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BioNet '96

Bio-Informatics and Pulspropagating Networks

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Selected Contributions

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Preface

This volume contains selected contributions to BioNet'96. The Workshop is the third in a series of workshops held since 1994. BioNet'96 resumes this series as a single session workshop held in Berlin-Adlershof, November 14 - 15, 1996.

The intention of the BioNet founders *Peter Puschmann, Gunnar Schoel, Horst Völz, Peter Bartsch, Manfred Lambertz, Manfred Langhorst, Christian Hamann, Werner Backhaus Horst-Michael Groß* at all was to establish a podium for the interdisciplinary discussion of global organizational principles and delaying effects in nervous system from the viewpoint of physical realistic ideas.

In different scientific disciplines we find a lot of approaches. Behind empirical models to investigate coherence or probability relationships in behavior we find structural models to verify functions of neural circuits.

For three years the workshop has been a small circle to talk about possibilities to inspire modeling techniques which allows better to understand global relationships in nervous system. Doing this the help of different (experimental) disciplines is necessary. Thus the character is interdisciplinary. Behind medical approaches the workshop is open to technical applications. In difference to comparable events we focus on analytical delay modeling techniques to describe control and function in nervous systems.

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Special acknowledgments to *Dr. Hagen Tiedtke*, Managing Director of the GFaI and *Prof. Dr. Alfred Iwainsky*, Head of the Directorate. Last not least I am grateful to all colleagues who have been engaged in preparing this workshop, especially to the members of my research group and to my wife *Gudrun Heinz* for their essential contributions to a successful preparation of the workshop.

Gerd Karl Heinz,

In Personal Matter

Inspired by Hodgkin/Huxley [5] there is an accurate knowledge to single neuron behavior and to behavior of comparable small networks in terms of electric or ionic current flow through the cell body. On the other hand, psychologists present detailed knowledge about global behavior and related areas in brain or in the nervous system, documented in various empirical modeling techniques. Physiologists and surgeons have a lot of practical experience.

But concerning the interpretation of structures in functional view we find a gap.

In the beginning of the forties the fiction of machinery computation combined with the interest in neuro-systems changed perceptions. Discretization of analog signals seems to appear as the way, to make things going in a digitized world. Electrical wires imploded to potentials, to nodes.

So no wonder that McCulloch/Pitts started the neural (and digital) age with a description of neural functionality in terms of discrete state machines. We find state-machines and matrix notations instead of time-functions or wave field descriptions to interpret pulse-interference circuits.

In the beginning fifties discrete 'neural' nets were qualified to learn. Delay modeling of wires does not seem to be necessary (Perceptron, back-propagation etc.) to understand neural networks. Perhaps, Jeffress' model was no longer of interest. Even biologists as Konishi remembered sometimes to interpret for example acoustical experiments.

Critic to the Pioneers?

The genius of computing pioneers was to discover digital calculable models of neural circuits. A time-function was interpreted in discrete values, delay portions are called states or samples. Explicit delay and time is removed from time-functions and substituted by states.

While McCulloch/Pitts starts [2] in 1943 with the words:

"The velocity along the axon varies directly with its diameter, from less than one meter per second in thin axons, which are usually short, to more than 150 meters per second in thick axons..."

in the following physical assumptions we read:

"... 2) A certain fixed number of synapses must be excited within the period of latent addition in order to excite a neuron at any time, and this number is independent of previous activity and position on the neuron.

3) The only significant delay within the nervous system is synaptic delay. ..."

Thus neural circuits with very different axonal and dendritic wiring are interpreted in the same minute with state sequences instead of time functions: It is not possible, to find any time-function in McCulloch/Pitts' paper.

What a mistake with fatal consequences! Else we find terms, characterizing the age of the following computer technology. Instead to use time-functions in a form like

$f_1(t) = f_2(t-\tau_1)\ v\ f_3(t-\tau_2)$

where τ_1 and τ_2 may be delays of real wires and *v* may be an component-wise operator like *AND*, *OR*, *MULT* or *ADD* we find terms comparable to

$N_3(t) :=: .N_1(t-1)\ .v\ .N_2(t-3)$

Thus, in the origin of neurocomputing we find a dangerous simplified description of physical reality in terms of delay.

In sight to the development of automaton (state machines) this might have been a very helpful way. But it covers ideas in the direction to interference, wave fields, relativity of time until today. The meaning of an intrinsic delay of a nerve fiber was lost for 50 years. A time function in the form $f(t-\tau)$ was replaced by a state- or sample sequence $N(t), N(t+1), N(t+2)$...

Only now we know the importance of delays as the method for data addressing in pulse-propagating networks.

Supposed, a neuron is excited by many different pulse-waves, then the possibility to excite is as much higher, as the quality of superimposition will improve. To destroy this timing structure of a network by using inadequate modeling techniques means to remove the physical background.

Forthcoming models after McCulloch/Pitts does not notice incremental delays on wires. The idea, delay can have a very influence on the function of a nerve circuit was disappearing more and more.

As a consequence the *synapse has been reduced to the learning weight* of a neuron. Nobody believes in the idea, *the location of a synapse is able to code the neural address* in an interference assumption [7]. So latest papers, discussing the phenomenon of non-interpretability of nerve networks in terms of structure-function equivalence [4] did not come across any mistake.

In this sight, Jeffress imagination was a short lightning flash in the dark.

On the other hand, the models of the Nobel-price candidates Hodgkin and Huxley (1952) [5] were precise enough to discover interferencial projections. But be it as it is, these models are partially over-loaded to make interference simulations with thousands of neurons. They were too slow to simulate neural fields in a time analysis manner, and nobody has found interference laws. Today it is time to recognize, that *a loss of sensitivity has produced painful mistakes over 50 years*!

At the one hand time and space properties have huge impact on the attainability of results. At the other hand, the re-interpretation of biological networks only is possible in case of structural equivalence. The real structure of a nerve net can be interpreted in a better way by delays and time-functions then by state machines. *We have forgotten that a (mathematical) state sequence is a special, discrete interpretation of a combination of physical time-functions.* It implies a special problem solving mechanism for iterative sets of equations that is usefull for time-functions in general.

At least time functions develop themselves physical properties which characterize delaying spaces. So a simple divergence of a single wire with spliced ends converging diametrically produces Huygens double split interference pattern - a phenomenon not to be found without delaying wires and pulse interference.

Pool of Neurons contra Interference Nets

The *wavelength of nerve impulses* is approximately between micrometers (non-myelinated) and millimeters (myelinated) [6]. The difference between different modeling techniques can be seen approximately in this dimension: If we suggest that neural excitement is higher as more closed different partial impulses reach the location of sensation in the neuron, it appears clear, that incoming impulses have to appear within the interval of their wavelength. Thus, the abstraction 'pool of neuron' (Amari etc.) is valid within a single interval of the wavelength.

If we suggest that most neurons have some axonal or dendritic wiring in the millimeter range, this means that *pool of neuron models are not useful to model nerve nets anyway*. Instead it is necessary to interpret nerve nets with delaying wires and space-time-functions. Finally we have to ask for superimposition criteria in space-time dimensions.

So the workshop also was introduced in order to increase the sensitive potential to use time-functions and realistic modeling techniques, to bring together medical experience and physical modeling techniques. We can summarize that the series of three workshops is on the way to generate successfully a central discussion: a discussion about the rule of delays in pulse-propagating networks. And we can summarize a second effect: the more we understand, that *delays cover the data addressing mechanisms in neural nets in general*, the more delays appear interesting for researches for different technical applications too.

Gerd Karl Heinz

Berlin, den 20.11.1996

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