科技资料

Computer Aided Systems Theory-EUROCAST '91

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Computer Aided Systems Theory – EUROCAST '91

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Preface

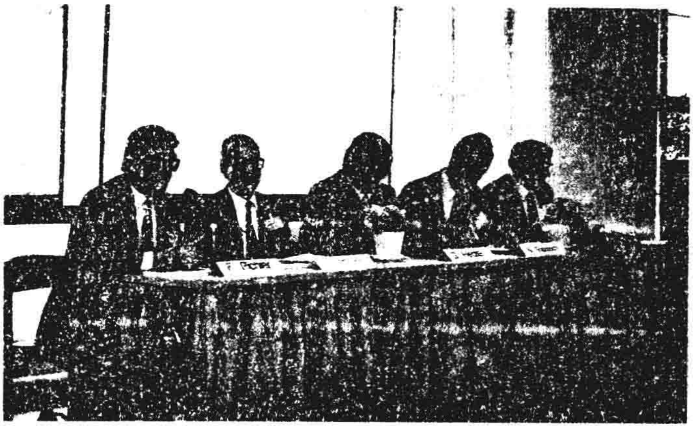
This volume contains a selection of papers presented at the second European workshop EUROCAST '91 held in Krems, Austria, in April 1991. It should give an overview on the current state of CAST research and its relation to CAD applications in the engineering fields. Publishing in the Lecture Notes in Computer Science is motivated by the following two reasons:
(1) CAST research requires the application of the most advanced information processing technology in software and hardware for the implementation of CAST method base systems
(2) the specific engineering disciplines (especially the field of information and control engineering) have the opportunity to present the state of the art in modelling tools to computer scientists

EUROCAST '91 proved that CAST research is still in its beginning state of development. However we can see by the results which were achieved in the workshop that progress towards a common understanding of the task is continuing.

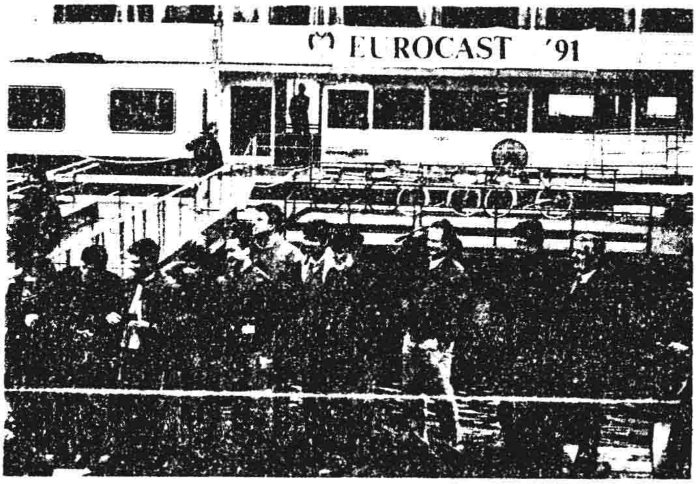
EUROCAST '91 was organized by the Wissenschaftliche Landesakademie Krems, Austria, in cooperation with the Johannes Kepler University Linz, Austria, and the Universidad de Las Palmas de Gran Canaria, Canary Islands, Spain. Professor Peter Kopacek, Conference-Chairman of the workshop, and his team deserve many thanks for the organizational work. The organizers are grateful for the co-sponsorship of the International Federation of Systems Research (IFSR), the International Federation of Automatic Control (IFAC), and the Technical Committee on Systems Engineering (SECOM).

The editors of this volume would once more like to thank our mentor in CAST research Professor Heinz Schwärtzel, Siemens Corporation Munich, and current president of the German Society for Computer Science, for his encouragement and advice. Many thanks also to Professor Gerhard Goos, University of Karlsruhe and Editor-in-Chief of the Lecture Notes in Computer Science, for his understanding and acceptance of our publication. A final word of thanks goes to the Springer-Verlag staff in Heidelberg for their help in publishing this volume.

February 1992 — Franz Pichler, Roberto Moreno-Díaz



EUROCAST'91
Opening Session



Having fun after
the boat trip
(despite of the
chilly April weather
condition)

SKETCHES from
EUROCAST'91
Krems/Austria

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1 SYSTEMS THEORY AND CAST METHODOLOGY

LINEAR AND ALGORITHMIC FORMULATION OF CO-OPERATIVE COMPUTATION IN NEURAL NETS

by

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SUMMARY

In this paper we consider a formulation of **neural computation** in terms of multilayer **co-operative processes** between local inference units. Each neuron is described in terms of a local computation **frame** with **slots** and **semantic tables** to represent the meaning of the input and output representation spaces. After some methodological remarks on the distinction between **processors** and **processes** in the **auditor paradigm**, we introduce the computational model of co-operativity where global computations are divided into a large number of dinamically reconfigurable sub-computations. Some theoretical requirements are considered and the lack of developments on **concurrent programming** is pointed out. Then, the **frame neuron** is introduced and the meaning of the different slots is stablished. Linear and algorithmic formulation appears as a particular case of the frame to which we can reduce all previous connectionistic formulations. This computational model is used to "revisit" the **analogical level** where neuronal function is formulated in terms of linear spatio-temporal filters followed by a threshold function.

A personal feeling underlying all the paper is the **lack of** appropriate **tools** in systems theory powerful enough to describe complex behavior such as that of **neural nets** where the linear and logic levels are not sufficient.

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1. INTRODUCTION

In this paper we consider neural computation in terms of co-operative processes between local operators complemented with semantic tables to represent the meanings of the input and output spaces. Each neuron is described in terms of a **local inference** frame with slots for identification, conectivity, mailing and local computation. The anatomy of the net is the biological counterpart of the co-operative architecture (a large number of programable "computers" which are connected by a message-passing communication network). The physiology of the net is the biological counterpart of the set of local processes carried out by **each neuron** according to the afferent information. To explain the complexity of emergent global behavior in terms of millions of neural inferences happening at each time is a problem of **analysis.** To **obtain** the large number of local sub-computations we need for the synthesis of an artificial neural net is a problem of **co-operative programming.** In co-operative computation the temporal sequences of local computations for each neuron cannot be determined in advance and because of that we need new developments from the field of parallel programming to advance in the formulation of neural computation.

The starting point of this formulation is the high **residual function** after traumatic and surgical lesions in the neural nets of animals and men. After **local lesion**, a set of specific symptoms arise, as well as a depression in the global function. Nevertheless, in general no specific function has been eliminated and the main lines of the functional organization still remain. Moreover, in many cases this specific **functional deficit** can be "recovered" by means of a rehabilitation process that reorganizes the residual function.

The historical works of **Lashley** (1929, 1937, 1951), **Luria** (1974) and **J. Gonzalo** (1952, 1978) suggest that neural processes has to be **co-operative** (at least the cortical ones) in such a way that neurons are functionally connected and working together towards common goals **genetically** programmed, with distributed computation and computational multiplicity of the same anatomic area. The behavior of individual neurons is not to much relevant, otherwise, the effect of standard lesions that eliminates more than **$8\cdot10^{14}$ cortical units** would be **catastrophic** and this is not the case. In **Lashley** work, animals were trained in various tasks. Associative tracts were cut or portions of brain removed and effects of these operations on initial learning were measured. **Luria** and **J. Gonzalo** used data from war injured men with well localized traumatic lesions. The functional deficit associated to lesions was evaluated measuring the residual function of the remaining brain. In figure 1 we shown a modified version of the **J. Gonzalo** results for **sensorial functions** degradation in terms of a "**scale factor**", which is function of the lesion's position and magnitude. The co-operative process maintains the general organization of sensorial functions. Nevertheless **acuity** and **differential sensitivity** decreases and some primary deficits **(scotoma)** appear.

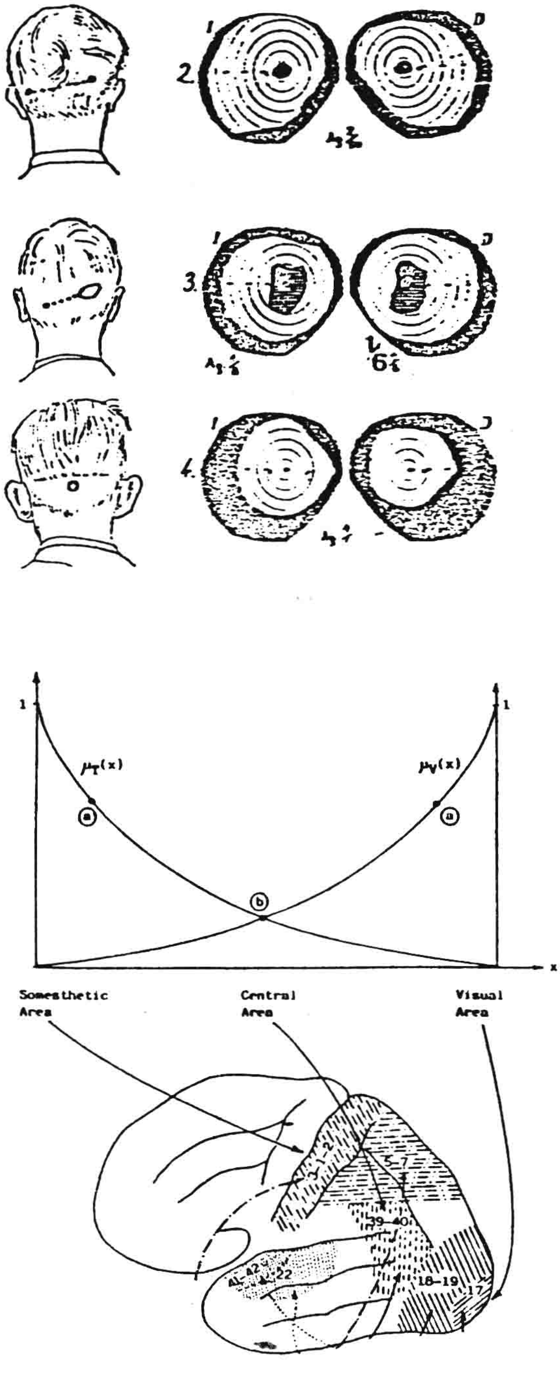

Figure 1. J. Gonzalo data on functional deficit and residual function in sensorial cortex after lesion. a) Examples of central scotomas. b) Fuzzy formulation of visual, central and somesthetic membership functions. (Mira and Delgado, 1987).

The claim for co-operative formulation of neural function is not new. The works of **Beurle** (1956), **Wilson and Cowan** (1972), **Freeman** (1975), **Montalvo** (1975), **Cragg and Temperley** (1954), **Eccles** (1984), **Mountcastle** (1979), **Edelman** (1981), **Delgado** (1978), **Szentagothai** (1979), **Mira et al** (1981), **Arbib** (1982), **Amari** (1982), to name but a few also point in this direction. More recently, in the fiorello of neural nets and connectionism, **McClelland** and **Rumelhart** (1987), **Hopfield** and **Tank** (1986), **Lippman** (1987), **Fahlman** and **Hinton** (1987), **Kohonen** (1988), **Widrow** and **Winter** (1988) and **Feeldman et al** (1988), have produced papers exploring the computational possibilities of **parallel distributed processing**. **Arbib** and **Hanson** (1987) have reported on the co-operative processes in the visual system with reference to the need of logical spaces built on relational structures relating to the semantic content of the stimulus. Previous works of **J. Mira**, **R. Moreno-Díaz** and **A.E. Delgado** (1983) also proposed a theoretical frame to study co-operative processes in Cerebral Dynamics in terms of layered computation on symbolic representation spaces.

From the perspective of **reliable computation** and **fault tolerance** there are also relevant contributions to the computational modeling of co-operativity. The reviews of **D.A. Rennels** (1980), **Stone** and **Bokhari (1978)** and **S.I. Kartashev - S.P. Kartashev** (1978) are representatives of this approach, that started with the **von Neumann** (1951) and **W.S. McCulloch** (1958) **research** on reliable computation from intrinsically unreliable components (**J. Mira et al**, 1981).

Finally, **Gul Agha** (1986, 1989) proposes a model of concurrent computation in distributed systems based on "**actors**" that can also be considered as a conceptual contribution to the co-operative formulation of neural functions. The concepts of dynamic reconfigurability and bounded/unbounded asynchronous communication buffers, as well as the emphasis on the need for new theoretical constructs and managing resources tools in **concurrent programming** are representatives of the pure computational needs for developments in the field of co-operative computation, without specific references to neural nets.

2. PROCESSORS AND PROCESSES IN THE AUDITOR PARADIGM

In dealing with the co-operative computation in neural nets several methodological comments seems relevant as starting point (**J. Mira**, 1990):

- * **2.1** The introduction of the **auditor** paradigm and the "two domains" theory: **proper** (evolutive and with **emergent codes**) and **descriptive** (representations with **imposed codes**).
- * **2.2** A Taxonomy of **levels** (cognitive domains).

- * **2.3** Clear distinction between neuronal **processors** and neuronal **processes** (**Mira** and **Delgado**, 1988).
- * **2.4** A **theoretical frame** of reference with the inclussion of the duality processor/process, structured in layers where neurons of each layer operate on the same input space to provide an output space, both being **spaces of representation** (**Mira et al**, 1980; **Mira** and **Moreno-Díaz**, 1988).
- * **2.5** Effective **procedures of calculus** to model neural processes in symbolic (cognitive) or subsymbolic (connectionistic) computations.

The introduction of the **auditor** in the description of the interactions within the Nervous System and of the Nervous System with the rest of the organism and with the environment is methodologycally crucial (Maturana, 1975 and Varela, 1979). Two phenomenological domains are always (explicit or implicitely) stablished: the **external observer** domain and the internal or **proper** domain. In the observer domain we have a descriptive system of reference and specific descriptions in terms of inputs, outputs and invented computational links to fit the observed data. Here the code is imposed amd can be arbitrary. We also have some organizational principles. The descriptive domain invented by the **observer/auditor** includes concepts such as neurophysiological signals (spikes and slow potentials), information, code, program, transfer function, memory, perceptions, learning, meaning and purpose.

The key point is not to make confussion between features of the description (observer domain) and effective processes in the proper domain. Here **the code is emergent** and never arbitrary. In the proper domain we have the actual component structures and organizations that effectively operates in the neural nets. The goal in Neural Modeling is to look after **artificial organizations** that defines a class of **information processing structures** which generates a phenomenology indistinguishable from the phenomenology proper of living systems of which we say behaves **intentionally**. Figure 2 illustrate the two domains representation. Please, observe that understanding and explanation of cerebral dynamic activities takes place always in the observer domain and strictly depends on **knowledge injection** concerning the organizational principles and computational structures suggested to embody neural function.

The **computational paradigm** at several levels of integration summarizes what we can call normal science today. We describe neurons and neural nets in terms of input and output spaces and a computational algorithm (analogic, logic or symbolic) that links these spaces in each level. For each of these levels, a clear distinction between **processors** and **processes** has to be made (Mira and Delgado, 1988; Mira, 1989). Processors (neurons) are physiological entities while processes are abstract computations described in terms of natural and programming languages and mathematics. From

Turing we are aware of the independency of both entities. The way in which neuronal processes are implemented using neuronal processors is a problem of neuronal architecture and neuronal programming.

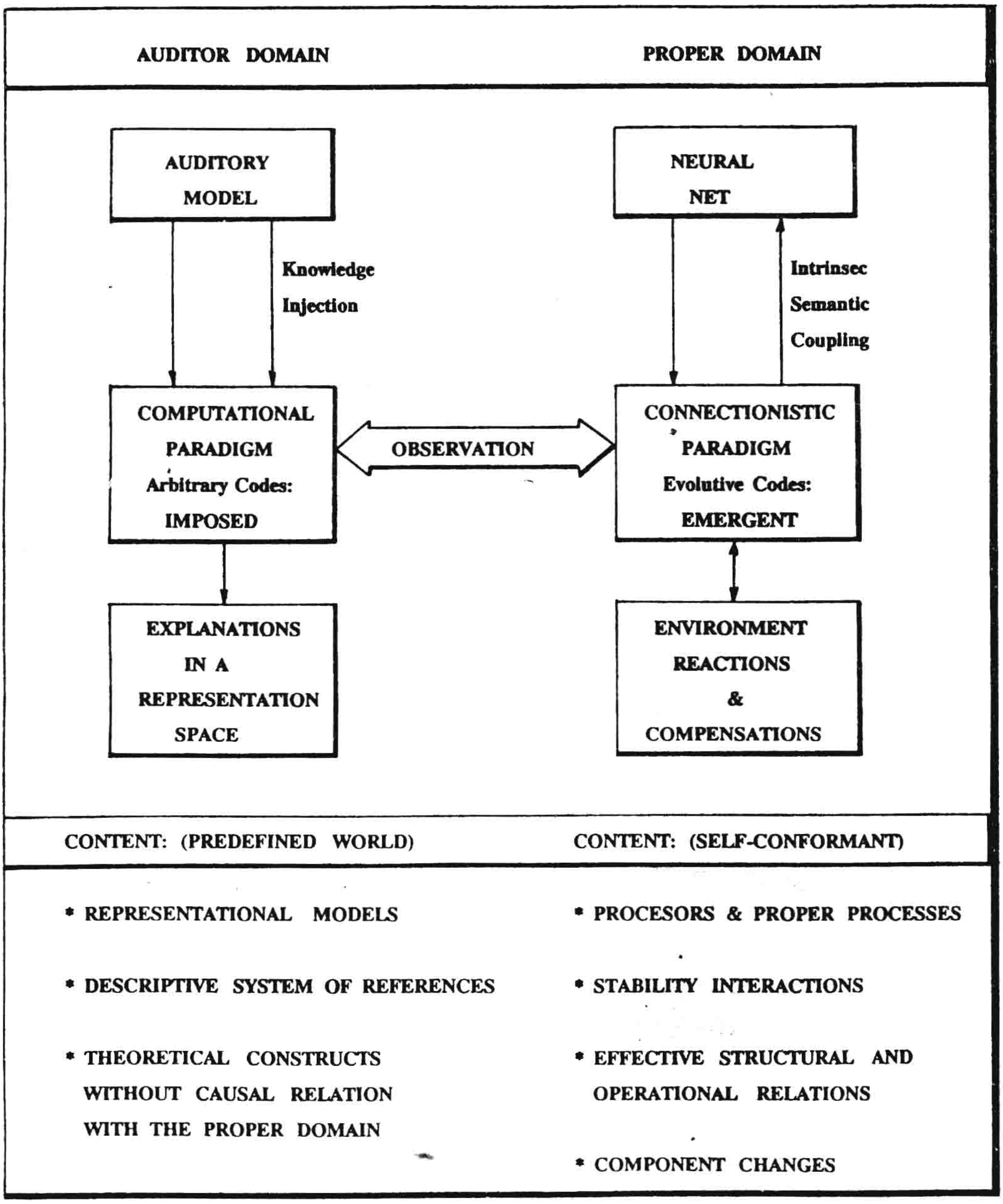

Figure 2. The auditor paradigm of two domains descriptions in the maturana and varela sense: clear distinction between imposed and emergent codes.

3. ANATOMICAL BASIS OF CO-OPERATIVE COMPUTATION

In the introduction we have seen some of the neuropsychological and clinical basis to support the co-opetative viewpoint in cerebral dynamics based on the lesion tolerance fact. Let us introduce here some references to the anatomical support. The work of **Cajal**, **Lorente de No**, **Scholl**, **Schmitt**, **Mouncastle**, **Shepherd**, **Ravic** and **Szentagothai**, to name but a few is representative of this perspective (see for example, **Schmitt** and **Worden**, 1979).

The **cerebral cortex** is an extensive layer of neural tissue of approximately **0.25 cm.** in thickness, **2200 cm^2** in surface and **580 cm^3** in volumen (**Scholl**, 1962). It contains principally **pyramidal** and **stellate** cells with high density, from **10** to **100** neurons per **mm^3** and a double **anatomical organization**: **horizontal** and **vertical**. Horizontally, the neurons are distributed in a series of **layers** with fuzzy frontiers, and different types of neurons predominate at each level. Vertically an organization in the form of columns with some **100** neurons in depth is observed. The horizontal organization is illustrated in figure 3 with the superposition of the afferent pathways (A, B, C) corresponding to primary fibers (A) for receptors. This informatio spreads out over **650 μ** and **overlaps** the cell bodies of about **5000 neurons**. Fibers B corresponds to information from secondary and associative areas and fibers C correspond to axons that are tangentially propagated and act on the majority of cortical neurons via the apical dendritic fields. Each layer is anatomically described in terms of the corresponding **Cajal's arch** around the dominant cell. Also in figure 3 are included the **Cajal's arch** for the strellate (b) and pyramidal layers (c). A massive number of "copies" of this circuits are distributed in "**space**" (processors) and changing its function with the "**time**" (processes).

The **anatomical support** for co-operative computation can be summarized in the following facts:

- **A.1** **Modularity** and high density.
- **A.2** **Massively tridimensional architecture** with more than 10^{11} computing elements.
- **A.3** **High connectivity** with massive convergent/divergent processes. More than **40000** inputs from **1000** to **250000** other elements and outputs to more than **60000** units.
- **A.4** **Genetic programming** of growing and specificity of connections.
- **A.5** **Anatomical reconfigurability** after lesion with fault tolerance and **reliable computation**.
- **A.6** **Time** and **space** as variables of calculus.
- **A.7** Architecture adequate to **concurrent computing**, in particular to asynchronous **multicomputers**, that uses a large number of programmable computers connected by message passing networks (**Agha**, 1989).

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