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Introduction to Interference Systems

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Contents

Motivation:

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

Mathematical (sets, weights, coefficients)

(1) $P \Rightarrow P'$

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

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

Physical (waves, delays, spaces)

(4) $P \Rightarrow P'$

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

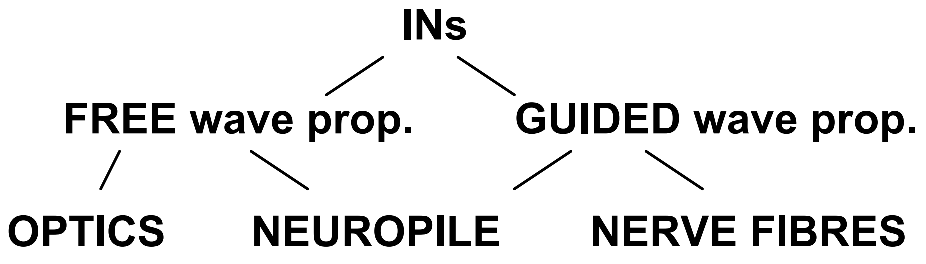
(6) then $p_i \Rightarrow p_{n-i}'$ (mirrored!!!)

-> Example NN <-> IN

What is an 'Interference Network' (IN)?

- Short connectable everywhere (neuro-pile)
- Homogeneous/Inhomogeneous (free/guided wave prop.)
- Wave propagation tied to boundles 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 spac*e

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

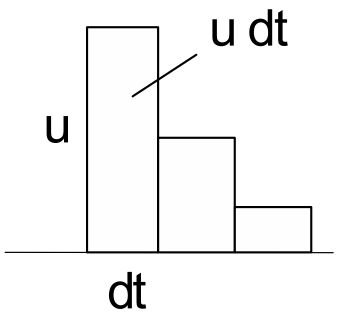
Excitability in Space and Time, Effective Value

Effective value of a signal

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

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

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



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

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

a) They meet at location 3:

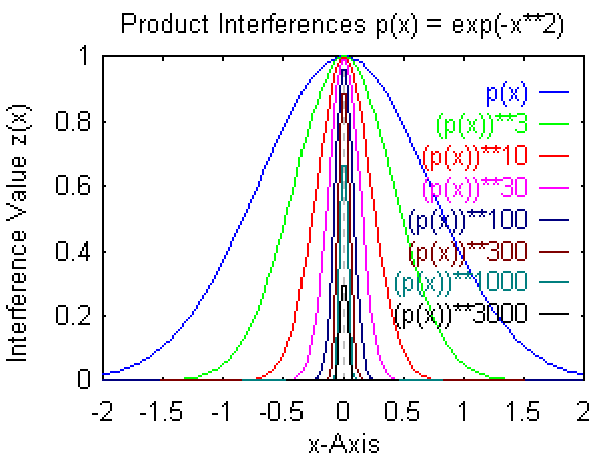
(12) $u(t) = \{0; 0; 1+1; 0; 0\}$

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

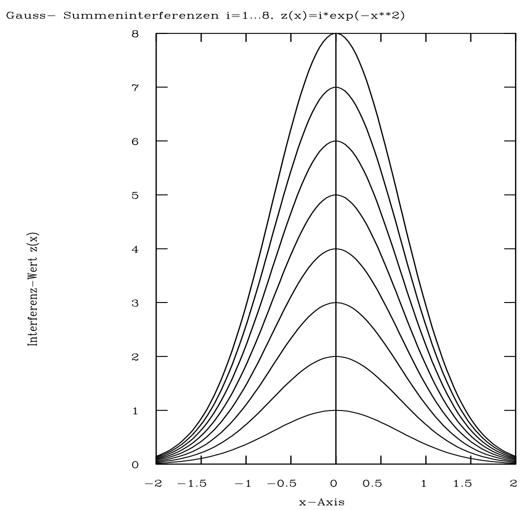
The closer the time correlation of time functions is, the higher is the effective value at the location.

Superimposition Type and Spatial Selectivity

Non-linear (exp):



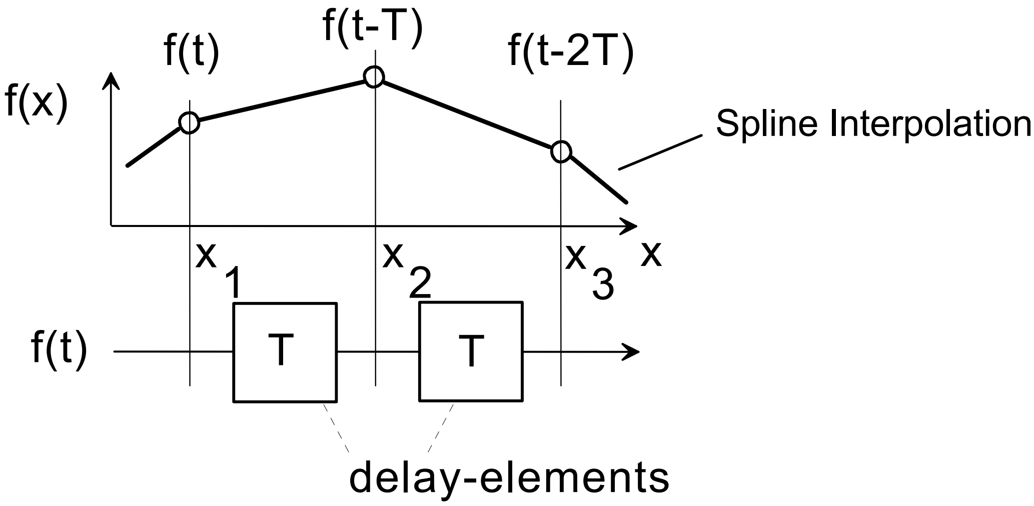
Additive:



- *non-linear superimposition* reduces the excitment 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)	x_1:	$f(x_1, t) = f(t)$
(15)	x_2:	$f(x_2, t) = f(t-T)$
(16)	x_3:	$f(x_3, t) = f(t-2T)$

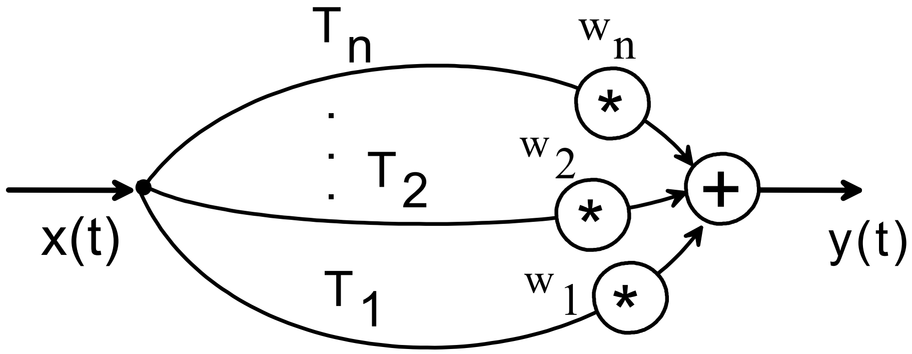
- Continuous wave field suggestion connecting the nodes
- Space-time function set is called *discrete wave field*

Examples:

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

Temporal: Frequency Filter

Simplest Interference Network:



Resulting time function

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

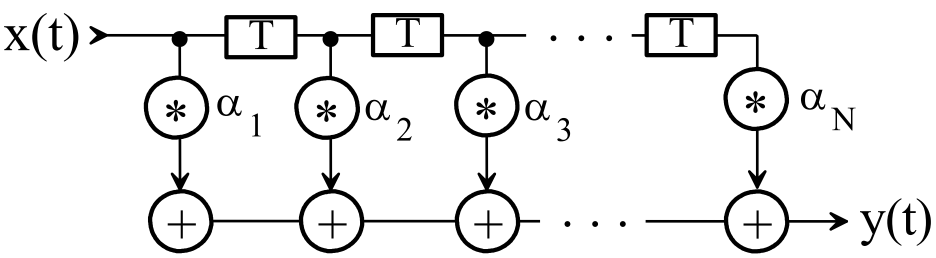
Frequency response

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

$T_n = nT$:

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

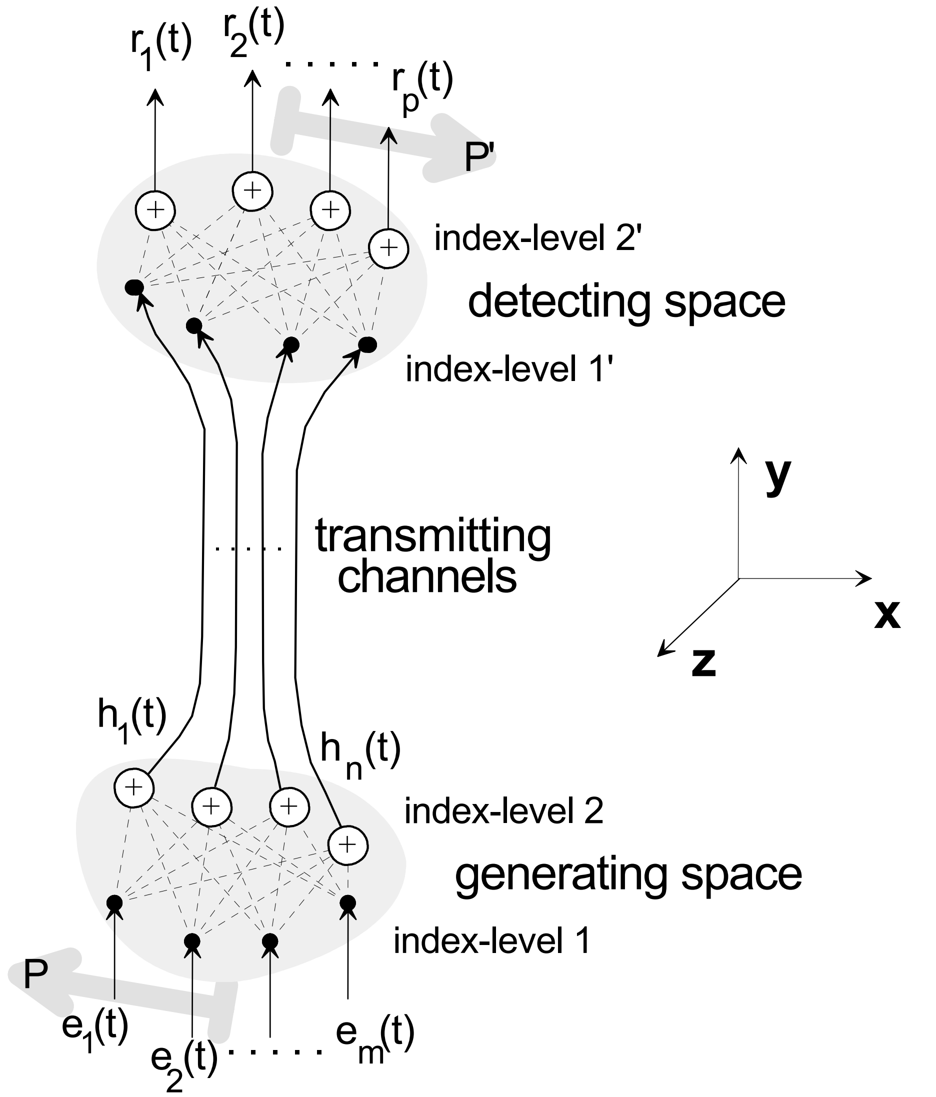
(20) $y(t) = \sum_{i=1}^{n} w_i\, x(t-T_i)$



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

Spatial: Projective Network

Combination of two layers of simple INs:

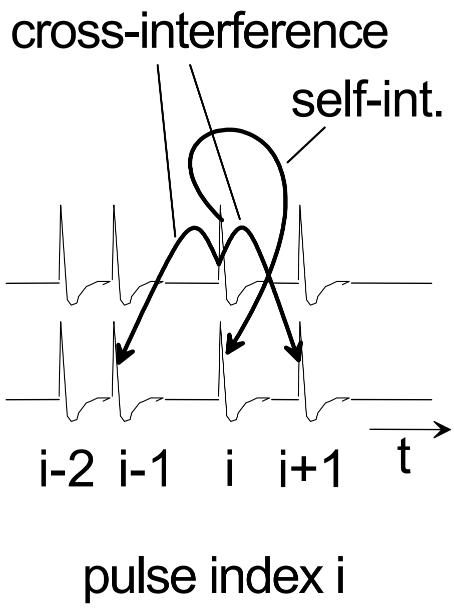


(21) $h_1(t) = e_1(t-T_{11}) + e_2(t-T_{21}) + \ldots + e_m(t-T_{m1}) \ldots$

(22) $r_1(t) = h_1(t-T_{11}) + h_2(t-T_{21}) + \ldots + h_n(t-T_{n1}) \ldots$

-> *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

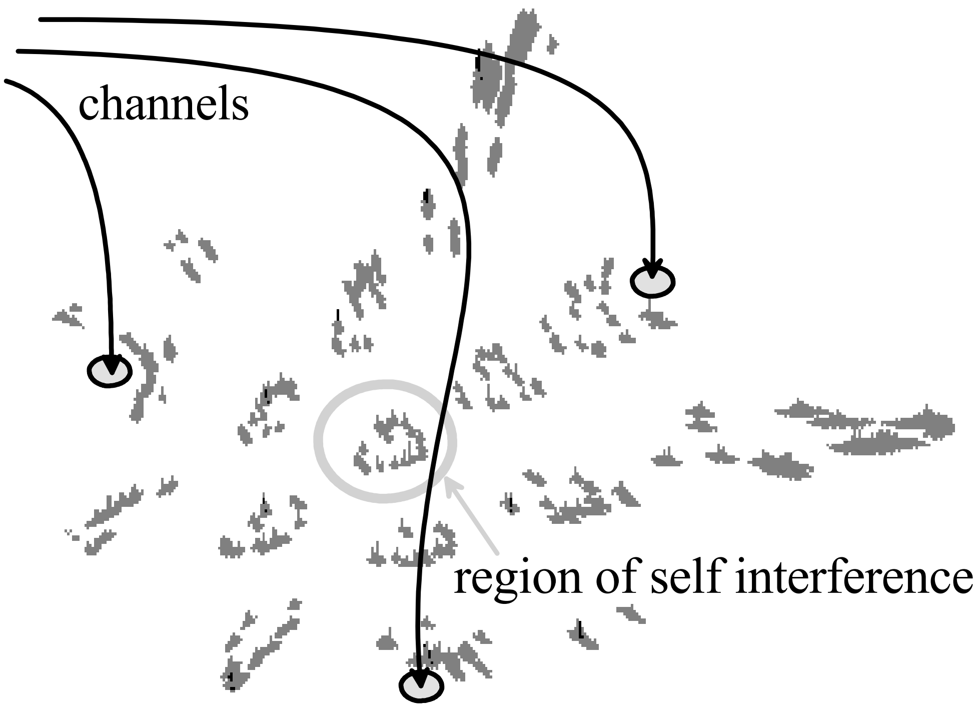
-> Nerve system uses pulses.

Spatial Properties ($w_i = 1$)

Self Reproduction (Lashley) for well-conditioned INs

(23) $n = d + 1$

space dimension *d*, channel number *n*



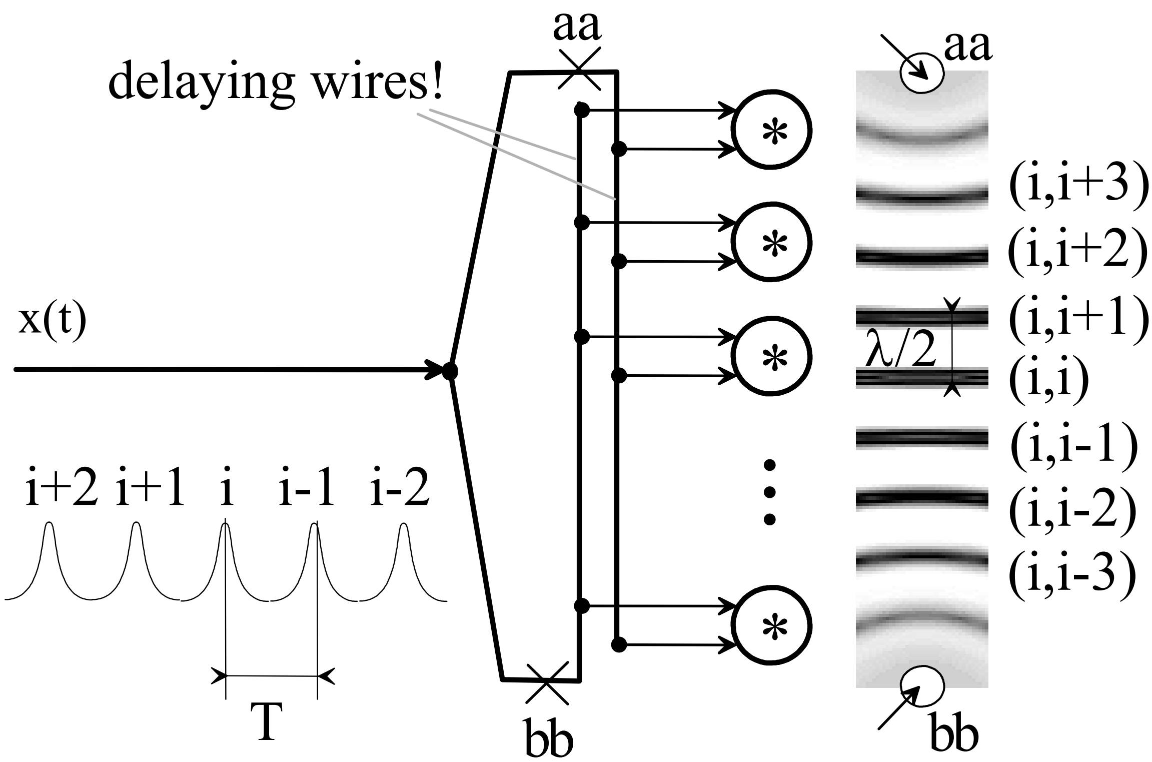
Further properties:

- 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

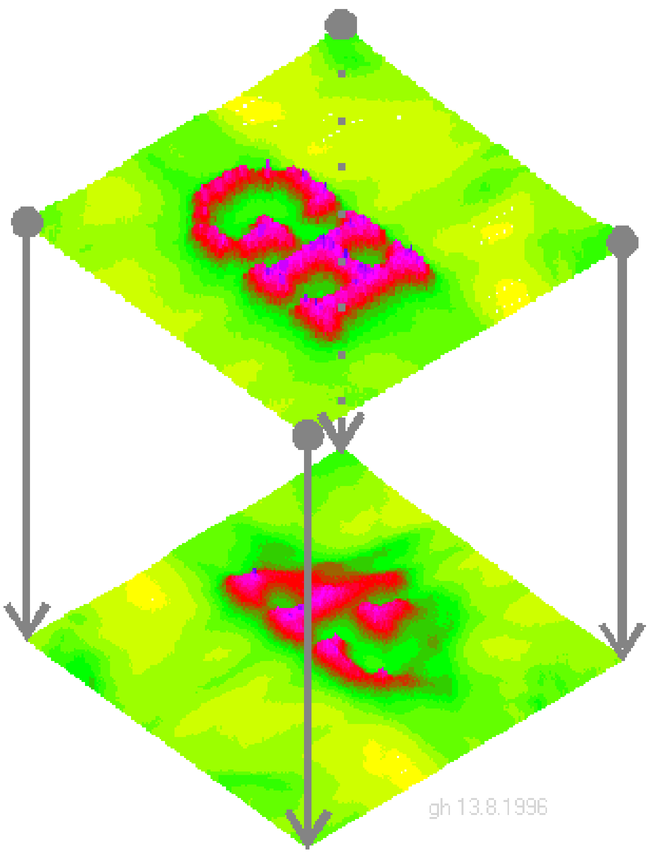
- Maximum effective values characterize any feature
- so, IN acts as feature mapping nets in general

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

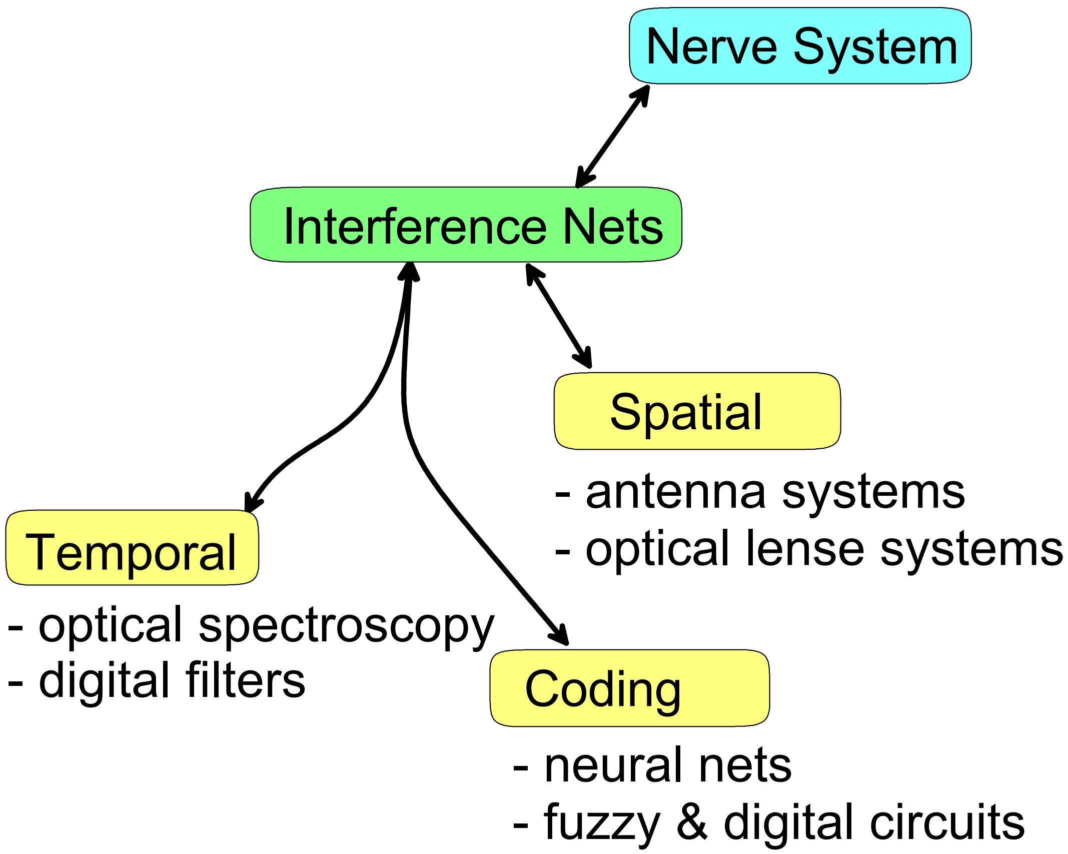
well-conditioned IN:

(24) $n = d + 1$

- *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:

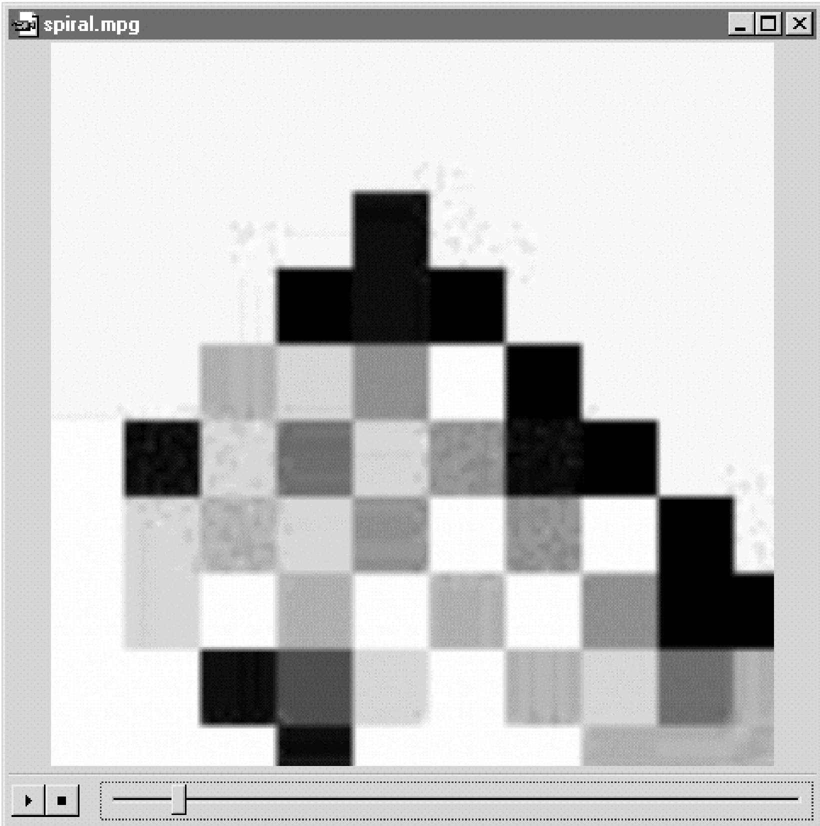


Fig.: NN wave field with friendly permission of Alain Destexhe, CNRS France[1] (part of spiral.mpg)

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

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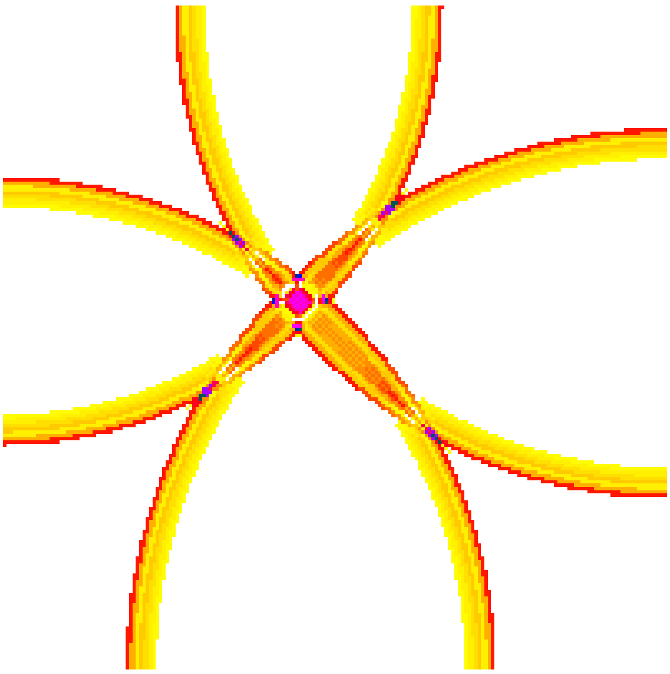
[1] http://cns.iaf.cnrs-gif.fr/Main.html, Destexhe@iaf.cnrs-gif.fr

Relativity of Space and Time, Colours

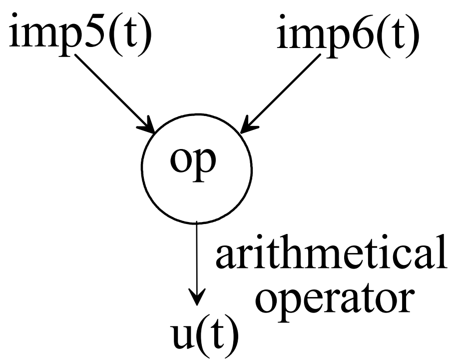
Nerve velocities versus pulse duration (s = vT):

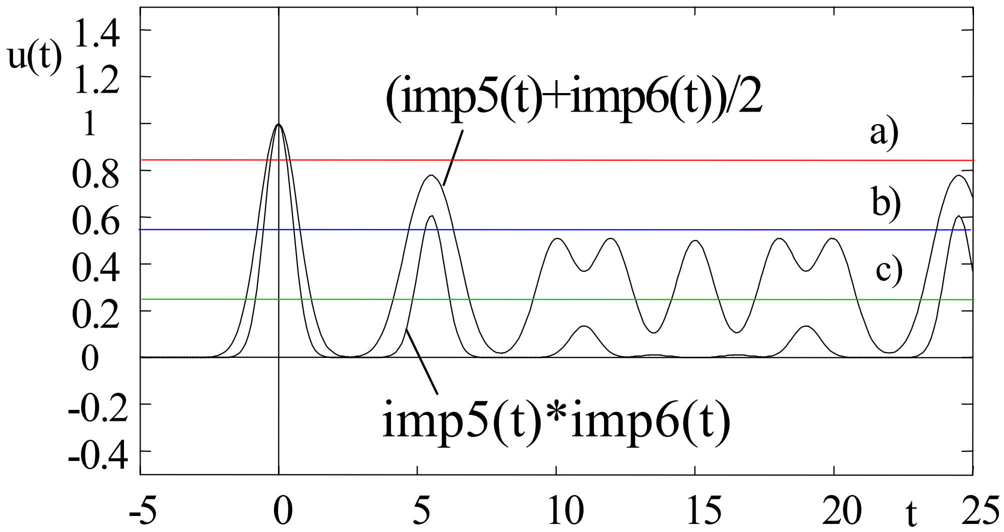
pulse duration T	velocity v	**pulse width s**
1 hour	1 mm/hour	**1 mm**
10 microseconds	100 m/sec	**1 mm**



- 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

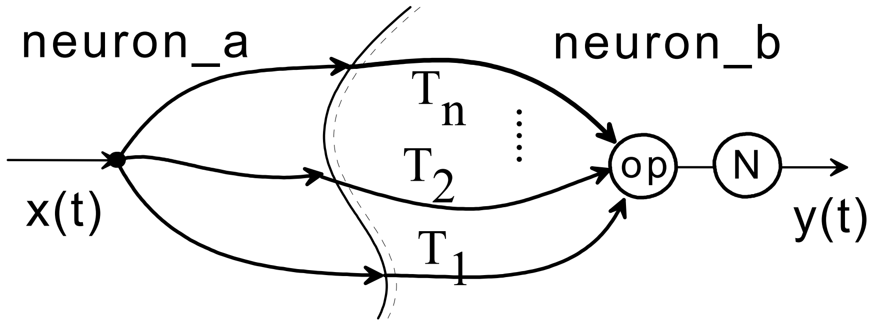
b) Only small differences in the ON-time

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 then 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]

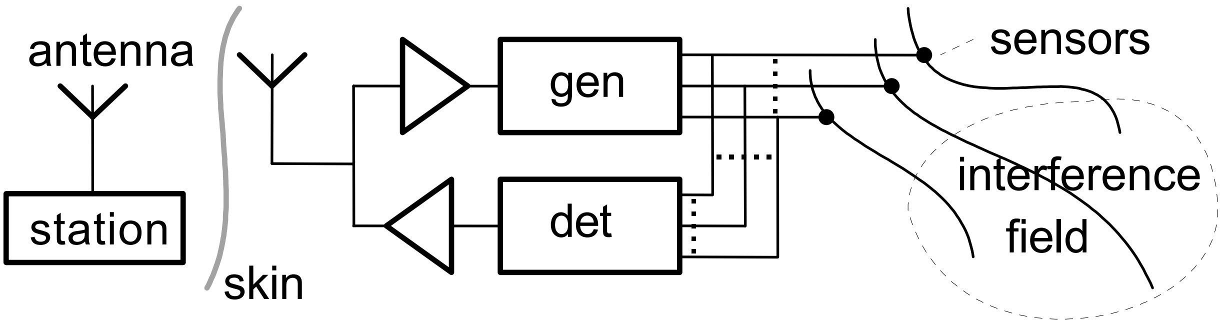
e) neighbourhood inhibition, if the delay trees of both neurons are identical (identical delay vectors), self-interference is suppressed

- A single neuron has no function!?

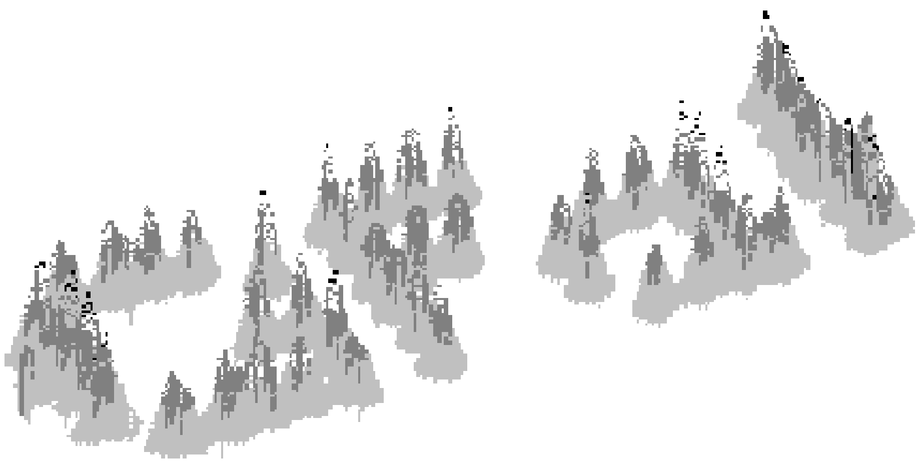
[2] Heinz, Puschmann, Schoel 1994

A Hypothetical Brain Interface (BI)

Hypothetical implanted Brain Interface:



4 channel interference image on one field[3]:



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

[3] 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 inhomogenity 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) $u(t) = \{0; 1; 0; -1; 0\}$

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

Interference within one sample

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

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

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

-> Wave deletion by refracteriness interval
-> Zone of attention by refract. deletion