation of metaphysicalistic organization, the following examples are chosen: the very basic model of understanding informing, a basic informational psychoanalytical, Freudian, Lacanian, and theorizing (theory) model. A complex informational system of understanding something is presented. Further, a case of distributed (informationally parallelized) system is demonstrated, sophisticating the Maruyama's[25] model of strategy decision making by operands being structured in the informationally metaphysicalistic sense. At last, the example of informational conceptualizing of a word (meaning) is presented by a metaphysicalistic scheme with two dictionaries.

[Pp. 136–140] Circularity and parallelism are two of the most significant informational features within informing of entities (marked by α, β, ...). The serial and parallel circularity can be expressed by

$$\alpha \vdash \beta \quad \text{and} \quad \alpha \Vdash \beta$$

where α informs β serial-circularly and parallel-circularly, respectively. A circular formula arises through an informational decomposition of the initial metaphysicalistic situation $\alpha \models \alpha$, where $\models$ represents the most general operator of informing (the previously used $\vdash$ and $\Vdash$ are already particularizations of $\models$)[26].

What seems to be important is the meaning-equational character of circular formulas in the form $\alpha \rightleftharpoons (\alpha \models \alpha)$, where $\alpha \models \alpha$ represents the serial and/or parallel intrinsic (metaphysicalistic) decomposition of α. Moreover, a circular formula, obtained by a circular decomposition of an operand α, can be solved (made explicit in dependence of the remaining operands) upon an arbitrary operand α_i of the circular formula, that is, for example $\alpha_i \rightleftharpoons (\alpha_i \models \alpha_i)$ according to the circular graph



The so-called circular gestalt $\Gamma^{\hookleftarrow}_{\rightarrow}(\alpha_i)$ includes $\frac{1}{n+2}\binom{2n+2}{n+2}$ circular-serial formulas, and thus, $\alpha_i \rightleftharpoons \Gamma^{\hookleftarrow}_{\rightarrow}(\alpha_i)$. In this way, the serial circular transition $\alpha_i \vdash \alpha_i$ and parallel circular transition $\alpha_i \Vdash \alpha_i$ can be defined as

$$(\alpha_i \vdash \alpha_i) \rightleftharpoons \Gamma^{\hookleftarrow}_{\rightarrow}(\alpha_i) \quad \text{and} \quad (\alpha_i \Vdash \alpha_i) \rightleftharpoons \Pi'^{\hookleftarrow}_{\rightarrow}(\alpha_i)$$

where $\Pi'^{\hookleftarrow}_{\rightarrow}(\alpha_i)$ represents the primitive parallelization of a serial circular decomposition of α_i.

[Pp. 141–144] What Chalmers[27] calls the *organizational invariance* could be comprehended as informational metaphysicalism of entities in its general or standardized form, that is as an entity's informational triplet: *informing* (a form of intending, inertia, perseverance, inertness) $\longrightarrow$ *counterinforming* $\longrightarrow$ *informational embedding*[28]. First trials of formalization of informa-

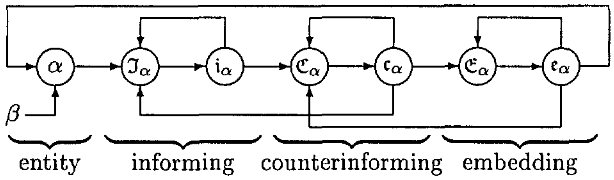
[25] MARUYAMA, M. 1993. A Quickly Understandable System of Causal Loops for Strategy Decision Making. Cybernetica **36:** 37–41.

[26] For serial, parallel, and gestaltistic structure of informational formulas and formula systems see at ŽELEZNIKAR, A.P. 1996. Informational Frames and Gestalts. Informatica **20:** 65–94.

[27] See CHALMERS, D.J. 1996. The Conscious Mind. Oxford University Press. New York, pp. 248–249 and 274–277.

[28] This kind of metaphysical organization (invariance) of entities was already proposed in ŽELEZNIKAR, A.P. 1987. On the Way to Information. Informatica **11:** 4–18 and later, more explicitly, in ŽELEZNIKAR, A.P. 1988. Principles of Information. Cybernetica **31:** 99–122.

tional metaphysicalism go back to the constitution of an informational language[29] and determination of informational metaphysicalism in the form of a standardized intrinsic organization of entities[30]. The outcome of these and some previous studies of metaphysicalism is the informational graph



Cases which follow fall into this 'invariant' organizational scheme[27], and components of a metaphysicalistically organized entity α concerning something β are always grouped into one of the three metaphysicalistic components of informing, that is, either into informing of an entity, or its counterinforming, or if not in the previous two categories, in the entity's informational embedding. This kind of organizational invariance seems to be reasonable, although it is quite artificial. However, it offers the possibility of an identifying informing of the entity (intention, informational perseverance, physical inertia, etc.), a possibility of counterinformational emerging (changing, arising, diminishing), and a last to the embedding maintaining and constituting (in the informational, physical, or phenomenal way) of the existing entity.

The basic model of understanding υ (certainly, in the spirit of a conscious entity) must include (intrinsically possess) something, which is the result of understanding of something β, called the meaning of something produced by υ, that is, $\mu_\upsilon(\beta)$. In this context, the meaning is the most essential product of understanding, which delivers the instantaneous answer to the understanding questioning (metaphysicalistic cycling) upon the meaning of something $\mu_\upsilon(\beta)$. Thus the meaning within the most primitive form of understanding arises within the informationally embedding part of the metaphysicalistic cycle, that is, appears after the embedding components $\mathfrak{E}_\upsilon$ and $\mathfrak{e}_\upsilon$, and is directly operationally linked to understanding υ.

[29]ŽELEZNIKAR, A.P. 1992. Towards an Informational Language. Cybernetica **35:** 139–158.

[30]ŽELEZNIKAR, A.P. 1993. Metaphysicalism of Informing. Informatica **17:** 65–80.

The basic psychoanalytical model has a similar metaphysicalistic organization as the basic understanding system. The correspondence to the standardized metaphysicalistic graph and the graphs for basic understanding, psychoanalytic, and Freudian treatment can be expressed by the following scheme of correspondence:

entity	informing	counterinforming	embedding
α	$\mathfrak{I}_\alpha$; $\mathfrak{i}_\alpha$	$\mathfrak{C}_\alpha$; $\mathfrak{c}_\alpha$	$\mathfrak{E}_\alpha$; $\mathfrak{e}_\alpha$
υ	$\mathfrak{U}_\upsilon$; $\mathfrak{i}_\upsilon$	$\mathfrak{C}_\upsilon$; $\mathfrak{c}_\upsilon$	$\mathfrak{E}_\upsilon$; $\mathfrak{e}_\upsilon$; μ_υ
π	$\mathfrak{C}_\pi$; $\mathfrak{c}_\pi$	$\mathfrak{U}_\pi$; $\mathfrak{u}_\pi$	$\mathfrak{E}_\pi$; $\mathfrak{e}_\pi$; $\mathfrak{a}_\pi$
σ	$\mathfrak{S}_\sigma$; ε_σ	$\mathfrak{I}_\sigma$; $\mathfrak{i}_\sigma$	$\mathfrak{E}_\sigma$; $\mathfrak{e}_\sigma$; $\mathfrak{s}_\sigma$

Here α, υ, π, and σ receive an internalistic informing from β. The meaning of the components of psychoanalytical models is the following: psychic entity σ, conscious informing $\mathfrak{C}_\pi$, consciousness $\mathfrak{c}_\pi$, unconscious informing $\mathfrak{U}_\pi$, unconsciousness $\mathfrak{u}_\pi$, informing of analytical embedding $\mathfrak{E}_\pi$, analytical embedding information $\mathfrak{e}_\pi$, and embeddingly analytical result $\mathfrak{a}_\pi$, which resolves the psychic dilemma β in the framework of the psychic entity σ as an informational entirety.

In a similar way, the next model—informational modeling of the Freudian treatment—can be explained, as follows, by the system of: self entity σ, ego's informing $\mathfrak{S}_\sigma$, the ego ε_σ, id's counterinforming $\mathfrak{I}_\sigma$, the id $\mathfrak{i}_\sigma$, super-ego's embedding informing $\mathfrak{E}_\sigma$, super-ego's embedding information $\mathfrak{e}_\sigma$ connecting the ego and the id with the self, and the super-ego $\mathfrak{s}_\sigma$.

The next three models become more and more complex in regard to the length of the circular formula system, where the additional feedback connections appear. Systems discussed are the basic Lacanian system, the theory system, and a more exhaustive system of understanding.

The system for the Lacanian discourse δ is constituted by the three discourse phases appearing in the Lacanian analytical treatment. In the informational (intentional) part of the discourse the so-called master's discourse (master's informing $\mathfrak{M}_\delta$ and master's analytical result $\mathfrak{m}_\delta$) and teacher's (university) discourse (teacher's informing $\mathfrak{T}_\delta$ and teacher's analytical result $\mathfrak{t}_\delta$) take place. The counterinformational part is represented by the hysteric's discourse (hysteric's informing $\mathfrak{H}_\delta$ and hysteric's analytical result $\mathfrak{h}_\delta$), by which, during the psychoanalytical procedure, within the circular organization the Lacanian discourse as an entirety, the turn to the analyst's discourse (analyst's informing $\mathfrak{A}_\delta$ and analyst's analytical result $\mathfrak{m}_\delta$) comes consequently to the surface (becomes possible). Operands of the Lacanian discourse δ belonging to the characteristic metaphysicalistic components are presented in in the following table:

entity	informing	counterinforming	embedding
α	$\mathfrak{I}_\alpha$; $\mathfrak{i}_\alpha$	$\mathfrak{C}_\alpha$; $\mathfrak{c}_\alpha$	$\mathfrak{E}_\alpha$; $\mathfrak{e}_\alpha$
δ	$\mathfrak{M}_\delta$; $\mathfrak{m}_\delta$; $\mathfrak{T}_\delta$; $\mathfrak{t}_\delta$	$\mathfrak{H}_\delta$; $\mathfrak{h}_\delta$	$\mathfrak{A}_\delta$; $\mathfrak{a}_\delta$
τ	$\mathfrak{D}_\tau$; $\mathfrak{d}_\tau$; $\mathfrak{A}_\tau$; $\mathfrak{a}_\tau$; $\mathfrak{T}_\tau$; $\mathfrak{t}_\tau$	$\mathfrak{P}_\tau$; $\mathfrak{p}_\tau$	$\mathfrak{E}_\tau$; $\mathfrak{e}_\tau$
υ	$\mathfrak{I}_\upsilon$; $\mathfrak{i}_\upsilon$; $\mathfrak{S}_\upsilon$; $\mathfrak{s}_\upsilon$; $\mathfrak{O}_\upsilon$; $\mathfrak{O}_\upsilon$; $\mathfrak{B}_\upsilon$; $\mathfrak{B}_\upsilon$	$\mathfrak{U}_\upsilon$; $\mathfrak{u}_\upsilon$; $\mathfrak{C}_\upsilon$; $\mathfrak{c}_\upsilon$	$\mathfrak{X}_\upsilon$; $\mathfrak{x}_\upsilon$; $\mathfrak{Y}_\upsilon$; $\mathfrak{y}_\upsilon$; $\mathfrak{P}_\upsilon$; $\mathfrak{p}_\upsilon$; $\mathfrak{Z}_\upsilon$; $\mathfrak{z}_\upsilon$; μ_υ

This table shows also the grouping of operands in the case of a theorizing model and a complex model of understanding.

How does a theory arise informationally? Which are the essential operands of such a model, and how are they grouped in regard to the metaphysicalistic components of a theory τ? As one can see, the theory model is more complex than the initial system describing the Lacanian discourse. The informational (in fact, the intentional of the theory) part has six components, namely: defining $\mathfrak{D}_\tau$, definitions $\mathfrak{d}_\tau$, axiomatizing $\mathfrak{A}_\tau$, axioms $\mathfrak{a}_\tau$, theorizing $\mathfrak{T}_\tau$, and theorems $\mathfrak{t}_\tau$. The counterinformational part is constituted by proving $\mathfrak{P}_\tau$ and theorem proofs $\mathfrak{p}_\tau$. Comparing to the Lacanian discourse, proving is a kind of hysteric attitude, by which the conceptualized (definitions, axioms, and theorems) has to be (in some way distantly in regard to, that is, by definitions and axioms) proved. The theory embedding $\mathfrak{E}_\tau$ produces together with the other components of the theory loop the embedding information $\mathfrak{e}_\tau$; the both components embrace not only the observing and informing of the other theory components upon the state and the structure of the arising theory, but also definitely confirm the correctness of the arisen theory situation.

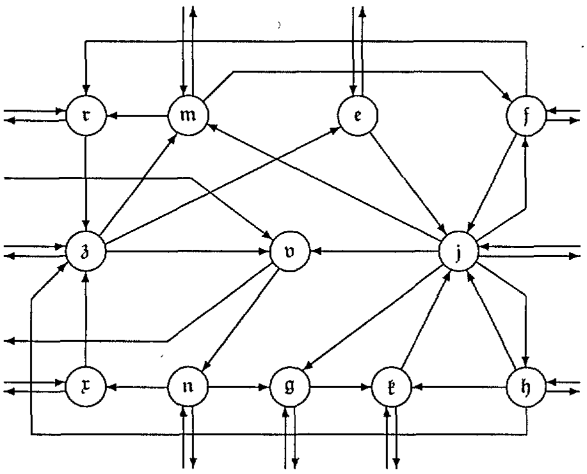
The last case in the table concerns an informational system υ of an entity β understanding. This system considers 8 serial and backwards connected components of understanding informing (intending), 4 serial and backwards connected components of understanding counterinforming, and 9 serial and backwards connected components of understanding embedding. Informing begins with intending $\mathfrak{I}_\upsilon$ and intention $\mathfrak{i}_\upsilon$. Then the so-called sensing $\mathfrak{S}_\upsilon$ with the sensibility $\mathfrak{s}_\upsilon$ of an emerging β-understanding follows. Observing $\mathfrak{O}_\upsilon$ and the produced observation $\mathfrak{o}_\upsilon$ are regular serial (and certainly parallel) components of understanding informing. The informing part of understanding υ is completed by the last component pair, which is the being conscious $\mathfrak{B}_\upsilon$ and, as a consequence, the consciousness $\mathfrak{b}_\upsilon$.

The counterinformational part of understanding includes the unconscious informing $\mathfrak{U}_\upsilon$ and that which could be called the unconsciousness $\mathfrak{u}_\upsilon$ within understanding υ. Further, this part of understanding enables the so-called conceiving $\mathfrak{C}_\upsilon$, from which the concepts $\mathfrak{c}_\upsilon$ come to the conscious surface out of the unconsciousness $\mathfrak{u}_\upsilon$.

The embedding part of understanding is the richest in regard to the number of its components. By signifying $\mathfrak{X}_\upsilon$ its decides upon the significance $\mathfrak{x}_\upsilon$ of the understood concerning something β. Similar is the role of making sense $\mathfrak{Y}_\upsilon$ producing the reasonableness $\mathfrak{y}_\upsilon$ of the understood. Within the embedding chain, perceiving $\mathfrak{P}_\upsilon$ produces the perception $\mathfrak{p}_\upsilon$ of the understood being responsible for concluding $\mathfrak{Z}_\upsilon$ resulting into conclusions $\mathfrak{z}_\upsilon$ about the understood. Finally, in the main loop of understanding the meaning μ_υ emerges, as a consequence of parallel, cyclic, spontaneous, and understanding informing of the whole system.

A metaphysical distributed system of a set of parallel-circularly coupled entities means that, out of all the circularly involved entities of the system, the three distinct components of metaphysicalism—informing $\longrightarrow$ counterinforming $\longrightarrow$ embedding—are viewed as single components being parallel represented by the circularly involved entities. The distribution principle is applied on a slightly modified Maruyama's model[31] Maruyama's model concerns a characteristic computer simulation delivering econometric and sociological parameters (in fact, values of increasing and decreasing of operands). The circularly structured informational parallel formula system $\varphi_{\|}^{*}(\mathfrak{e}, \mathfrak{f}, \mathfrak{g}, \mathfrak{h}, \mathfrak{j}, \mathfrak{k}, \mathfrak{m}, \mathfrak{n}, \mathfrak{r}, \mathfrak{v}, \mathfrak{x}, \mathfrak{z})$ is presented by the informational graph

[31] MARUYAMA, M. 1993. A Quickly Understandable System of Causal Loops for Strategy Decision Making. Cybernetica **36:** 37–41.



Each of the operands $\mathfrak{e}$, $\mathfrak{f}$, $\mathfrak{g}$, $\mathfrak{h}$, $\mathfrak{j}$, $\mathfrak{k}$, $\mathfrak{m}$, $\mathfrak{n}$, $\mathfrak{r}$, $\mathfrak{v}$, $\mathfrak{x}$, $\mathfrak{z}$ is metaphysically organized, however all the input, output, informing, counterinforming, and embedding components of the operands form a separate, parallel structured, informational unit, for instance[32],

$$\begin{array}{lcl}
\|\varphi_{\|}^{\leftrightarrows}\rangle & \rightleftharpoons & (\mathfrak{e};\ \mathfrak{f};\ \mathfrak{g};\ \cdots;\ \mathfrak{x};\ \mathfrak{z}); \\
\|\models\varphi_{\|}^{\leftrightarrows}\rangle & \rightleftharpoons & (\models\mathfrak{e};\models\mathfrak{f};\models\mathfrak{g};\cdots;\models\mathfrak{x};\models\mathfrak{z}); \\
\|\varphi_{\|}^{\leftrightarrows}\models\rangle & \rightleftharpoons & (\mathfrak{e}\models;\mathfrak{f}\models;\mathfrak{g}\models;\cdots;\mathfrak{x}\models;\mathfrak{z}\models); \\
\|\mathfrak{I}_{\varphi_{\|}^{\leftrightarrows}}\rangle & \rightleftharpoons & (\mathfrak{I}_{\mathfrak{e}};\ \mathfrak{I}_{\mathfrak{f}};\ \mathfrak{I}_{\mathfrak{g}};\ \cdots;\ \mathfrak{I}_{\mathfrak{x}};\ \mathfrak{I}_{\mathfrak{z}}); \\
\|\mathfrak{i}_{\varphi_{\|}^{\leftrightarrows}}\rangle & \rightleftharpoons & (\mathfrak{i}_{\mathfrak{e}};\ \mathfrak{i}_{\mathfrak{f}};\ \mathfrak{i}_{\mathfrak{g}};\ \cdots;\ \mathfrak{i}_{\mathfrak{x}};\ \mathfrak{i}_{\mathfrak{z}}); \\
\|\mathfrak{C}_{\varphi_{\|}^{\leftrightarrows}}\rangle & \rightleftharpoons & (\mathfrak{C}_{\mathfrak{e}};\ \mathfrak{C}_{\mathfrak{f}};\ \mathfrak{C}_{\mathfrak{g}};\ \cdots;\ \mathfrak{C}_{\mathfrak{x}};\ \mathfrak{C}_{\mathfrak{z}}); \\
\|\mathfrak{c}_{\varphi_{\|}^{\leftrightarrows}}\rangle & \rightleftharpoons & (\mathfrak{c}_{\mathfrak{e}};\ \mathfrak{c}_{\mathfrak{f}};\ \mathfrak{c}_{\mathfrak{g}};\ \cdots;\ \mathfrak{c}_{\mathfrak{x}};\ \mathfrak{c}_{\mathfrak{z}}); \\
\|\mathfrak{E}_{\varphi_{\|}^{\leftrightarrows}}\rangle & \rightleftharpoons & (\mathfrak{E}_{\mathfrak{e}};\ \mathfrak{E}_{\mathfrak{f}};\ \mathfrak{E}_{\mathfrak{g}};\ \cdots;\ \mathfrak{E}_{\mathfrak{x}};\ \mathfrak{E}_{\mathfrak{z}}); \\
\|\mathfrak{e}_{\varphi_{\|}^{\leftrightarrows}}\rangle & \rightleftharpoons & (\varepsilon_{\mathfrak{e}};\ \varepsilon_{\mathfrak{f}};\ \varepsilon_{\mathfrak{d}};\ \cdots;\ \varepsilon_{\mathfrak{x}};\ \varepsilon_{\mathfrak{z}})
\end{array}$$

The reader may imagine how in the distributed metaphysicalistic system would perform essentially differently (self-organizationally) in comparison with the standard econometric computer simulation system. Another, additional challenge would be, to take instead the parallel distributed system $\|\varphi_{\|}^{\leftrightarrows}\rangle$ of already metaphysically organized components $\mathfrak{e}$, $\mathfrak{f}$, $\mathfrak{g}$, $\mathfrak{h}$, $\mathfrak{j}$, $\mathfrak{k}$, $\mathfrak{m}$, $\mathfrak{n}$, $\mathfrak{r}$, $\mathfrak{v}$, $\mathfrak{x}$, $\mathfrak{z}$, a system $^{\mu}\|\varphi_{\|}^{\leftrightarrows}\rangle$, which is by itself (as presented by the informational graph) organized metaphysically. This would mean that, for instance, some serially coupled components would represent the informing of $^{\mu}\|\varphi_{\|}^{\leftrightarrows}\rangle$, the next ones the counterinforming, and the rest the embedding of $^{\mu}\|\varphi_{\|}^{\leftrightarrows}\rangle$.

The last case deals with the informational problem of conceptualization of a word in a natural language, by means of other words, phrases, sentences, and groups of sentences. In this kind of informing several informationally auxiliary and main dictionaries can be used.

The essay concerning metaphysicalistic organization shows how roles of metaphysicalistically (circularly) coupled entities are always dualistic in the sense of informing-observing phenomenalism. This means, that causality is dualistic too, and the roles of cause and consequence in an informational loop are relative to each other in regard to the circularly involved operands. On the other side, that what Chalmers calls organizational invariance begins to obtain its ambiguous and vague outlines.

*

* *

The undersigned believes that these short look into Cybernetica, the most profound and excellent journal on cybernetic philosophy, research, and scientific studies , principles, and theories will be of interest for both the readers and authors of *Informatica*. Among different professional cybernetics journals, *Cybernetica* remains also the most heterogeneous and innovatively open publication, being convenient for various problems emerging in the intuitive, consciousness, and the other complexly parallel and circularly organized worlds.

Selected, summarized, and commented
by *A.P. Železnikar*

[32] Operand $\|\alpha\rangle$ marks a parallel (distributed) structure, described in Πόλεμος of Consciousness (in this issue of *Informatica*). Notation ε is introduced instead of $\mathfrak{e}$ to distinguish the metaphysicalistic embedding information from the exchange rate $\mathfrak{e}$ in the upper informational graph.

Informatica, an International Journal for Computing and Informatics, repeats the Call for Papers for the issue of an interdisciplinary volume dedicated to the informational problems of consciousness, entitled

Consciousness as Informational Phenomenalism

Informatica **21** (1997) No. 3

The scientific program of the volume includes the following:

1. consciousness as an informationally emerging entity in events, processes and systems of understanding;
2. innovative formal symbolism for study, research and expression of dynamically structured and organized (arising, emerging, generic) events, processes, and systems of consciousness;
3. philosophical (existence, phenomenology), cognitive (intention, qualia, understanding), linguistic (semiotic, pragmatic), psychological (experience, feeling), physiological, neuronal (connectionist), cellular (biological), cybernetic (self-organized) and other views of consciousness as informational phenomenon;
4. physical (space-time, quantum, thermodynamical), chemical (molecular) and other natural models of consciousness as informational phenomena;
5. consciousness as learning, memorizing, associative, concluding, and intelligent processes of behavior;
6. classical, computational and artificial-intelligence approaches (stressing artificialness and constructivism) for understanding and modeling of the consciousness phenomenology;
7. emerging terminology and systematics (structure, organization) of consciousness.

Informatica **21** (1997) No. 3, in an enlarged volume, is fixed as the special issue. The deadline for the paper submission in electronic form (ASCII or LaTeX) and in printed (readable) form is April 15, 1997. The final LaTeX-ing of texts will be performed by the *Informatica*'s experts.

Correspondence: E-mail addresses: `anton.p.zeleznikar@ijs.si`, `matjaz.gams@ijs.si`, and `mitja.perus@uni-lj.si`.

Printed-paper mail address: M. Gams, Jožef Stefan Institute, Jamova c. 39, SI–1111 Ljubljana, Slovenia.

Please submit the papers in electronic form (only exceptionally in the paper form) as soon as possible, so they could be reviewed and well-LaTeX-ized in time.

Call for Papers

Parallel and Distributed Database Systems

Special Issue of Informatica

Parallel and distributed database technology is a core of many mission-critical information systems. New challenging problems are posed by the growing demand for large-scale, enterprise-wide, high- performance solutions. Innovative approaches and techniques are necessary to deal with the rapidly expanding expectations with regard to massive data volume processing, performance, availability, and solutions scalability.

The scope of this Special Issue includes all aspects of parallelism and distribution in database systems. The Issue will focus on design, development and evaluation of parallel and distributed database systems for different computing platforms and system architectures.

Original papers are solicited that describe research on various topics in parallel and distributed database systems including, but not limited to, the following areas:

- Distributed database modeling and design techniques
- Parallel and distributed object management
- Interoperability in multidatabase systems
- Parallel on-line transaction processing
- Parallel and distributed query optimization
- Parallel and distributed active databases
- Parallel and distributed real-time databases
- Multimedia and hypermedia databases
- Databases and programming systems
- Mobile computing and databases
- Transactional workflow control
- Parallel and distributed algorithms
- Temporal databases
- Data mining/Knowledge discovery
- Use of distributed database technology in managing engineering, biological, geographic, spatial, scientific, and statistical data
- Scheduling and resource management

Time Table and Contacts

Papers in 5 hard copies should be received by November 1, 1996 at one of the following addresses.

North & South America, Australia:

Bogdan Czejdo czejdo@beta.loyno.edu, Department of Mathematics and Computer Science, Loyola University, 6363 St. Charles Ave., New Orleans, LA 70118, USA

Europe, Africa, Asia:

Tadeusz Morzy morzy@pozn1v.put.poznan.pl, Institute of Computing Science, Poznan University of Technology, Piotrowo 3a, 60-965 Poznan, Poland

Silvio Salza salza@dis.uniroma1.it, Dipartimento di Informatica e Sistemistica, Universita di Roma La Sapienza, Via Salaria 113, I-00198 Roma, Italy

E-mail information about the special issue is available from the above guest editors.

Notification of acceptance will be sent before March 1, 1997. The special issue will be published in the middle of 1997.

Format and Reviewing Process

Papers should not exceed 5,000 words. Each paper will be refereed by at least three anonymous referees.

Call for Papers

Parallel Computing with Optical Interconnections

Special Issue of *Informatica*
`http://www.cps.udayton.edu/ pan/info`

Communications among processors in a parallel computing system are always the main design issue when a parallel system is built or a parallel algo- rithm is designed. With advances in silicon and Ga-As technologies, pro- cessor speed will soon reach the gigahertz (GHz) range. Traditional metal-based communication technology used in parallel computing systems is becoming a potential bottleneck. This requires either that significant progress need to be made in the traditional interconnects, or that new interconnect technologies, such as optics, be introduced in parallel computing systems.

Fiber optic communications offer a combination of high bandwidth, low error probability, and gigabit transmission capacity and have been used exten- sively in wide-area networks. Advances in optical and optoelectronic tech- nologies indicates that they could also be used as interconnects in parallel computers. In fact, many commercial massively parallel computers such as the Cray T3D use optical technology in their communication subsys- tems. Papers in this special issue will be selected to focus on the poten- tial for using optical interconnections in massively parallel processing systems, and their effect on system and algorithm design.

The topics of interest include but are not limited to the following:

- Various optical interconnections,
- Optical pipelined buses,
- Multistage interconnection networks,
- Reconfigurable optical architectures,
- Embedding and mapping of applications and algorithms,
- Emulation of different models,
- Algorithms and applications exploiting parallel optical connections,
- Data distribution and partitioning,
- Task scheduling,
- Performance Evaluation,
- New analytical methods for optical interconnections,
- Scalability analysis,
- Computational and communication complexities.

Publication is scheduled for an issue in 1998. Four copies of complete manuscripts should be sent to one of the guest editors (see address below) by May 15, 1997. All manuscripts must conform to the normal submission requirements of INFORMATICA. Notification of acceptance will be sent by October 15, 1997.

Guest Editors of the Special Issue

North & South America, Australia

Professor Yi Pan, Computer Science Department, The University of Dayton, Dayton, OH 45469-2160, USA, Email: `pan@hype.cps.udayton.edu`

Professor Keqin Li, Dept. of Mathematics and Computer Science, State University of New York, New Paltz, New York 12561-2499, USA, Email: `li@mcs.newpaltz.edu`

Europe, Africa, Asia

Professor Mounir Hamdi, Department of Computer Science, Hong Kong Univer- sity of Science and Technology, Clear Water Bay, Kowloon, Hong Kong, Email: `hamdi@cs.ust.hk`

Call for Papers (New Journal)

Intelligent Data Analysis - An International Journal

An electronic, Web-based journal
Published by Elsevier Science

URL: `http://www.elsevier.com/locate/ida`, `http://www.elsevier.nl/locate/ida`

Important e-mail addresses:
Editor-in-Chief: A. Famili
(`famili@ai.iit.nrc.ca`)
Editorial Office: Heather D. Joseph
(`h.dalterio@elsevier.com`)
Subscription Information:
`USDirect@elsevier.com`

Introduction

As science and engineering disciplines become more and more computerized, the volume and complexity of the data produced on a day-to-day basis quickly becomes overwhelming. Traditional data analysis approaches have proven limited in their ability to generate useful information. In a wide variety of disciplines (as diverse as financial management, engineering, medical/ pharmaceutical research and manufacturing) researchers are adapting Artificial Intelligence techniques and using them to conduct intelligent data analysis and knowledge discovery in large data sets.

Aims/Scope

The journal of Intelligent Data Analysis will provide a forum for the examination of issues related to the research and applications of Artificial Intelligence techniques in data analysis across a variety of disciplines. These techniques include (but are not limited to): all areas of data visualization, data pre-processing (fusion, editing, transformation, filtering, sampling), data engineering, database mining techniques, tools and applications, use of domain knowledge in data analysis, machine learning, neural nets, fuzzy logic, statistical pattern recognition, knowledge filtering, and post-processing. In particular, we prefer papers that discuss development of new AI architectures, methodologies, and techniques and their applications to the field of data analysis. Papers published in this journal will be geared heavily towards applications, with an anticipated split of 70oriented, and the remaining 30

Editor-in-Chief

A. Famili
National Research Council of Canada,
Canada

Editorial Board

Information for Authors

General

The journal of Intelligent Data Analysis invites submission of research and application papers within the aims and scope of the journal. In particular, we prefer papers that discuss development of new AI architec- tures, methodologies, and techniques and their applications to the field of data analysis.

Manuscript

The manuscript should be in the following format. The first page of the paper should contain the title (preferably less than 10 words), the name(s), address(es), affiliation(s) and e-mail(s) of the author(s). The first page should also contain an abstract of 200-300 words, followed by 3-5 keywords.

Submission

To speed up the production process, authors should submit the text of original papers in PostScript (compressed file), to the Editor-in-Chief (address below). Any graphical or tabular files should be sent in separate files in Encapsulated PostScript or GIF format. The corresponding author will receive an acknowledgement, by e-mail.

The standard format (Times Roman) is preferred. The Manuscript should not exceed 35-40 pages of text (or the compressed/uuencoded PostScript file should not be more than 1.0 Meg).

References

All references in the paper should be listed in alphabetical order under the first author's name and numbered consecutively by arabic numbers. The structure of the references should be in the following format:

(a) Example of journal papers: R.A. Brooks, Intelligence without Representation, Artificial Intelligence, 47 (1) (1991), 139-159.

(b) Example of monographs: A. Basilevsky, Applied Matrix Algebra in the Statistical Sciences, North- Holland, Amsterdam, (1983).

(c) Example of edited volume papers: J. Pan and J. Tenenbaum, An Intelligent Agent Framework for Enterprise Integration, in: A. Famili, D. Nau and S. Kim, eds., Artificial Intelligence Applications in Manufacturing, MIT Press, Cambridge, MA, (1992), 349-383.

(d) Example of conference proceedings papers: R. Sutton, Planning by Incremental Dynamic Programming, in: Proceedings of the 8th International Machine Learning Workshop, Evanston, IL, USA, Morgan Kaufmann, (1991), 353-357.

(e) Example of unpublished papers: C. H. Watkins, Learning from Delayed Rewards, Ph.D. Thesis, Cambridge Uni- versity, Cambridge, England, (1989).

The Review Process

Each paper will be reviewed by at least two reviewers. The authors will receive the results of the review process through e-mail. The authors of conditionally accepted papers are expected to revise their papers within 2-3 months.

Proofreading

Authors will be responsible for proofreading. Final copies of papers will be made available to the author and should be verified by the author within three working days. No new material may be inserted in the text at the time of proofreading.

Final Manuscript

When paper accepted, the publisher requires an electronic copy of the paper in one of the following formats, along with the originals of figures and tables.

Papers can be submitted in any one of the following formats:

- FrameMaker,
- WordPerfect,
- MicroSoft Word or
- Postscript.

Graphical files must be submitted separately, in either PostScript or GIF formats. A paper copy original is also required for any graphical material.

Journal of Intelligent Data Analysis will be a fully electronic, refereed quarterly journal. It will contain a number of innovative features not available in comparable print publications. These features include:

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A. Famili, Ph.D. Phone: (613) 993-8554 Editor-in-Chief, Intelligent Data Analysis Fax : (613) 952-7151 Senior Research Scientist email: famili@ai.iit.nrc.ca Institute for Information Technology http://ai.iit.nrc.ca/ fazel National Research Council of Canada, Bldg. M-50, Montreal Rd. Ottawa, Ont. K1A 0R6 Canada

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Call for Papers

PDCS '97 – Parallel and Distributed Computing and Systems

9th International Conference,
Georgetown University Conference Center
Washington, D.C., U.S.A., October 13-16, 1997

Sponsored by International Association
of Science and Technology for Development (IASTED)

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Purpose

The International Conference on Parallel and Distributed Computing and Systems, sponsored by IASTED, is a major annual forum for scientists, engineers, and practitioners throughout the world to present the latest research results, ideas, development, and applications in all areas of parallel and distributed processing. The 1996 conference attracted researchers from 34 countries. The 1997 meeting (PDCS '97) will be held in Washington, D.C., U.S.A., and will include keynote addresses, contributed papers, tutorials, and workshops.

Scope

The main focus of PDCS '97 will be parallel and distributed computing and systems viewed from the three perspectives of architecture and networking, software systems, and algorithms and applications. Topics include, but are not limited to, the following:

ARCHITECTURE AND NETWORKING

- SIMD/MIMD processors
- Various parallel/concurrent architecture styles
- Interconnection networks
- Memory systems and management
- I/O in parallel processing
- VLSI systems
- Optical computing
- Computer networks
- Communications and telecommunications
- Wireless networks and mobile computing

SOFTWARE SYSTEMS

- Operating systems
- Programming languages
- Various parallel programming paradigms
- Vectorization and program transformation
- Parallelizing compilers
- Tools and environments for software development
- Distributed data- and knowledge-base systems
- Modelling and simulation
- Performance evaluation and measurements
- Visualization

ALGORITHMS AND APPLICATIONS

- Parallel/distributed algorithms
- Resource allocation and management
- Load sharing and balancing
- Task mapping and job scheduling
- Network routing and communication algorithms
- Reliability and fault tolerance
- Signal and image processing
- Neural networks
- High-performance scientific computing
- Application studies

Paper Submission Guidelines

Papers reporting original and unpublished research results and experience are solicited. Papers will be selected based on their originality, significance, timeliness, relevance, and clarity of presentation. Accepted and presented papers will be published in the conference proceedings. A special issue consisting of selected papers from PDCS '97 will be published in an IASTED/ISMM journal.

Please send four copies of a manuscript to the program committee chair at the following address by March 15, 1997: Professor Keqin Li, PDCS '97 Program Chair, Dept. of Mathematics and Computer Science, State University of New York, New Paltz, New York 12561-2499, U.S.A. Phone: (914) 257-3534. Fax: (914) 257-3571. Email: li@mcs.newpaltz.edu.

A manuscript should not exceed 15 pages, including tables and figures. In the cover letter, please indicate the author for correspondence, and his/her complete postal address, phone and fax numbers, and email address (make sure the email address is current and working).

Tutorials/Workshops

Several workshops are being planned on PDCS '97. Each workshop will focus on a particular topic, and consists of several presentations and open discussion. A one-page abstract of each workshop presentation will be published in the conference proceedings. The proposal for a workshop should include the title, topics covered, proposed/invited speakers, and estimated length (hours) of the workshop.

PDCS '97 will also offer half-day tutorials in parallel and distributed computing. Each tutorial proposal should provide the title, topics, targeted audiences, and instructor's biography.

Anyone wishing to teach a tutorial or organize a workshop in connection with PDCS '97 should submit four copies of his/her proposal to the vice program chair at the following address by March 15, 1997: Professor Yi Pan, PDCS '97 Vice Program Chair, Department of Computer Science, University of Dayton, Dayton, Ohio 45469-2160, U.S.A. Phone: (513) 229-3807. Fax: (513) 229-4000. Email: pan@hype.cps.udayton.edu.

Important Dates

- Paper submission deadline: March 15, 1997
- Author notification: May 15, 1997
- Camera-ready version due: July 1, 1997
- Workshop/tutorial proposal due: March 15, 1997
- Conference: October 13-16, 1997

Mailing List

For more information or to be placed on the mailing list, please contact: Ms. Pen Harms, IASTED PDCS '97 Secretariat, 1811 West Katella Avenue, Suite 101, Anaheim, CA 92804, U.S.A. Tel: 714-778-3230. Fax: 714-778-5463. Email: iasted@orion.oac.uci.edu.

Call for Papers

Artificial Intelligence and Soft Computing

IASTED International Conference
July 27-August 1, 1997
Banff, Canada

Sponsor

The International Association of Science and Technology for Development - IASTED In cooperation with the American Association for Artificial Intelligence (AAAI)

Scope

- Artificial intelligence - Expert systems - Neural networks - Knowledge acquisition - Knowledge representation - Knowledge engineering - Object-oriented techniques - Expert systems design procedures and tools - Natural languages - Computational linguistics - Architectures for natural languages - Algorithms - Intelligent databases - Intelligent control - Intelligent agents - Distributed artificial intelligence - Image understanding - Logic programming - Advisory systems - User interface - Machine learning - Fuzzy expert systems - Approximate reasoning - Automated reasoning - Reasoning methods - Temporal and spatial reasoning - Fuzzy logic - Fuzzy systems - Verification, validation - Testing - Theory of neural networks - Modelling - Simulation - Architecture - Learning algorithms - Planning and scheduling - Applications, all areas including: Engineering, Science, Business, Economics, Power systems, Transportation, Decision making, Management, Environmental systems, Banking, Government, Education - Others

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SUBMISSION OF ABSTRACTS

Initial paper selection will be based upon abstracts. An abstract should present a clear and concise view of the motivation of the subject, give an outline of the paper, and provide a list of references. The abstract should not exceed 600 words. The International Program Committee will make the decision concerning the acceptance of the papers.

Three copies of the abstracts should be received at the IASTED Secretariat - ASC'97, #80, 4500 - 16 Avenue NW, Calgary, AB, Canada, T3B 0M6 by January 6, 1997. Authors should provide a maximum of five keywords describing their work, and must include a statement confirming that if their paper is accepted one of the authors will attend the conference to present it. Please include the full name, affiliation, full address, telephone number, fax number, and email address of the corresponding author.

Notifications will be mailed by March 3, 1997. Authors of accepted papers will be required to submit their camera-ready final papers and registration by May 2, 1997. Papers received after that date will not be included in the proceedings. The International Program Committee reserves the right to reject any final manuscripts if quality is low. If this should occur, the authors will be notified by May 15, 1997 and their registrations will be refunded.

IMPORTANT DEADLINES

Abstracts due: January 6, 1997
Acceptance notification: March 3, 1997
Camera-Ready Manuscripts and Registrations: May 2, 1997

For more information or to be placed on the mailing list, please contact:
IASTED Secretariat
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Announcement and Call for Papers

ADBIS '97 – Advances in Databases and Information Systems

First East-European Symposium on
St.-Petersburg (Russia), September 2 - 5, 1997
In cooperation with the ACM SIGMOD
Sponsored by the Russian Foundation for Basic Research

Aims and Scope

The East European Symposium on Advances in Databases and Information Systems (ADBIS) - a series of annual high quality international conferences - will provide a forum for the exchange of scientific achievements between the research communities of Eastern Europe and the rest of the world in the area of databases and information systems. It continues and consolidates the series of ADBIS workshops organized by the Moscow ACM SIGMOD Chapter and the East-West Database workshops.

The new annual Symposium will be hosted by different countries of the Eastern Europe including the Czech Republic, Estonia, Poland, Russia, Slovakia, Slovenia, the Ukraine (this list is open and only indicates an immediate possibility of the countries to host the Symposium).

The symposium will consist of regular sessions with technical contributions reviewd and selected by an international program commitee, invited talks by leading experts, tutorials, and special sections like industrial programs and posters on ongoing research projects in Eastern European countries.

ACM SIGMOD will actively support the organisation of the Symposia and warrant the high quality of the program. The Moscow ACM SIGMOD Chapter serves as a focal point of the event. The organizers have the ambition to make the ADBIS Symposium the premier database and information systems conference in Eastern Europe, to increase interaction and collaboration between researchers from East and West and to provide an internationally recognized tribune for the presentation of research.

Topics

The ADBIS'97 Symposium focuses on emerging and innovative approaches through which advanced information systems (IS) and system-level functions can be developed within the distinct frameworks. New large- and middle-scaled IS components, their performance issues, their reliability, their architectures and applications, and progress in their design, implementation and deployment technologies will continue to be emphasized.

Additionally, the symposium addresses to the uprising subjects and topics. Among which are the emerging theories, computational principles, technologies and architectures within which novel principles and techniques can be developed and applied to address practical issues for large- and middle-scaled information systems, such as integrity constraints, consistency, performance, object management, interoperability, cooperative systems, transaction management, distributed computations, client-server systems, etc.

Submissions are invited on topics including, but not limited to, the following:

- Object-oriented and computational models
- Ontological modeling and specification
- Enterprise Modeling
- Requirements engineering
- Design engineering
- Re-engineering and legacy systems
- Methodologies and tools
- Activity modelling and advanced transaction and workflow models
- Data Warehousing
- Parallel and distributed databases
- Deductive and object-oriented databases
- Data mining, knowledge discovery and knowledge bases

- Interfaces to databases and information systems
- Novel database application areas
- Scientific databases and information systems
- Large area information systems on the Internet (based on WWW, CORBA, Java technologies)
- Multimedia information systems
- Interoperable, heterogeneous environments and systems
- Semantic interoperability, megaprogramming and reuse

Information for Authors

Only electronic submissions will be considered. The authors are invited to send extended abstracts of their contributions not exceeding 4000 words (4–5 pages) in LaTeX (Postscript for pictures) or in Postscript before March 7, 1997 to the address:

`adbis97@sigmod.ipi.ac.ru`

At least one of the authors of accepted papers is expected to attend the Symposium. Full versions of accepted papers (LaTeX source, Postscript for pictures is required) must be sent to the same address by June 13, 1997 for printing and distribution to participants of the symposium. The papers should not exceed 8000 words. Final paper versions for the proceedings must be e-mailed before October 30, 1997.

Negotiations are taking place for publication of the proceedings by the Kluwer Academic Publishers.

An HTML version of this call for papers is available from

`http://www.ipi.ac.ru/sigmod/adbis/adbis97`

The ADBIS workshops have provided special sections to Russian Basic Research Foundation (RBRF) contributions as well Ph.D students contributions over the past few years. Selected presentations and contributions are continue to be identified for development into full proceedings papers.

Important Dates

Submission of extended abstracts March 7 Notification of acceptance or rejection May 15 Full papers by email for Symposium June 13 Symposium September 2 - 5 Final version of paper for the proceedings October 30

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A welcome

We welcome your contribution to this new symposium. We are confident you will find exciting and thoughtful discussions of principles and practices of future information systems, innovative information technologies and presentations. We hope and belive that the Symposium will assist you to pursue the choice of forward-looking testbeds.

Machine Learning List

The Machine Learning List is moderated. Contributions should be relevant to the scientific study of machine learning. Mail contributions to `ml@ics.uci.edu`. Mail requests to be added or deleted to `ml-request@ics.uci.edu`. Back issues may be FTP'd from `ics.uci.edu` in `pub/ml-list/V`<X>`/`<N> or N.Z where X and N are the volume and number of the issue; ID: anonymous PASSWORD: <your mail address> URL- `http://www.ics.uci.edu/AI/ML/Machine-Learning.html`

THE MINISTRY OF SCIENCE AND TECHNOLOGY OF THE REPUBLIC OF SLOVENIA

Address: Slovenska 50, 1000 Ljubljana, Tel.: +386 61 1311 107, Fax: +386 61 1324 140.
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Minister: Prof. Andrej Umek, Ph.D.

The Ministry also includes:

The Standards and Metrology Institute of the Republic of Slovenia
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The Industrial Property Protection Office
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Office of the Slovenian National Commission for UNESCO
Address: Slovenska 50, 1000 Ljubljana, Tel.: +386 61 1311 107, Fax: +386 61 302 951.

Scientific Research and Development Potential.
The statistical data for 1994 showed that there were 275 research and development institutions in Slovenia. Altogether, there were 12,029 employees, of whom 5,841 were researchers, and 6,188 were expert, technical personnel and others.

In the past ten years, the number of high qualified researchers has almost doubled: the number of Ph. D. graduates increased from 1,100 to 1,988, while the number of M. Sc.s rose from 650 to 1,595. The "Young Researchers" (i.e. postgraduate students) program has greatly helped towards revitalizing research. The average age of researchers has been brought down to 40, with one-fifth of them being younger than 29.

The table below shows the distribution of researchers according to educational level and sectors (in 1994):

Sector	Ph.D.	M.Sc.
Business enterprises	93	327
Government	574	471
Private non-profit organizations	14	25
Higher education organizations	1307	772
Total	1988	1595

Financing Research and Development.
Statistical estimates indicate that 1,6% of GDP was spent on research and development in Slovenia in 1994. More than half of this comes from public expenditure.

Income of R&D organizations spent on R&D activities in 1994 (in million US$):

Sector	Total	Basic res.	App. res.	Exp. dev.
Business ent.	101,3	6,6	48,8	45,8
Government	46,1	22,4	13,7	9,9
Private non-p.	1,4	0,3	0,9	0,2
Higher edu.	39,1	17,4	13,7	8,0
Total	187,9	46,9	77,1	63,9

The policy of the Slovene Government tends to increase the budget funds in favour of R&D.

The Ministry of Science and Technology is a government institution responsible for controlling expenditure of the R&D budget funds, in compliance with the National Research Program (NRP) and criteria provided by the Law on Research Activities. The Ministry finances research or cofinances development projects through public bidding, while it directly finances management and top-level science in national institutes.

The focal points of R&D policy in Slovenia are:

- maintaining the high level and quality of research activities,
- stimulating collaboration between research and industrial institutions,
- (co) financing and tax exemped for companies engaged in technical development and other applied research projects,
- further professional development of leading experts,
- close involvement in international research and development projects,
- ransfer of the knowledge, technology and experience.

Source of data: Statistical Office of the R Slovenia.

Errata: This page should appear also in *Informatica* Vol. 20, No. 3, however, due to a technical error an old version of this page was printed. Executive editors apologies for this error.

JOŽEF STEFAN INSTITUTE

Jožef Stefan (1835-1893) was one of the most prominent physicists of the 19th century. Born to Slovene parents, he obtained his Ph.D. at Vienna University, where he was later Director of the Physics Institute, Vice-President of the Vienna Academy of Sciences and a member of several scientific institutions in Europe. Stefan explored many areas in hydrodynamics, optics, acoustics, electricity, magnetism and the kinetic theory of gases. Among other things, he originated the law that the total radiation from a black body is proportional to the 4th power of its absolute temperature, known as the Stefan–Boltzmann law.

The Jožef Stefan Institute (JSI) is the leading independent scientific research in Slovenia, covering a broad spectrum of fundamental and applied research in the fields of physics, chemistry and biochemistry, electronics and information science, nuclear science technology, energy research and environmental science.

The Jožef Stefan Institute (JSI) is a research organisation for pure and applied research in the natural sciences and technology. Both are closely interconnected in research departments composed of different task teams. Emphasis in basic research is given to the development and education of young scientists, while applied research and development serve for the transfer of advanced knowledge, contributing to the development of the national economy and society in general.

At present the Institute, with a total of about 700 staff, has 500 researchers, about 250 of whom are postgraduates, over 200 of whom have doctorates (Ph.D.), and around 150 of whom have permanent professorships or temporary teaching assignments at the Universities.

In view of its activities and status, the JSI plays the role of a national institute, complementing the role of the universities and bridging the gap between basic science and applications.

Research at the JSI includes the following major fields: physics; chemistry; electronics, informatics and computer sciences; biochemistry; ecology; reactor technology; applied mathematics. Most of the activities are more or less closely connected to information sciences, in particular computer sciences, artificial intelligence, language and speech technologies, computer-aided design, computer architectures, biocybernetics and robotics, computer automation and control, professional electronics, digital communications and networks, and applied mathematics.

The Institute is located in Ljubljana, the capital of the independent state of **Slovenia** (or S♡nia). The capital today is considered a crossroad between East, West and Mediterranean Europe, offering excellent productive capabilities and solid business opportunities, with strong international connections. Ljubljana is connected to important centers such as Prague, Budapest, Vienna, Zagreb, Milan, Rome, Monaco, Nice, Bern and Munich, all within a radius of 600 km.

In the last year on the site of the Jožef Stefan Institute, the Technology park "Ljubljana" has been proposed as part of the national strategy for technological development to foster synergies between research and industry, to promote joint ventures between university bodies, research institutes and innovative industry, to act as an incubator for high-tech initiatives and to accelerate the development cycle of innovative products.

At the present time, part of the Institute is being reorganized into several high-tech units supported by and connected within the Technology park at the Jožef Stefan Institute, established as the beginning of a regional Technology park "Ljubljana". The project is being developed at a particularly historical moment, characterized by the process of state reorganisation, privatisation and private initiative. The national Technology Park will take the form of a shareholding company and will host an independent venture-capital institution.

The promoters and operational entities of the project are the Republic of Slovenia, Ministry of Science and Technology and the Jožef Stefan Institute. The framework of the operation also includes the University of Ljubljana, the National Institute of Chemistry, the Institute for Electronics and Vacuum Technology and the Institute for Materials and Construction Research among others. In addition, the project is supported by the Ministry of Economic Relations and Development, the National Chamber of Economy and the City of Ljubljana.

Jožef Stefan Institute
Jamova 39, 61000 Ljubljana, Slovenia
Tel.:+386 61 1773 900, Fax.:+386 61 219 385
Tlx.:31 296 JOSTIN SI
WWW: http://www.ijs.si
E-mail: matjaz.gams@ijs.si
Contact person for the Park: Iztok Lesjak, M.Sc.
Public relations: Natalija Polenec

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INFORMATICA
AN INTERNATIONAL JOURNAL OF COMPUTING AND INFORMATICS
INVITATION, COOPERATION

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The coordination necessary is made through the Executive Editors who examine the reviews, sort the accepted articles and maintain appropriate international distribution. The Executive Board is appointed by the Society Informatika. Informatica is partially supported by the Slovenian Ministry of Science and Technology.

Each author is guaranteed to receive the reviews of his article. When accepted, publication in Informatica is guaranteed in less than one year after the Executive Editors receive the corrected version of the article.

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Informatica

An International Journal of Computing and Informatics

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