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7

Faculty of Information Technology
King Mongkut's University of Technology North Bangkok, Bangkok, Thailand

Dr. G. Heinz
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March 28, 2011

Dear Dr. Heinz,

I am very delighted and honored to invite you to be a guest speaker at "The 7th International Conference on Computing and Information Technology (IC2IT 2011, http://www.icit.org)" organized by King Mongkut's University of Technology North Bangkok (KMUTNB, http://www.kmutnb.ac.th) during May 11-12, 2011. The areas of interests are as follows: Neural Network, Fuzzy System, Computational Intelligence, Data Communications, Computer Network, Security & Forensic, Decision Support, Image Processing, Pattern Recognition, Software Engineering, Information Technology, Computer Education, Data Mining, and Knowledge Management, and Applications.

We are now preparing papers for the proceedings of IC2IT 2011. Currently, we have approximately 70 papers already accepted for publishing in the proceedings and presenting at the conference as we selected from over 125 submissions from more than 10 countries. This conference will joint with the 7th National Conference on Computing and Information Technology (NCCIT 2011). There will be altogether approximately 300 audiences attending to the invited talks in this joint conference.

I would like to also invite you to consider preparing a paper, the same topic that you will give a talk at the conference, to publish in the proceedings as an invited author. The format of the paper can be formatted as you like; however, we would like to encourage you to prepare the same format as template attached herein. Please submit the paper at the earliest of your convenience date but should be not later than April 22, 2011, just before we will send the proceedings to the publisher. Please send the invited paper to pym@kmutnb.ac.th and cc: to pmeesad@gmail.com.

We would be very appreciated if you accept our invitation as both a keynote speaker and an invited author for IC2IT 2011. For this matter, KMUTNB will be responsible for your traveling cost and accommodations during your participating IC2IT in Bangkok.

We are looking forwards to seeing you in Bangkok at the conference.

Sincerely Yours,

Monchai Tiantong.

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Interference Networks as a Generalizing Signal Theory between Integral Transformations, Artificial Neural Nets, Optics and Acoustics

Abstract

Observing time domain properties (delays, excitement locations, time functions at locations, velocities) we find general communication principles of nerve networks. We will call the abstraction 'Wave Interference Network' (IN).

Signals on wires of IN have distributed, inherent delays. In absence of central clocks, all signals appear distributed. Every shift of information is binding to delays. The term 'interference' means a universal superimposition or interaction of mostly non-periodic, spiking and delayed time functions. In contrast to artificial neural nets (ANN), IN mirror the resulting maps in the same way as nerve nets do (somatotopy).

Analyzing the spherical flow of time functions in two or more dimensions, we find wave properties. IN create an abstract wave theory without materialistic background. Observing meeting places of waves and relating interference integrals, a special understanding of information theory can occur: the location of a circuit codes the behavior of a network. Comparing interference properties between mapping mechanisms, we find seeing and hearing as the same thing.

Analyzing self-interference properties (interference of a single wave), we find movement and zooming of maps. Observing cross-interference conditions relating to the pulse-pause, we find basic relations for the mapping of noises by contrast to visual mapping.

The lecture addresses questions of a general understanding of pictures of thought (imagination), visual maps, sound maps or movement maps in nerve systems in the same way, as it addresses technical applications (acoustics, Radar, Sonar, lens systems, feedback controls, GPS, cellular networks, convolution codes, integral transformations or digital filters).

One can guess the potential of nerve-like interference systems, remembering our whole signal theory consists on integral transformations (FFT, Convolution, Laplace, Hilbert, Wavelet etc.) with two time-functions, while one of 40 billion pyramidal neurons of the human brain has on average 7400 synapses.

Introduced as basic course lecture, the IN-approach creates a potential for education of students in different fields. It combines central parts of optics, neural nets, acoustics, filter theory, control theory, electron-physics, cellular automaton, integral transforms and neuroscience under the same roof of ideas.

CV

Born 1954 in southern East-Germany (GDR), Gerd Heinz got the first diploma for electronics-technology from Technical University Dresden in 1976. His industry carrier started 1976 at Institute for Telecommunication (INT) Berlin-Schoeneweide in a team realizing the first microprocessor system within East-Berlin, based on Intel's i8008. In 1978, he received a second, post-gradual diploma for microelectronics at TU Dresden.

With the design of the first integrated circuit (IC) in the Berlin territory, a PCM-regenerator with 120 transistors, he had 1979 first scientific success. 1980 he become group leader, and later department leader for full-custom design of integrated circuits for telecommunication. 1988 he received a doctorate in microelectronics from Humboldt-University Berlin about non-linear delay dynamics of digital gates.

In 1987 a call of the GDR-Academy of Sciences (AdW), Institute for Cybernetics and Information technology (ZKI) reached him. He founded a microelectronics design department at AdW-ZKI Berlin. 1990 his team worked in the field of fast data path architectures. He developed basic concepts for fast pipelining architectures basing on trees, today implemented in most modern microprocessors.

Extending artificial neural network theory by mirroring projections, since 1992 he works about interfering time functions in networks (Interference Networks, IN). With a first application of IN he got worldwide first acoustic images and movies between 1995 and 1996. With his GFaI-team he sold the first, produced "Acoustic Camera" 2001 to Porsche AG.

For inventions and findings he got different German awards: the "National Price Class 2" (GDR/1987), the "Otto von Guericke Price" (2001), the "Berlin/Brandenburg Innovation Price" (2003). His Acoustic-Camera team was nominated for the "German Future-Award" 2005 and he got the DVS-Abicor-Innovation Price 2008 for the first real-time, spectral welding system.

Find further details on the page http://www.gfai.de/~heinz.

Interference Networks as Generalizing Signal Theory

between Integral Transformations, Neural Nets, Optics, Electrics and Acoustics

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***Abstract* – In different technical fields, relative delays of signals define the function. In case of Radar, Sonar, GPS, digital filter, optics, earthquake prediction or nerve nets they play the main important rule. Trying to extract the main structural information of all these different techniques, most of them become decomposed into delays (edges) and operators (nodes). Binding nodes additional to spherical coordinates and suggesting, all information needs time to bridge spaces, and larger delays imply larger edges, resulting delay graphs get spherical properties. Time- and space-functions characterize the flow of information in such nets. They flow wave-like, giving specific possibilities for a better understanding of field properties. Integration about combination (sum, multiplication, fuzzy sum) of space functions at nodes, called 'interference integral', shows the relation between time-function and image – also optical images show interference integral properties. We will call the abstraction 'Interference Network (IN)'. Following this way, IN shows a physical connection between seeing and hearing, between time-function and image, independent of the physical substrate or delay space, that means acoustic, optic, ionic (nerve-like) or electric delaying spaces. The term 'interference networks' contributes the fact, that most of analysis in physics is done today with numeric discretisation.**

"Mathematics is an experimental science,
definitions do not come first, but later on."
Oliver Heaviside

I. Introduction

Thinking about Radar for cars, per coincidence I found 1992, that nerve nets project images like optical lens systems only *mirroring*. This was (sorry: is up to now) new in neuroscience, but predictable for engineers in optics, Sonar or Radar developments. The thumb-experiment [2] showed 1992 predictable wave-like nerve-properties. New applications were first acoustic images and films – not known in acoustics [16]. So what is the common knowledge between Radar, nerve net, and acoustics?

General ideas for IN were born in the years 1992/1993 as an attempt to understand something more about nerve networks [3]. The term 'Interference Networks' appeared later to set some boundaries to theories of 'Artificial Neural Networks (ANN)'. Find an introduction in [12].

Analyzing the flow of information in delaying systems, a common knowledge stands behind approaches using delays. Independent of the medium, in different fields we find comparable technologies for information processing:

- Acoustic imaging:
- Supersonic Arrays
- A, B, M – methods
- SONAR
- Electric field imaging and localization:
- Global Positioning System (GPS)
- RADAR
- Radio telescopie and –interferometrie:
- Superimposition of images - VLA
- Superimposition of time functions – SKA
- Optical projection systems
- Nerve nets (ionic conduction)
- EKG, EEG
- Artificial neural nets
- Integrated circuits
- Quantum mechanics

Most of the technologies use different 'languages', which means, each direction uses own codes and abbreviations. It is sometimes not easy to understand details. Some of the common technologies in all fields are integral-transformations, like

- Correlation
- Modulation
- Convolution
- Fourier-transformation
- Wavelet-transformation

If we think about common properties, it is to hope IN-abstraction can push the different directions, learning from the other. IN tries to appear as a common language, knowledge and simplest abstraction layer.

Sorted by task, we find applicable fields for IN:

- Spatial techniques
- Optical projections
- GPS
- Radio telescopie
- Radar
- Antenna construction
- Sonar
- Acoustic cameras
- Temporal tasks
- Digital filter
- Frequency maps
- Nyquist plots
- Coding tasks
- Neural nets
- Cell phones

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- Digital circuits
- State machines

The fields use common knowledge about differential equations, angular frequencies, complex numbers, time functions, wavelengths, velocities, and delays. However, the specific knowledge in the fields is very different and complex.

Periodic waves occupy nearly all approaches, suggesting *waves are always periodic*. For example, the *wave* and the *wave function* in Wikipedia [10] define *periodic* wave functions using *complex numbers* and *angular frequencies*. Non-periodic character of IN approach shows, this is definitely not true. In describe non-periodic or periodic waves.

The document shows, that *non-periodic* 'time-function waves' exist in time domain. They have interesting properties, for example to understand nerve nets or to reach ultra-high speeds in integrated circuit design. *Waves* appear as a generalizing term including *non-periodic* and *periodic* case, although the paper is to focus exclusively on properties of non-periodic waves.

Analyzing the probable location of a signal, IN suggest 'waves of information distribution'. A concept for wave visualization gives the chance to understand interference systems of any kind clearer. Integration over wave fields in time produces locations for valid signal conjunctions, and in an optical association the term 'image'. We find a concept of synchronization without clocks in nerve nets.

The lecture will be the first attempt, to start a cautious, formal characterization of IN.

II. SYNCROTOPIC CAUSALITY

Calculating Boolean functions with Karnaugh-maps, nobody would think about time relations. We consider, the signals 'are infinitely long'. However, in real world, all reasons have a live time; reasons have to occur exactly *in the right time at the right place* relative to the other to guarantee any function or malfunction of anything.

Arthur Schopenhauer introduced the term 'causality' [1] in a meaning of sequential delay chains: any cause B follows on a reason A, or A causes B.

Figure 1. Synchrotopy - crash between an airplane and a helicopter. Devices have to be at the same time at the same place to cause a crash [9].

Enhancing Schopenhauer's definition [1], engineers use the term 'causality' for synchronous mechanisms with more inputs too; for example: synchronizing clock and data at a latch, a crash between helicopter and airplane (Fig.1) or a modulation between two time-functions.

The airplane-helicopter crash shows the central idea of interference nets: If information has a short wavelength (length of the devices) a causal event (crash) is only possible with very precise timing.

For correct work of causal mechanisms, delays and synchronization have the main impact. Correct combination of information needs a correct timing of all respective inputs relative to the other. If signals in a circuit come too early or too late, the circuit would not work: If I reach the station too late, I will miss the train. To reach the destination, we need synchronism between events at the same time and location: for example between the 'train' and 'me'.

Thinking about a precise word for causality in time and location it is possible to combine words with Greek language portions: *together* (syn-), *time* (chronos) and *location* (topos) to the new word '*synchrotopy*'. Interference nets describe *synchrotopic circuits*. This has not so much to do with clocks, rather we have to talk about *relative* flow of information and about relative delayed signals.

III. DISTANCE MEASURES

Every physical signal or information needs time to bridge spaces. *Every physical time function appears delayed at a destination, which has a different location*. As longer is the distance, as longer is the partial signal delay. The interference net (IN) approach has only on rule: Propagation of signals with zero delays between any distances in space is not allowed. *Every distance and the corresponding delay produces an delay between two nodes* of the IN.

To analyze time-functions in one or more space dimensions, we calculate the geometrical shift of the time-function by delay for each pixel (voxel) in space.

Different applications have different measures for distance r and delay τ, combined over velocity v:

a) Nerve nets show inhomogeneous delay structure relating to the thickness and length of the wires (axons or dendrites). Modeling the fine-structure needs detailed delay graphs for each connection, consisting of processing nodes and delaying edges. On larger scales, Euclidian space seems to be applicable.

b) Large, digital, integrated circuits (IC) have a orthogonal wiring in x- and y-direction, sometimes called Manhattan-style [13]. Distance r between any two points in orthogonal connected space is for the most integrated circuits the sum of absolute values in x- and y-direction, see for example [4] 'Bild 2c',

(1) $$\|r\| = \tfrac{1}{v}\left(|x - x_0| + |y - y_0|\right).$$

c) Radar, GPS, Sonar, optics or acoustic applications often address a linear, Euclidian distance measure. The delay τ for each voxel in space or pixel on area can be computed dependent of distance *r* in the well known form

$$\|r\| = \tfrac{1}{v}\sqrt{(x-x_0)^2 + (y-y_0)^2 + (z-z_0)^2}\,. \quad (2)$$

In binary-clocked, routing networks, also the Hamming-distance can play a rule for distance measures, [13].

IV. Unit System

Because of the physical background, the use of physical time-functions is necessary, that means systems between distance, velocity, time or frequency and delay. It is supposed and further not noted, that each task starts with initial scaling of time-functions to a physical system of units. Application of matrix and vector notations is only used at any second level of information processing. We prefer one-dimensional time-functions as vectors (matrices of format *(1, n)* or *(n,1)*) with unique time scale, which means, with identical sampling rates.

V. Wave Measures

Any duration of validity of a signal in relation to the net geometry or size has higher importance, as higher are the data rates related to transmission velocity. Thinking about very high data rates on large networks, any synchronisation becomes more and more difficult. Suggesting a delaying space, the system size, velocity, and maximum data rate correspond, using the term 'wave-length', known from electronics.

The **geometrical wave distance** Λ for a signal data rate *f* with velocity *v* corresponding to duration T is

$$\Lambda = vT = v/f \quad (3)$$

The interval of signal presence – the **geometrical wave length** - is the length λ of a wave, relating to velocity *v* and interval τ of signal validity

$$\lambda = v\tau \quad (4)$$

Examples:

Connecting some ATM-signals running with f = 155 Mbit/s on wires with velocity $1/v$ = 10 ns/m on coax cable, the possible interval of signal validity is of interest. For a 1:1 signal/pause ratio we get $\lambda = v/2f$ = 30 cm.

Inspecting nerve dendrites with v = 3 m/s and a pulse width of 0.1 ms generates geometrical pulse length $\lambda = v\tau$ = 3 m/s · 0.1 ms = 0.3 mm.

VI. Time- Function and Space-Function

Using the term 'time-function', we talk in interference nets about two very different thinks: about *time-functions* or about *space functions*. Using for example a term *f(vt-r)*, we have the possibility, to run *r* or *vt* as parameter on the horizontal axis.

Independent of the space measure norm, we prefer functions that move in space with constant velocity *v*. Any time-function can have an initial delay (pre- or post-delay) of *T*, which means, it can come into a field pre- or post-delayed dependent of the signs. In detail, we get for 3-dimensional spaces following forms.

a) **Time-function** visualization: Distance *r* is a constant, *f(t,r) = f(t)*, running parameter is *t*. The interest concerns on a time-function at a location or node. We get oscillographic functions dependent of parameter *t* (time for horizontal axis of plots) for a single location (x_o, y_o, z_o).

$$f(t) = f\left(\tfrac{x_0}{v}, \tfrac{y_0}{v}, \tfrac{z_0}{v}, t, T_0\right). \quad (5)$$

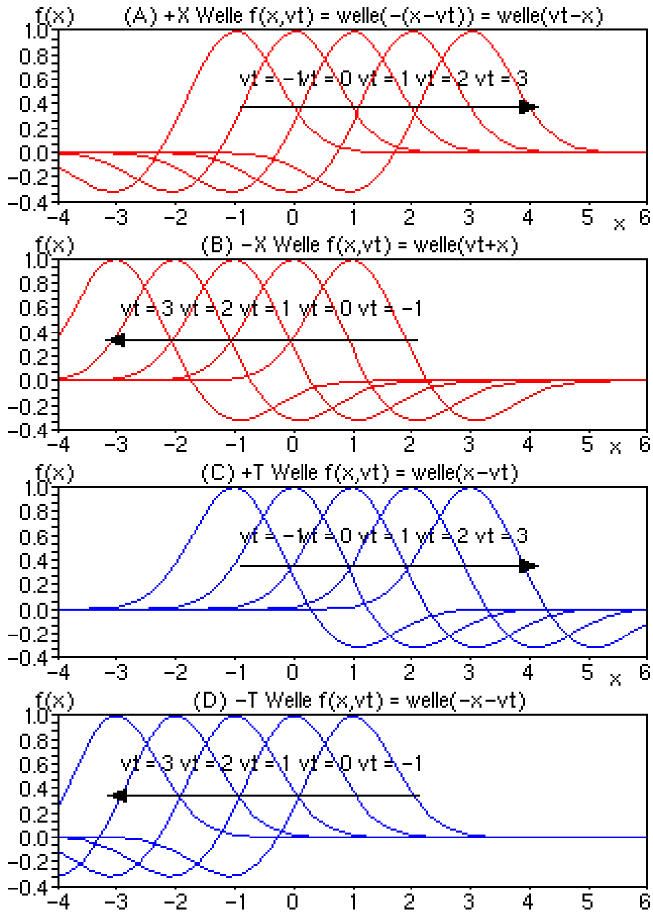

Figure 2. One-dimensional location functions, see the Scilab-source in homepage [4], image 'Bild 1'. Two parameters, *vt* and *x*, create four schemes A…D. Cases A and B show waves with tail at the end, C and D shows waves with tail in front.

b) **Space-function** visualization: time *t* is constant, *f(t,r) = f(r)*, running parameter is *r*. The interest is to follow the flow of information thru a network. We prefer subsequent images (movies) dependent of location parameters (x,y,z) or distance measures r, where the time parameter vt_i runs with the image number i.

$$(6) \qquad f(x,y,z) = f(x,y,z,vt_i,vT_0).$$

In the first case, f has time measure, in the second case, f has geometric measure. Index zero concerns a fixed value; without any index, the running parameter is concerned.

VII. Discretization Between Time and Space

Inspecting a time-function flowing over a certain location (x_o,y_o,z_o) in space, the measure between steps vt (geometric measure) is different to the grid of the space. For accurate calculation it is possible to use interpolation functions (splines) between incoming time-function values to ensure proper discretisation. Without interpolation, wave field images can get edges in colour mappings.

In signal processing it is common use, to define operations on discrete time-series. Because of the grid differences in space and time, for interference networks it is of high importance, to work with classical time function properties and with physical measures.

VIII. Visualization of Signal Propagation

In *one-dimensional case* it is common, to plot subsequent space-functions, each with the next time shift vt, compare with [4], Scilab-source behind movie 'Bild 1'. To generate a 'still' movie as figure, it is also common, to draw images with parametric values vt, in a style comparable to Fig.2.

Visualization in *higher dimensional space* with some more waves needs a different approach. It appeared to be the best practice, to add all waves in a field *for each location separately* (net node, pixel, voxel). The sum changes the colour value relative with the value, Fig.3, a…c. Examples with Scilab- source code behind movies or images can be found again on the web, see [4]. Visualization of ***waves*** at time point t and at location (x,y,z) is

$$(7) \qquad f(x,y,z,t) = \sum_{j=1}^{m} w_j(v_j t - r_j),$$

where j is the time-function number index, w_j is the incoming time function, v_j is the velocity of the time function and r_j is the distance to the source point of the wave j, see Fig.3, a…c. $f(x,y,z)$ is the resulting time function to plot at point (x,y,z).

For any network- operation at any node – that can be again a sum, a product, a difference, a quotient, a fuzzy sum or something else between incoming time-functions, we construct by analogy a term for the ***operation*** Ψ of the node. Again m is the number of time functions (channels). The resulting function g at node (x,y,z) becomes

$$(8) \qquad g(x,y,z,t) = \mathop{\Psi}_{j=1}^{m} w_j(v_j t - r_j).$$

For operations, products or sums have high importance.

Fig. 3d) shows for example behind waves (a…c) the result of a product-Ψ-operation, a product between three waves exactly at the time point, the three waves (range between 0 and 1) meet. Before and after meeting of waves, the product field is zero. Only at the time point, and at the location, the waves meet, the product is different from zero. However, how is it possible to conserve this short moment into an image?

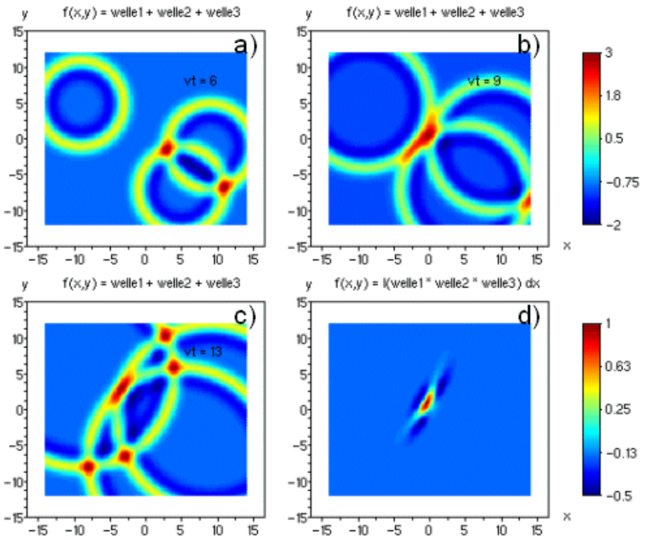

Figure 3. a) to c): Space-function waves in two dimensions with Euclidian distance, d) corresponding. Ψ-operation as multiplicative interference integral.

IX. Interference Integrals

Nerve neurons act like pulse generators. If any Ψ-operation produces any value above a limit, the respective neuron (node) gives a short pulse.

In technical applications, the result of a wave collision ('interference') is to conserve for satisfactory time to produce an 'integral image'. A summation (integration) of all values at each node (different from zero) is a first solution. Any interference integration can in the simplest case be written as **moving average** filter over $g(t)$ at location (x,y,z)

$$(9) \qquad Y(x,y,z) = \tfrac{1}{n}\sum_{i=1}^{n} g(x,y,z,t_i).$$

If time points on $g(t)$ are infinite dense, or if we have a 'analytical' time function for $g(t)$, we define the **interference integral** Y over $g(t)$ as

$$(10) \qquad Y(x,y,z) = \int_{-\infty}^{\infty} g(x,y,z,t)\,dt\,.$$

Variables (x,y,z) mark the concerning node, pixel or voxel in space.

Nevertheless, the way to calculate interference integration can be different. If we use for example as Ψ-operator a sum, (case of the 'Acoustic Camera' [5]), the operator- and wave fields are identical. Remembering, addition of time functions produces a new time function *g(t)*, it is convenient, to store the resulting time function *g(t)* for each node. Reasoned by wave addition for operation in case of acoustic images, the space-function wave field *f* is identical to the operational wave field *g* of the node. Here the **effective value** shows for example the noise image *Y*,

$$(11) \qquad Y(x,y,z) = \frac{1}{T}\int_{0}^{T} \sqrt{g(x,y,z,t)^2}\,dt\,.$$

A mouse-shift onto any pixel (node) in the resulting field plays the time function *g(t)* of the pixel (they can be different) [6]. This way, we can listen into the interference integral image to get a better understanding for noises behind coloured emissions.

What we name colloquial with the term 'image' (optical lens image, acoustic image) appears in theory as interference integral of waves, unconcerned, if the nature of waves is periodic (optical case) or non-periodic (nerve nets).

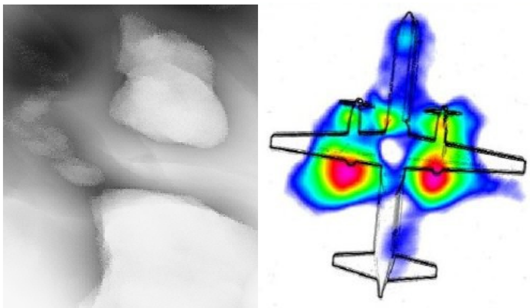

Figure 4. Interference integrals (reconstruction of generator spaces): left) 30-channel electrocorticogram (ECoG) [19]; right) 30-channel acoustic image of a landing turbo-prop airplane [18].

X. Types of Interference

If the data rate within a field carrying many signals, becomes too high, or if the pulse length becomes too wide, or if an average fire rate in a net becomes too high, the probability increases, that independent waves of different sources reach per coincidence any receiver just at the same time. In acoustic imaging, the behaviour is known as 'aliasing', in microscopy we talk about 'diffraction rings'.

Central problem is the possibility, that waves of different origin or of different index reach at the same time the same location. It needs no imagination, that the signal density, the quotient between length of the valid signal and length of the whole wave has substantial importance. Usage of *periodic signals* (light, sound) produces the most problems to avoid aliasing or cross interferences.

If we suppose, any time-function of a signal can be constructed of a sum of separate waves of identical index *n*, shifted by delays τ and *T*,

$$(12) \qquad f(t) = \sum_{0}^{n} f(t - T_n - \tau_n)$$

(compare to [4], source code of 'Bild 2a'), where *n* is the number of waves in the signal, *T* is any pre-delay and τ associates the distance from the source.

We subdivide into three groups.

(a) If waves of identical index *n* meet everywhere in the field, we call it *'self interference'*. The term associates properties of optical projections and images.

(b) If waves of different index *n* – but from an identical source - meet, we talk about *'auto interference'*, associating the auto-correlation of signals.

(c) If waves of different sources meet, we call it *'cross-interference'*, associating the cross-correlation of signals or the aliasing within images.

The division is of some importance, because any kind of non-periodic and some kind of periodic signal-processing is addressed.

Optical images, produced by lens systems, are projections in self-interference. With delay-inversion and resulting map-inversion, the image reconstruction of acoustic cameras is in self-interference too.

Auto-interference characterizes the large field of signal processing between frequency-filters and linear feedback shift registers (LFSR). LFSR symbolize the idea: One signal runs in a circle, and is combined with delayed parts of it.

Last not least cross interferences play mostly the negative rule – cross interference is not desired in every kind of imaging technology. But in nerve nets, it can play the important rule for hearing and association.

XI. Convolution and Integral Transformation

Missing a better term, in [3] appeared the term interference-convolution (Interferenzfaltung). Teuvo Kohonen, a well-known neuro-scientist, did not agree with this term for calculation of wave-fields. He asked 1995 "Is this really a convolution?" So let us discuss the features of interference nets to realize known convolutions

$$(13) \quad y = x * h = \int_{-\infty}^{\infty} x(\tau)\, h(t-\tau)\; d\tau .$$

The output sequence is y, input sequence is x and the impulse-response is h. Using a discrete, finite form, the Cauchy product of two sequences

$$(14) \quad y_n = x(n) * h(n) = \sum_{k=0}^{n} x(k) h(n-k) ,$$

a time-series of a 'wave' x is running over a barrier h, while an addition of all combinations for each n is necessary. Subdividing into a possible sequence shows series in form

$$(15) \quad y(n) = x(0)h(n) + x(1)h(n-1) + \ldots + x(n)h(0)$$
$$(16) \quad y(n+1) = x(0)h(n+1) + x(1)h(n) + \ldots + x(n)h(1)$$
$$(17) \quad y(n+2) = x(0)h(n+2) + x(1)h(n+1) + \ldots + x(n)h(2)$$

For each y the x-series is multiplied inverse with the h-series. If x and h or k and n differ in size, we fill zeros. The realization is known as 'finite impulse response' (FIR) filter, where x is the input series, h are the coefficients and y is the output series.

Reordering the set of equations by shifting each raw one position more to the left gives

$$(18) \quad y(n) = x(0)h(n) + x(1)h(n-1) + \ldots + x(n)h(0)$$
$$(19) \quad y(n+1) = x(1)h(n) + x(2)h(n-1) + \ldots + x(n+1)h(0)$$
$$(20) \quad y(n+2) = x(2)h(n) + x(3)h(n-1) + \ldots + x(n+2)h(0).$$

We find time index movement of x and y in the same direction, while the 'barrier' coefficients h stand still. The direct IN-realization of convolution is a digital 'finite impulse response' (FIR) filter of infinite length.

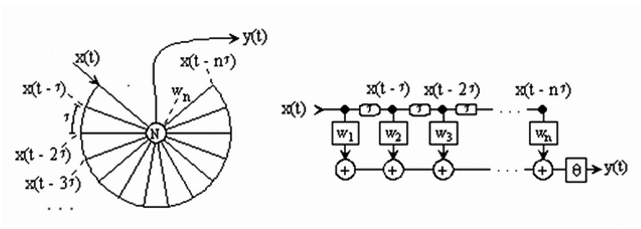

Figure 5. Convolution in nerve-like properties. Classical FIR (right) and IN drawing of FIR (left). It is not allowed, to give information infinite fast from one node to the other. Output $y(t)$ uses a single node. By analogy to neural circuits, here the pulse-response h was drawn as weight w_n [3]. The IN-circuit associates a pyramidal-neuron.

The disadvantage of classical FIR realisation for IN approaches is, that all $y(n)$ need to have the same time slot, thus all summations have to be done within one node at a single location. To find an IN-realization without zero delays one edges the node of y has to fill a single location. Arrangements Fig.5 and Fig.6 do not violate the IN-rule of finite velocity between nodes, source [3].

Some words about Fig.5: While the input series run along the circumference, the output is central. Dependent of the application, any code, which meets the weights w_n at the neuron N produces an output different to zero. The delays between circle and centre are equal and have only the influence; the output comes by that delay later. The pro of this IN-like realization is, that it uses no hidden delays. Known from design of microcontroller design, hidden delays include bottlenecks, if operations (addition, multiplication…) have to be done without enough time.

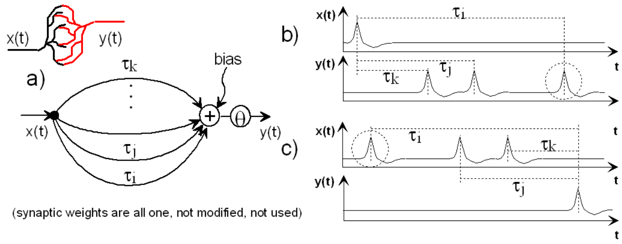

Figure 6. Second IN-realization of a convolution in nerve-like properties, source [3]. The delay chain appears subdivided into a series of separate delays.

Fig.6, source [3], shows a second realization. The idea is to split the delay-series within the input into different, separate delays, each carrying and delaying the input-function by a increasing delay

$$(21) \quad \tau_1 = \tau$$
$$(22) \quad \tau_2 = \tau + \tau$$
$$(23) \quad \tau_3 = \tau + \tau + \tau$$

… … …

$$(24) \quad \tau_n = n\ \tau$$

The function is identical to classic convolution. The network in this form seems to be predestined to generate and detect bursts, we find everywhere in nerve system. Bursta seem to act like codes, which can be transferred over single wires without any interference projection. This seems to be important, if code is to send over single, long wires to the extremities.

Although not proven, we find in nerve nets different possibilities for such arrangements. The hope is that a neuro-scientist anytime can verify such a circuit.

Coming back to Kohonen's question: "Is this really a convolution?" now we can answer: Yes and no. We find convolution cicuits, but the wave mechanism is different. And verification in nerve system has to be done.

Following the way of convolution, we can construct interference nets for other *integral transformations*, avoiding edges with zero delays between nodes.

XII. Delay Vector, Mask

Any spatial arrangement between nodes produces delays between nodes. If any node has n neighbours, a group of n delays τ_i characterize the delays at the node. Using a column vector T, we get

$$(25) \quad T = [\tau_1, \tau_2 \ldots \tau_n].$$

The mask is e central idea in different fields to compensate delays. In case of the Acoustic Camera [6] the mask is used to compensate for each pixel (2D-version) or voxel (3D-version) the delay to the corresponding microphone [6].

Example: Point S in Fig.7 has two delays to the next nodes, the delay vector *T* of *S* has two elements, *T = (SA, SA')*.

XIII. PROJECTING CIRCUITS

The main idea of IN concerns the calculation of physical projections. Known from optical lens systems, physical projections mirror the images or maps between input and output.

Parallel to the 1993 paper of Konishi [11] "Noise location of the barn owl", the title page of [3] (1993 again) showed an IN for a nerve-like projecting circuit, Fig.7. Signal delays basing on finite velocities supposed, the edges have delays proportional to the length of edges.

The function is as follows. Any receiving node *M* multiplies the incoming time functions. While time-functions have a value-range between zero and one, excitement of M appears only, if signals come 'synchrotop'. If a sender *S* submits a time-limited signal (pulse) with short wave length, the contra-lateral receiver gets the two partial waves, going over *A* respective *A*', parallel at the same time. Thus, any information flow in this network is only possible between contra lateral senders and receivers.

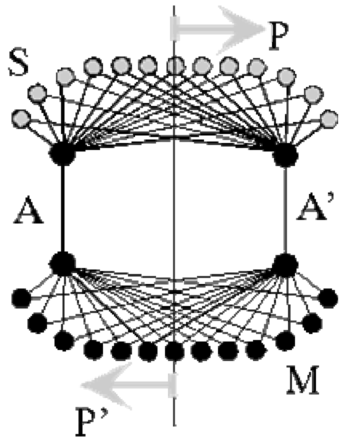

Figure 7. Simplest projecting network, title page of [3]. The net mirrors a vector or map *P* of the input into a vector or map *P*' at the output.

Any map *P* projects a mirroring map *P*' to the other side. Using different velocities, sizes and wavelengths, it is possible to study the circuit properties with nerve-like parameters, using the IN-approach. The circuit gives a first idea about signal addressing in systems without clock.

In abstract speaking, point *M* is *synchrotop* to point *S*. Map *P* is *synchrotop* to the mirroring map *P'* in case of error-free projection.

- *Self-Interference Properties*

Is the sum of delays Δ (scalar number) between synchrotopical points on a single path and together the time-difference between begin and end of propagation,

$$\Delta = \sum_{i=1}^{k} \tau_i \tag{26}$$

and is *j* the number of all interesting paths for a self-interference projection, the delays of all paths have to be equal

$$\Delta = \Delta_1 = \Delta_2 = \ldots = \Delta_j \, . \tag{27}$$

Using delay vectors, the well-ordered sum of delay vectors between synchrotopical nodes is the delay Δ (scalar)

$$\Delta = [1,1,\ldots 1] \cdot \sum_{p=1}^{q} T_p \, . \tag{28}$$

The raw-vector of ones has the size of column vector *T*. This projection law is valid only for self-interference. Additional pre-delays change everything.

Examples: Circuit Fig.7 dissociates in three delay vectors: for the transmitting field (top), the carrier field (middle) and the receiving field (bottom); q = 3; vector-size is two. Clocked latch: Without malfunction, it is possible to include equal delays into wires for clock and data-input.

- *Auto-Interference Properties*

A wave series of a single time-function maps onto a single point, if additional delay paths exist, having time-differences corresponding to frequencies or codes. We will call it 'auto-interference' projections. Any frequency is detectable at a single location by a delay difference Δ between adjacent nodes

$$\Delta = 1/f = \left|\tau_1 - \tau_2\right| . \tag{29}$$

Any code is detectable using convolution circuits, see Fig.5. Find more in [12].

- *Cross-Interference Properties*

Cross interference appears between different channels and different wave indices in different forms. In acoustics, we talk about 'side lobes', in nerve system about 'pain' or 'confusion'. Find a simulation of cross-interference overflow dependent of average pulse-distance here [17].

- *Reconstruction and Projection*

Using channel data, we have two possibilities: To reconstruct the sources of generator space (any natural data, Acoustic Camera, ECoG), or to project into the receiver space, validity examination (next). The numeric calculation does not generally change, but the delays have opposite signs. In case of computer reconstructions we use *negative delays* corresponding to $f(x/v + \tau)$.

XIV. OVER-CONDITIONED SYSTEMS

Using many more then two edges *A*, *A'* for the connection within self-interfering fields (case of lens systems in optics) we get additional space conditions for the sums of distances. It is no longer possible to find conditioned solutions in the whole space. In optics, we get axial-near sharpness. For the case of nerve nets, we need additional inhomogeneities in distance measures. For example, using three channels in a two dimensional field, three waves produce a single interference location. Using four channels, we need a three dimensional space. Using *n* channels, we need a space dimension of *n-1*, to have the chance to propagate all waves to a single point. If the space dimension is *d*, and the channel number is *n*, to avoid over-conditioning in homogeneous space we find

(30) $d = n + 1$.

To overcome the restriction, the main idea for the Acoustic Camera with 32 channels in 3-dimensional space was 1993, to use negative delays for an exact compensation of all delays of the acoustic space [6] between each microphone and each reconstructable node (pixel/voxel).

Is following the nerve system limited to 4 channels (3-dimensional)? Supposing, nerve system uses sometimes more then four channels (three dimensions) for a self-interference projection, for example, we think about *n* channels. How to use n-channels to make clear projections in 3-dimensional space? With axial-near sharpness, like optics? Thinkable. But nerve net has a second possibility. It can increase the space dimension to (*d-1*). This idea seems to be crazy for the first moment. But looking through a microscope, we find a network, that is filled with loops and meshes over and over. We find a very inhomogeneous micro-structure, far away from Euclidian norm.

XV. Movement and Zoom

What happens, if a *pre-delay* on a wave source point delays the incoming wave? The waves from opposite directions will meet at a different location, the point of interference will shift to the delayed source point, compare to animation 'Bild 3b', [4]. Therefore, interference integrals shift also to this location. We call the effect 'Movement', compare to [14].

In the case, we modify the *field velocity*, by holding all other conditions constant, the points of wave interference - the interference integral shifts as well, but in different manner. The interference integral image begins to zoom like a zoom-camera, compare to [15].

XVI. Example: Waves of Signal Integrity

To make things transparent, let us analyse a race condition in integrated circuit design, comparable to [4], movie 'Bild 2c'. The Scilab source code is behind the image.

Forcing high communication rates in integrated circuit design, many signals have a limited duration of validity (validity interval). For a correct function of each signal conjunction (AND, OR, EXOR, SUM etc.) the signal duration of stable inputs has to overlap (cover) the possible variance of input delays.

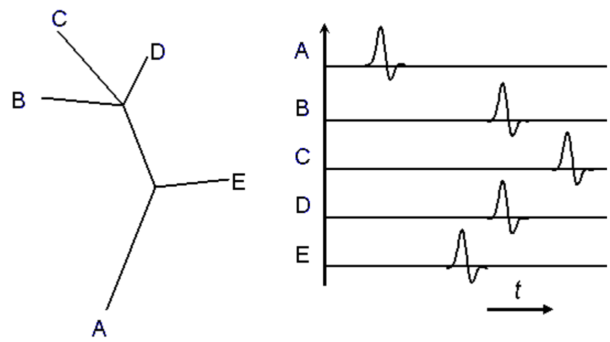

Figure 8. Supposing finite velocities, in every physical network or circuit (electric, ionic, optical, acoustic, sonar) the connection scheme (left) produces a *dependent* timing- or delay- scheme (right)

We have to deal more and more with signals that come too early or too late. In integrated circuit design, larger circuits produce more 'timing problems'. However, the circuit designer receives the function (connection scheme) and the timing scheme in separate specifications. He has to achieve both specifications, unable to know exactly, how.

To generate a rectangular space-function, we use a Scilab 'function definition'. Instead of Gaussian, we can also define a rectangular wave function removing the slashes.

```
deff('y=welle(u)','if u<0 | u>3 y=0; else y=1; end')
```

The function returns a single number, if it is called with a single number. To produce a wave-function, the time-function *f(t-x/v)* moves in geometry-domain in the form *g(vt-x)*

```
welle1 = welle(vt - sqrt((x-x1)^2 + (y-y1)^2)).
```

Input is the time parameter *t*, multiplied with the field velocity *v* to a location parameter *vt*. Output is *welle1*. The function definition of *welle* comes into process. Inputs *x1* and *y1* are the entry-points of the wave. The wave function runs within a three-level loop from inside to outside in *x*, *y* and *vt*. Finishing slopes *x* and *y*, a single image is finished, and the value counter for *vt* increments.

Calculation of waves and I^2 uses in this example a pixel-oriented form. Because we like to have all waves on the same field, we add the single parts

```
f(ix,iy) = welle1 + welle2 + welle3.
```

Matrix *f(ix,iy)* has the size of the image field. Calculation of the operator space uses a multiplication for every single pixel

```
i(ix,iy) = welle1 * welle2 * welle3.
```

To get the interference integral (the image), integration uses a summation. Initial value of matrix *g* is zero

```
g = i + g;    h = g .* dx.
```

Vector *h* avoids destruction of *g*. The program plots a series of wave images and as the last image the interference integral.

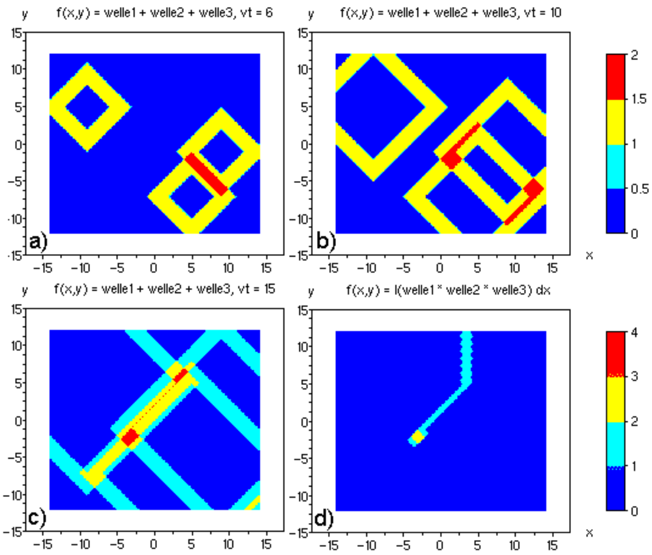

Figure 9. Orthogonal wiring of an IC produces diagonal validity waves a)…c). Three signals with limited validity time (bright) come into the field. To find a place for a correct conjunction of all three, the maximum of the interference integral d) shows a single location for a correct conjunction location, Scilab-source and wave field movie see [4].

XVII. Summary

A network class, consisting of operational nodes and delaying edges, called ‘interference networks’, shows ‘waves of information’. Introducing space-functions in more then one dimension shows the possibility to analyze periodic and non-periodic wave fields of signals. The wave field calculus uses an addition of the space functions for each node. Parallel to the wave field the operations field (Ψ-field) gives the possibility to find wave collisions. Integration over the operations field produces the so called ‘interference integral’, colloquial named as ‘image’. The interference integral and its inverse gives the chance to construct images from time-functions (acoustic camera) or to produce time functions from images. So it predicts the unity of ‘to see’ and ‘to hear’ for nerve system. The work shows that coupling of theories of wave fields to periodic functions is confusing [10]. The background of interference network theory shows, how to deal with non-periodic waves too. Because it makes no difference between periodic or non-periodic time functions, it appears as a generalization for many wave field approaches.

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