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Introduction to Interference Systems

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Motivation:

Mathematical and physical 'projectivity' as relation between two sets of values:

Mathematical (sets, weights, coefficients)

(1) $P \Rightarrow P'$

(2) if $P = \{p_1, p_2, \dots, p_n\}$ and $P' = \{p'_1, p'_2, \dots, p'_n\}$

(3) then $p_i \Rightarrow p'_i$ (non-mirrored)

Physical (waves, delays, spaces)

(4) $P \Rightarrow P'$

(5) if $P = \{p_1, p_2, \dots, p_n\}$ and $P' = \{p'_1, p'_2, \dots, p'_n\}$

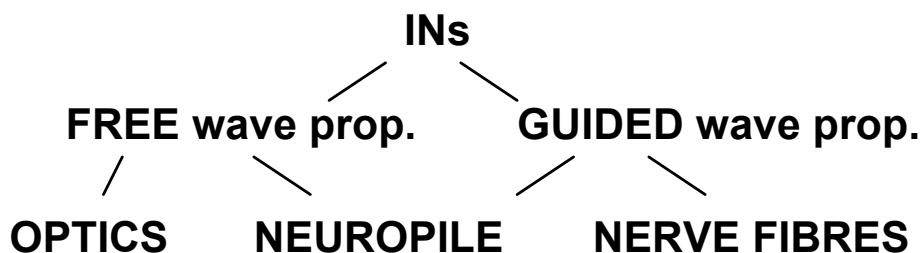
(6) then $p_i \Rightarrow p'_{n-i}$ (mirrored!!!)

-> Example NN <-> IN

What is an 'Interference Network' (IN)?

- ◆ Short connectable everywhere (neuro-pile)
- ◆ Homogeneous/Inhomogeneous (free/guided wave prop.)
- ◆ Wave propagation tied to bundles of wires
- ◆ Wired net in space and time dimensions
- ◆ Processing units (neuron) have places in 3D-space
- ◆ Wires have co-ordinates in 3D-space
- ◆ Signals bridges distances with delays
- ◆ Wiring delays are mostly length to width proportional
- ◆ Wires can have different velocity classes (colours)
- ◆ Neurons compute signals *in time and in space*

Types:



Fields of IN-Research

- ◆ Data addressing principles:
 - Spatial correspondence between generator and detector fields
 - Who addresses whom?
- ◆ Data processing principles:
 - Temporal correspondence and frequency/code selectivity of arrangements
 - On which event (time function) occurs which reaction?
- ◆ Eigeninterference properties (spatial projectivity)
 - Parameter influence
 - How to create a projection?
- ◆ Crossinterference properties (temporal selectivity)
 - Parameter influence
 - How to create a behaviour?
- ◆ Relations between net geometry, time-functions and behaviour in general
- ◆ Interference learning and selforganization

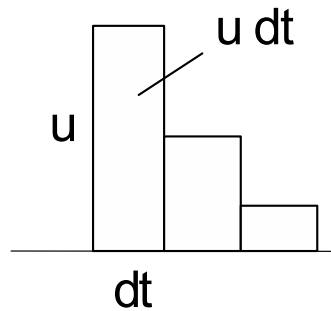
Excitability in Space and Time, Effective Value

Effective value of a signal

$$(7) \quad u_{eff} = \sqrt{\frac{1}{T} \int_{-T/2}^{T/2} u^2(t) dt}$$

$$(8) \quad u_{eff}^2 = \frac{1}{N dt} \sum_{n=1}^N u^2(n dt) dt$$

$$(9) \quad u_{eff} = \sqrt{\frac{1}{N} \sum_{n=1}^N u^2(n dt)}$$



Effective Value between two Waves

Example:

pulse from left ---> {

1	2	3	4	5
---	---	---	---	---

 } <--- pulse from right
(each pulse one unit high and one unit long)

a) Two pulses at locations 2 and 4:

$$(10) \quad u(t) = \{0; 1; 0; 1; 0\}$$

$$(11) \quad u_{eff}(t) = \text{SQRT}\{(0+1^2+0+1^2+0)/5\} = 0,63$$

a) They meet at location 3:

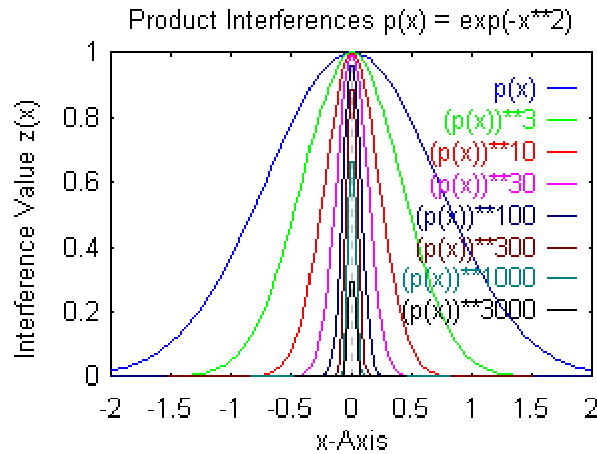
$$(12) \quad u(t) = \{0; 0; 1+1; 0; 0\}$$

$$(13) \quad u_{eff}(t) = \text{SQRT}\{(0+0+2^2+0+0)/5\} = 0,89$$

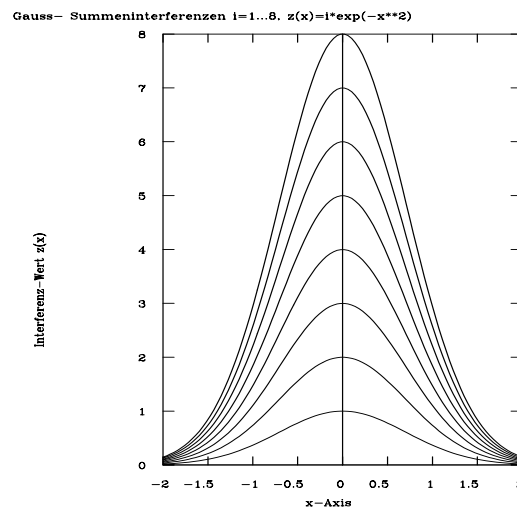
The closer the time correlation of time functions is, the higher is the effective value at the location.

Superimposition Type and Spatial Selectivity

Non-linear (exp):



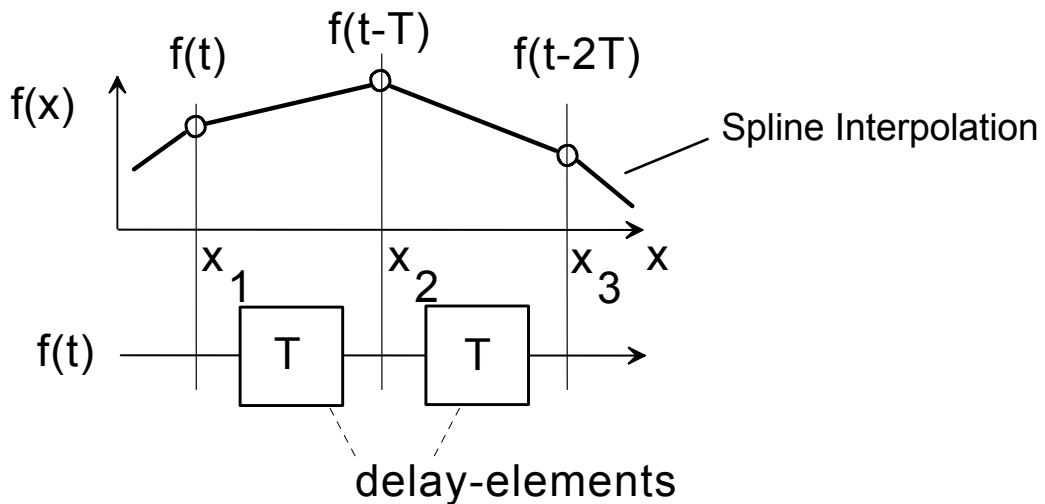
Additive:



- ◆ *non-linear superimposition* reduces the excitement region, increases spatial selectivity
- ◆ *linear superimposition* reproduces the excitement location independent of the number of interfering signals
- ◆ Purkinje cell: ...80.000 synapses, non-linear

Wave Field of a (Mathematical) Procedure

- ◆ Time functions $f(t)$, location functions $f(x)$
- ◆ Delay elements T , nodes x



Time functions for locations x_1 to x_3 :

$$(14) \quad x_1: \quad f(x_1, t) = f(t)$$

$$(15) \quad x_2: \quad f(x_2, t) = f(t-T)$$

$$(16) \quad x_3: \quad f(x_3, t) = f(t-2T)$$

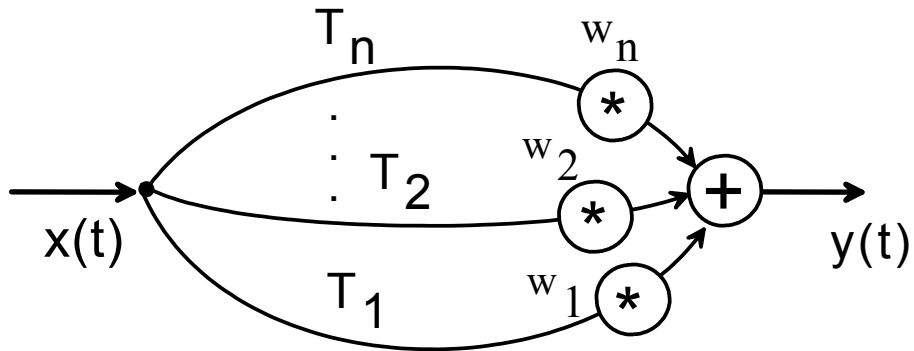
- ◆ Continuous wave field suggestion connecting the nodes
- ◆ Space-time function set is called *discrete wave field*

Examples:

- One-dimensional wave field: FIR-filter
- Two-dimensional wave field: array multiplier

Temporal: Frequency Filter

Simplest Interference Network:



Resulting time function

$$(17) \quad y(t) = w_1 x(t-T_1) + w_2 x(t-T_2) \dots w_n x(t-T_n)$$

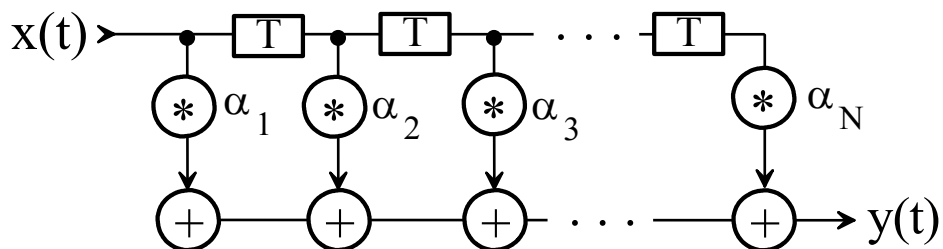
Frequency response

$$(18) \quad A(p) = \frac{L\{y(t)\}}{L\{x(t)\}}, \quad a(t) = L^{-1}\{A(p)\} \quad (L: \text{Laplace Transf.})$$

$T_n = nT$:

$$(19) \quad y(t) = w_1 x(t-T) + w_2 x(t-2T) \dots w_n x(t-nT)$$

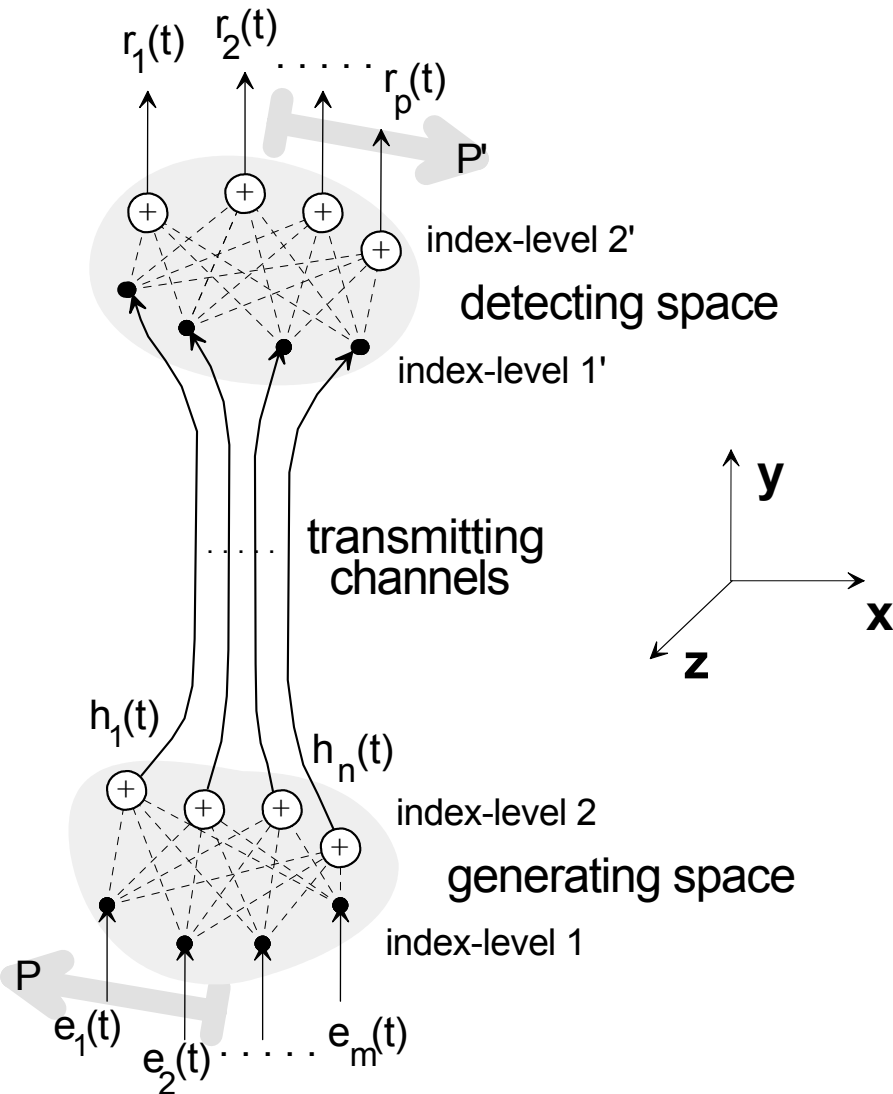
$$(20) \quad y(t) = \sum_{i=1}^n w_i x(t-T_i)$$



-> This is a Finite Impulse Response Filter (FIR)!

Spatial: Projective Network

Combination of two layers of simple INs:

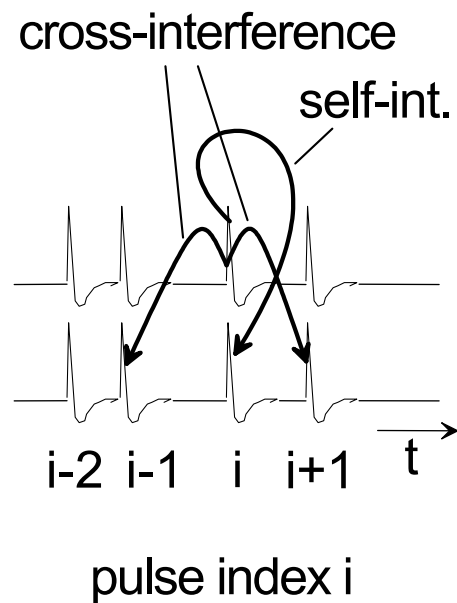


$$(21) \quad h_i(t) = e_1(t-T_{1i}) + e_2(t-T_{2i}) + \dots + e_m(t-T_{mi}) \dots$$

$$(22) \quad r_1(t) = h_1(t-T_{1l}) + h_2(t-T_{2l}) + \dots + h_n(t-T_{nl}) \dots$$

-> called *H-Interference Transformation (HIT)*; Heinz 1994

Self- and Cross-Interference



- ◆ *Self interference* characterises the ability of *location-transformations*
- ◆ while *cross interference* characterises the *spectral, code-, or frequency content* of a signal set

Signal Type Dependence

- ◆ Sinoidal: maximum cross interference
- ◆ Pulse-like: cleanest self interference projections

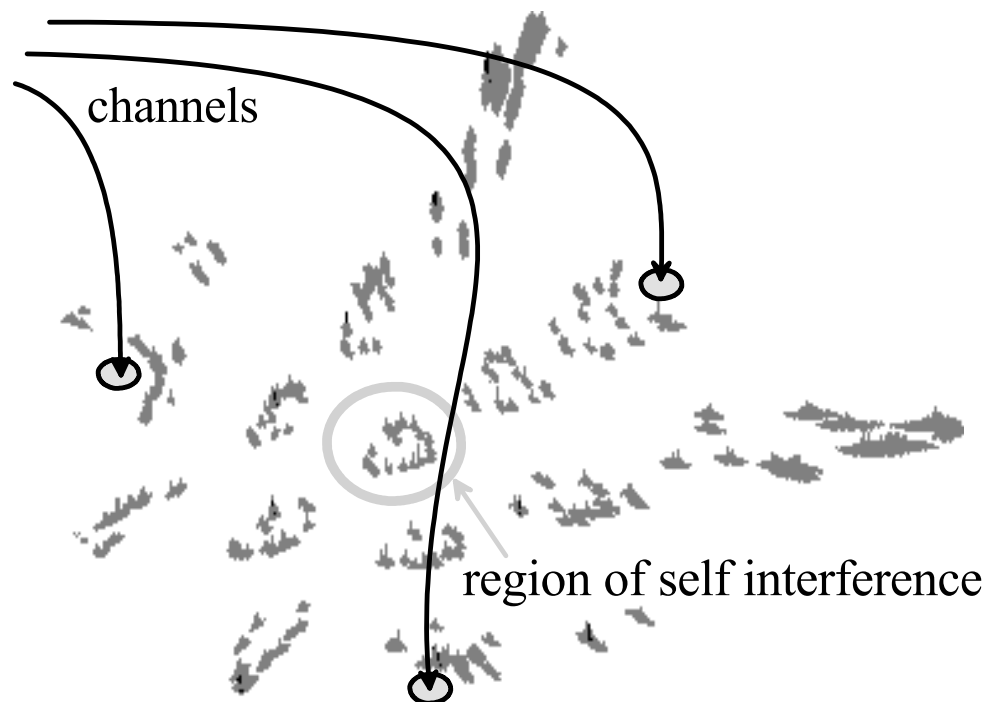
-> *Nerve system uses pulses.*

Spatial Properties ($w_i = 1$)

Self Reproduction (Lashley) for well-conditioned INs

$$(23) \quad n = d + 1$$

space dimension d , channel number n



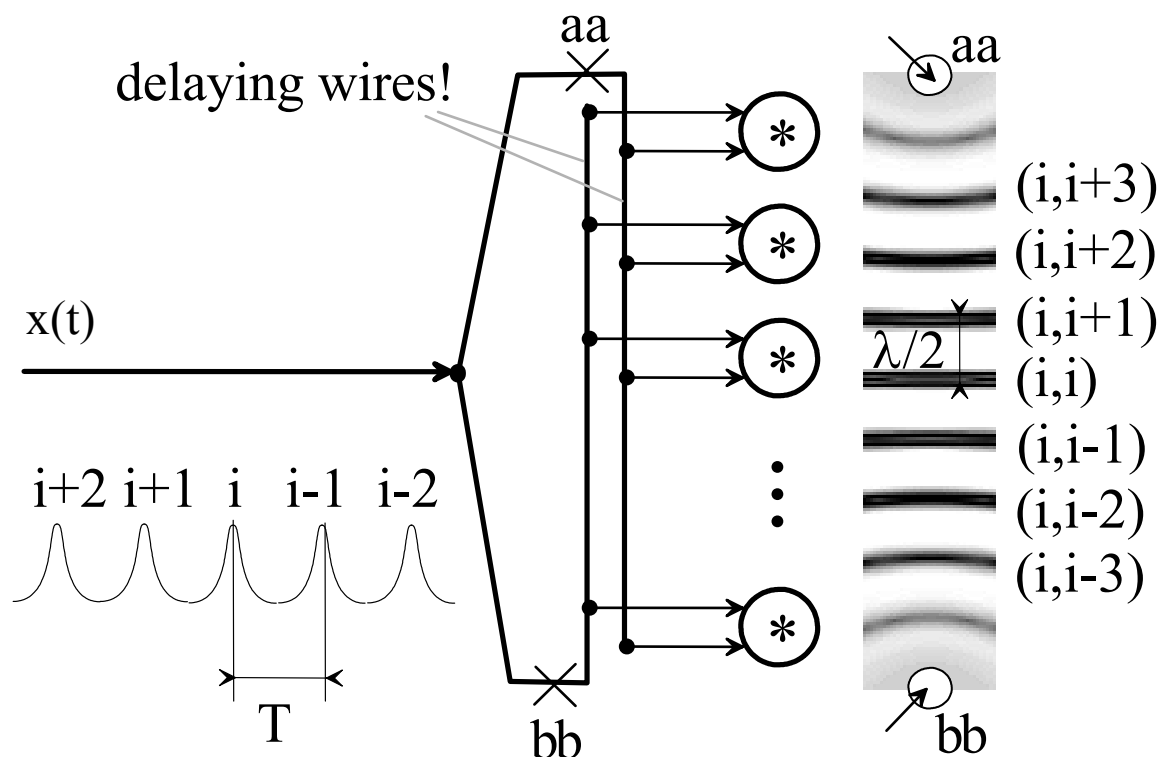
Further properties:

- ◆ Zooming
- ◆ Moving
- ◆ Overlay
- ◆ Over-Conditioning (removes Lashley)

All characterised by self-interferences!

Temporal Properties

Frequency/Code Mapping



Further properties:

- ◆ Overflow (pain)
- ◆ n-channel maps
- ◆ wave flow

All characterised by cross-interferences!

Interferential Feature Maps with Nerves

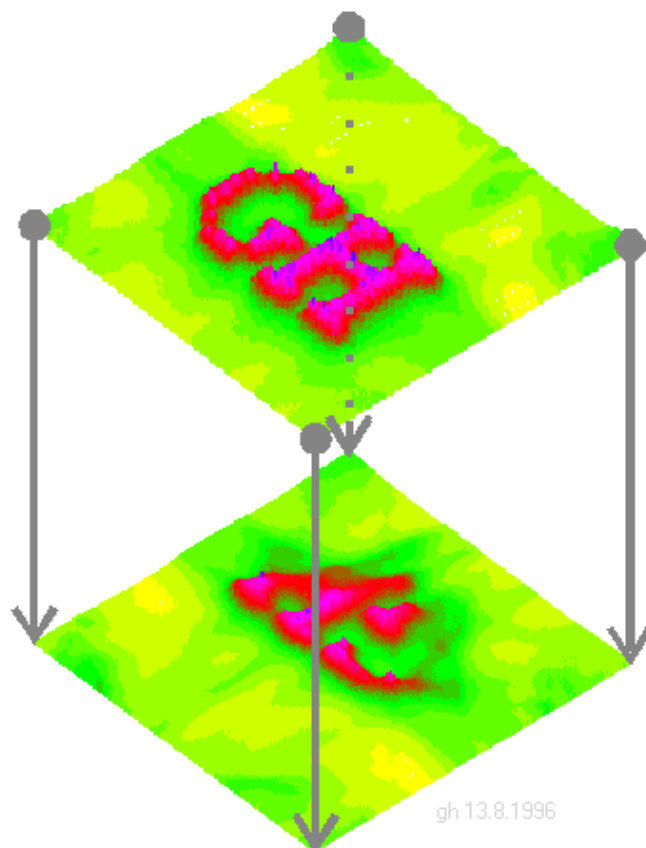
- ◆ Maximum effective values characterize any feature
- ◆ so, IN acts as feature mapping nets in general

3D-restriction for free (optical) wave space:

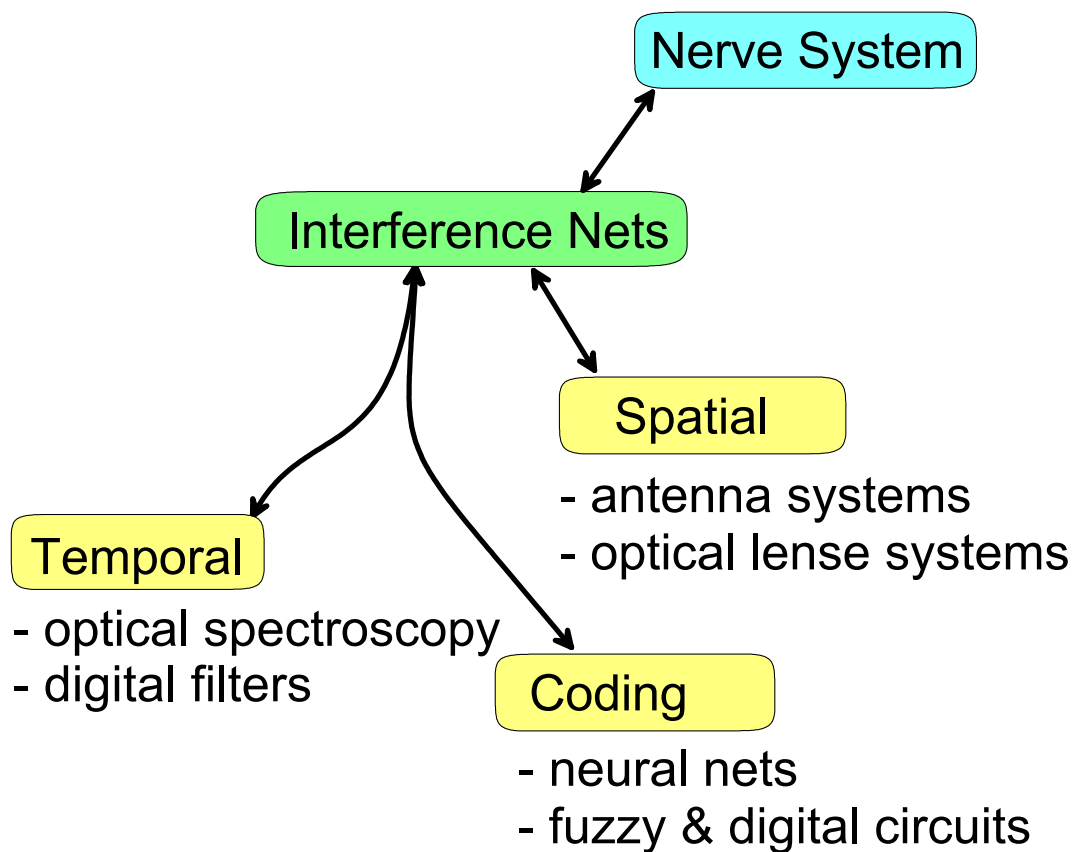
well-conditioned IN:

$$(24) \quad n = d + 1$$

- ◆ *restricts the possible channel number to four channels*
- ◆ *solution: inhomogenous (wiring) wave space*



Hyperclass Interference Nets and Subspaces



Interference network Spatial and Temporal Granularity of NN

Also matrix-like NNs show wave field properties:

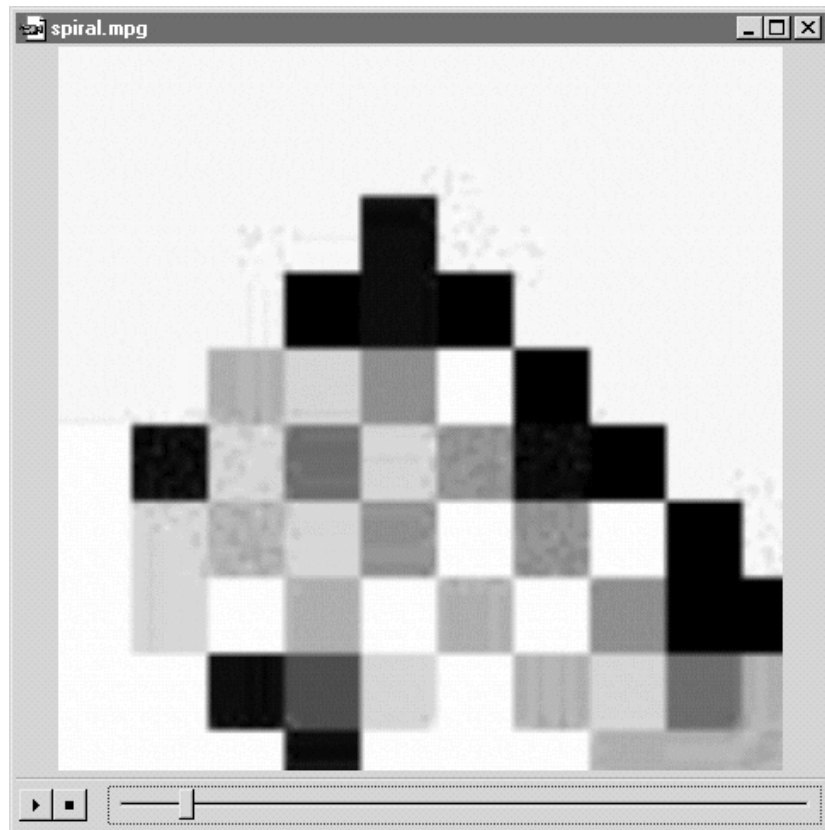


Fig.: NN wave field with friendly permission of Alain Destexhe, CNRS France^{1]} (part of spiral.mpg)

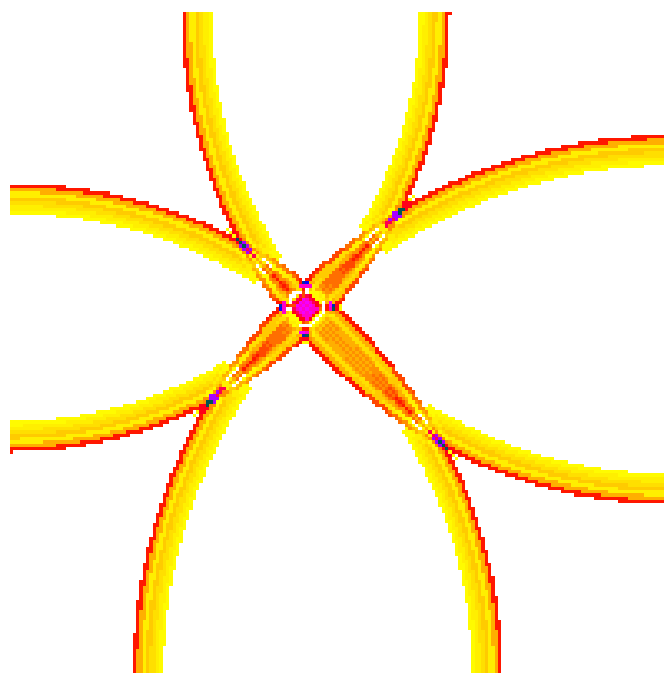
-> *All Neural Networks are Wave Interference Networks, but nobody knows this!*

^{1]} <http://cns.iaf.cnrs-gif.fr/Main.html>, Destexhe@iaf.cnrs-gif.fr

Relativity of Space and Time, Colours

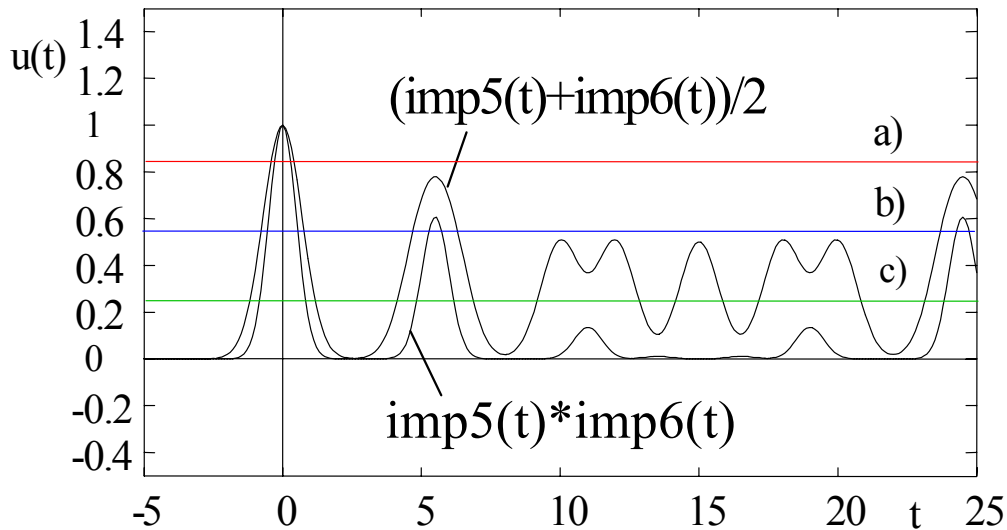
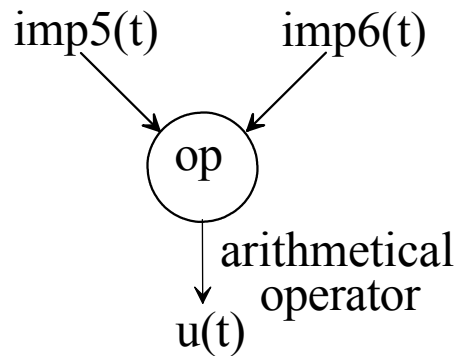
Nerve velocities versus pulse duration ($s = vT$):

pulse duration T	velocity v	pulse width s
1 hour	1 mm/hour	1 mm
10 microseconds	100 m/sec	1 mm



- ◆ Sharpness of excitation depends from *geometrical* wavelenght only
- ◆ A nerve fibre carries a lot of different velocities, called *colours*

Thresholds define Behaviour



Threshold levels a)...c):

a) For addition and multiplication nearly identical

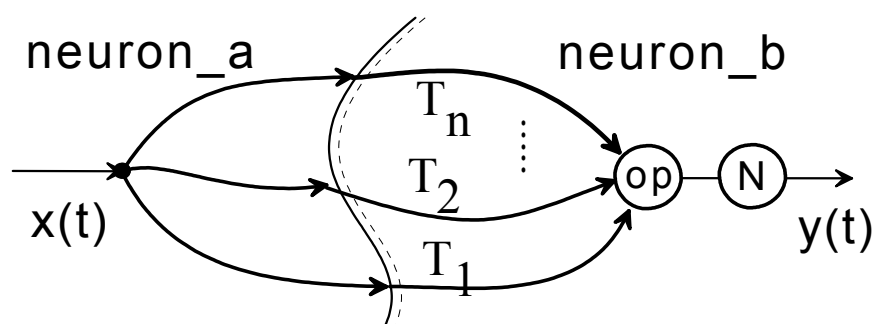
b) Only small differences in the ON-time

c) Significant different output functions comparable to the difference between logical AND and OR.

- ◆ Threshold levels contribute also to behaviour

Basic Functions of Neurons

Simplest IN: coupling of more than one neuron(s):



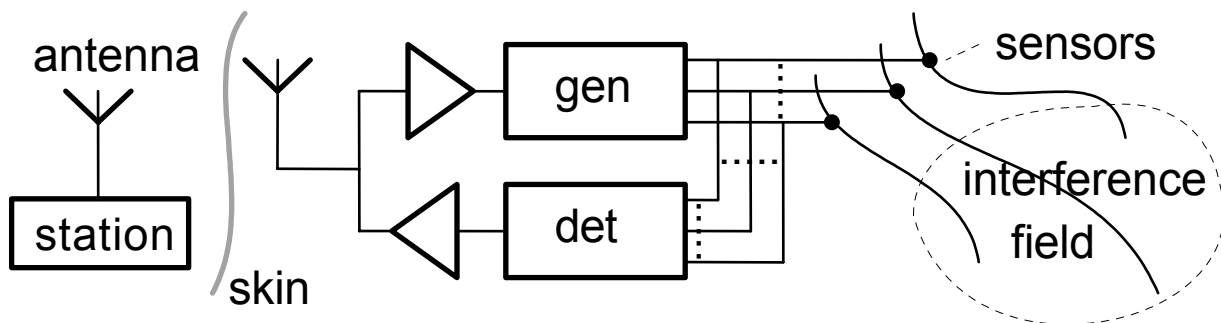
Performance of this circuit^{2]}:

- a) Code generation, suggested op is a summative operator
 - b) Code detection, suggested op is multiplicative
 - c) Data-adressing via bursts
 - d) threshold generation if we use a lot of inputs and a fine tuned normalisation function N ; [5]
 - e) neighbourhood inhibition, if the delay trees of both neurons are identical (identical delay vectors), self-interference is suppressed
- ◆ A single neuron has no function!?

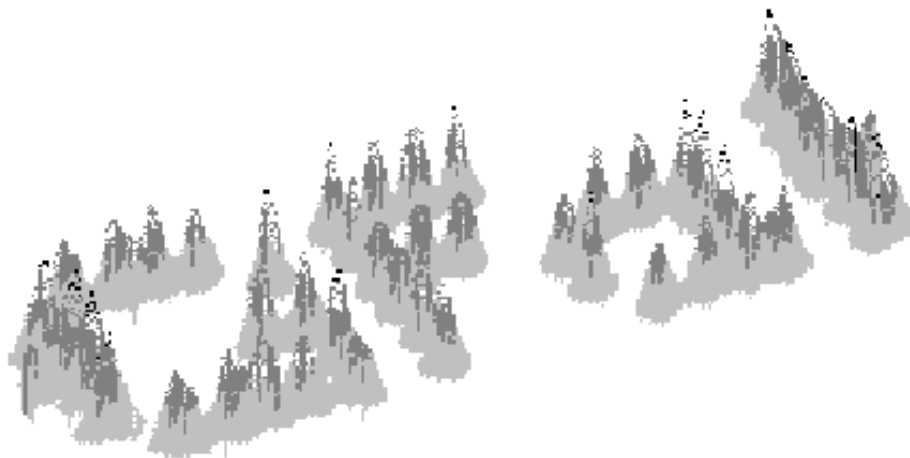
^{2]} Heinz, Puschmann, Schoel 1994

A Hypothetical Brain Interface (BI)

Hypothetical implanted Brain Interface:



4 channel interference image on one field³¹:



- ◆ Do you remember the first computer screens for ASCII-text with 40 columns and 25 rows?

³¹ http://www.gfai.de/www_open/perspg/g_heinz/sim/simdemo.htm

Conclusion

- ◆ Different usage of the term projectivity offered category interference networks (IN)
- ◆ Introducing waves in net-like structured algorithms we demonstrated discrete wave fields in delaying networks
- ◆ To analyse relations between speech and seeing we observed spatial and temporal properties of INs
- ◆ Spatial and temporal properties are closely related to self- and cross-interferences of corresponding time functions
- ◆ Properties of superimposition of time-functions show possibilities for geometrical pulse length variations depending on operator-class and threshold level
- ◆ Lashleys 'holographic brain of rats' appears as a property of interference nets
- ◆ To realise IN-feature maps with high channel numbers, we need net inhomogeneity to realise projections within natural 3D-space
- ◆ Pulse-like time-function shapes produce minimum cross interference and highest projection quality
- ◆ A first suggestion for a hypothetical brain interface is offered
- ◆ Interferential approaches demand different signal properties by contrast to pulse-density modulated networks

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Excitability (2)

(Effective Value between two Waves)

Pulses interfere with different signs

$$(25) \quad u(t) = \{0; 1; 0; -1; 0\}$$

$$(26) \quad u_{\text{eff}}(t) = \text{SQRT}\{(0+1^2+0+-1^2+0)/5\} = 0,63$$

Interference within one sample

$$(27) \quad u_2(t) = \{0; 0; +1-1; 0; 0\} = \{0; 0; 0; 0; 0\}$$

$$(28) \quad u_{\text{eff}}(t) = \text{SQRT}\{(0+0+0+0+0)/5\} = 0$$

Waves with different signs delete each other at the place of (highest) interference.

-> Wave deletion by refracteriness interval

-> Zone of attention by refract. deletion