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# Time Pattern, Data Addressing, Coding, Projections and Topographic Maps between Multiple Connected Neural Fields - a Physical Approach to Neural Superimposition and Interference

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## Contents

- Simple interference circuit (burst)
- Delay Mask of a Location
- Space-Time Properties
- Interference between two fields
- Interference transformation (HIT)
- Properties of projections (moving, zooming, conjunction, spectra)
- HIT-properties (reconstruction, projection, movies)


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# Problems to Understand Bio-Neural Networks

- short-connections everywhere
- principles of data addressing unknown
- how to realise neighbourhood inhibition
- large receptive fields contra high location sensibility
- pulses goes on all possible ways (Daumenexperiment 1992)
- mirrored projections (homunculus)
- relations between time and space
- unexciteability by single synaptical stimulus

# Model Assumptions

to demonstrate simple effects reasoned by relative timing:

- time functions at locations (not at wires) in space
- time-functions combined in mathematically and physically correct manner
- distances between neurons in space produce (incremental) delays
- wiring delay includes synaptic delay
- synaptic weights are uniform, unused and unchanged
- pulses pass through soma without being influenced in timing or wave form
- neural model with uniform weights consists of wire delays and adder
- non-linear threshold function is necessary for interference integrals

# Simplest Interference Circuit

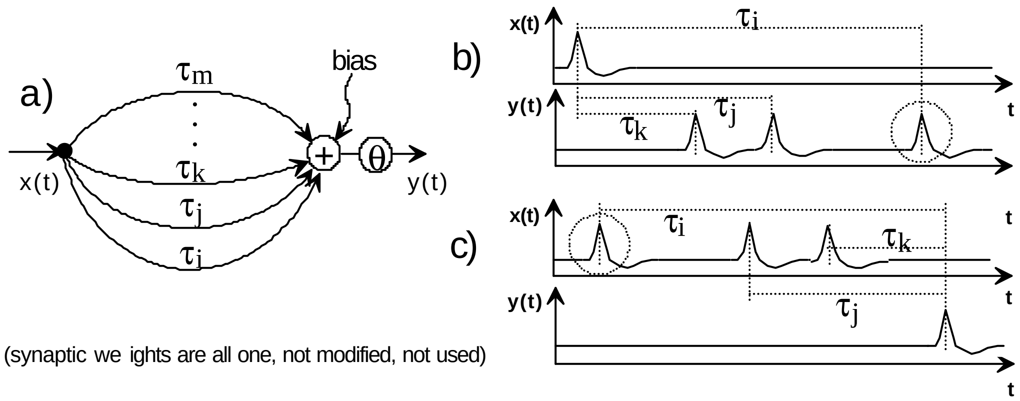


**Fig. 1: Basic functions of a neuron or a neural group**
**a) Circuit structure**
**b) Burst generation with low bias**
**c) code detection with high bias**

## Time function

$$y(t) = \theta(x(t-\tau_i) + x(t-\tau_j) + x(t-\tau_k) + ... + x(t-\tau_m) + bias)$$

## Discussion

- OR-character (high bias): single input impulse produces a burst, Fig. 1.b (*burst- or code-generation*)
- AND-character (low bias): on burst single follows output impulse, Fig. 1c (*burst- or code- detection*)
- OR-character and delays smaller the pulse-width: see [5] and [6] (*gating potential generation*).

# Bursts, Data Addressing and Neighbourhood Inhibition

## Mask M and inverse mask M*

*Delay Mask M* $= \{t_1,\ \ t_2,\ldots,t_k\}^T$

delays over all paths have to be equal in components

$M + M^* = T$ *(interference condition)*

$$\text{with}\quad M = \begin{pmatrix}\tau_1\\ \tau_2\\ \vdots\\ \tau_i\end{pmatrix}\ \text{and}\quad T = \tau\begin{pmatrix}1\\ 1\\ \vdots\\ 1\end{pmatrix}\ \text{follows}\quad M^* = \begin{pmatrix}\tau-\tau_1\\ \tau-\tau_2\\ \vdots\\ \tau-\tau_i\end{pmatrix}.$$

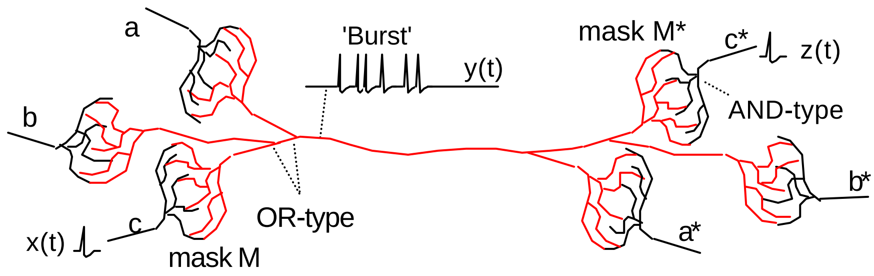


**Fig. 2: Directed, multiple data transmission via one axon. Only that receiver is addressed which possesses the complementary key in form of the inverse mask M* of the sender. Signal flow only c -> c* and c* -> c**

## Discussion

- one fibre can carry different data streams (***data addressing***)
- oscillations between neighbours prevented (***neighbourhood inhibition***).

# Delay Mask of a Location, Space-Time Properties

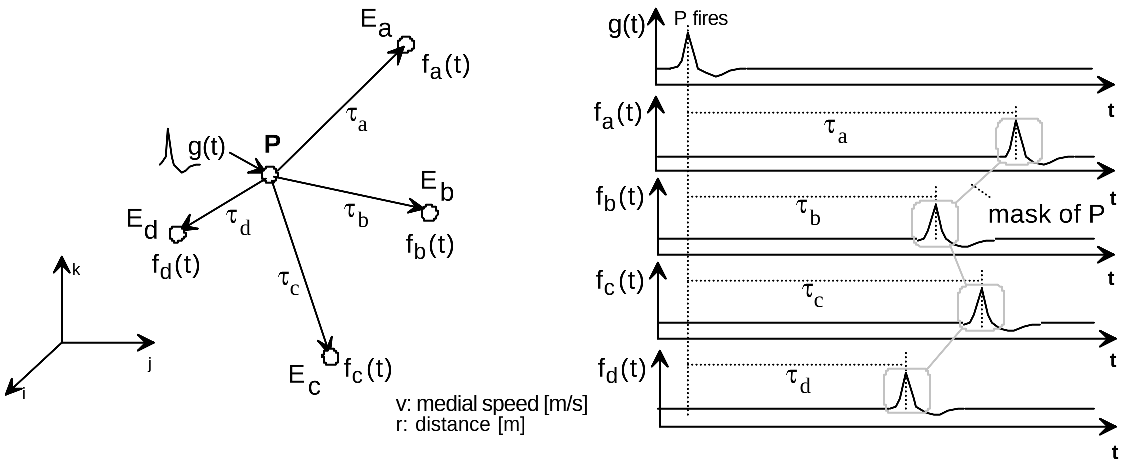


**Fig. 3: Expansion of neural waves in 3D-space with time functions: Any location *P* burns its delay mask (its address) into channel data stream**

time function with $v = \{a, b, c, d\}$:

$$f_v(t) = g(t - \tau_v) = g(t - \frac{r_v}{v_v})$$

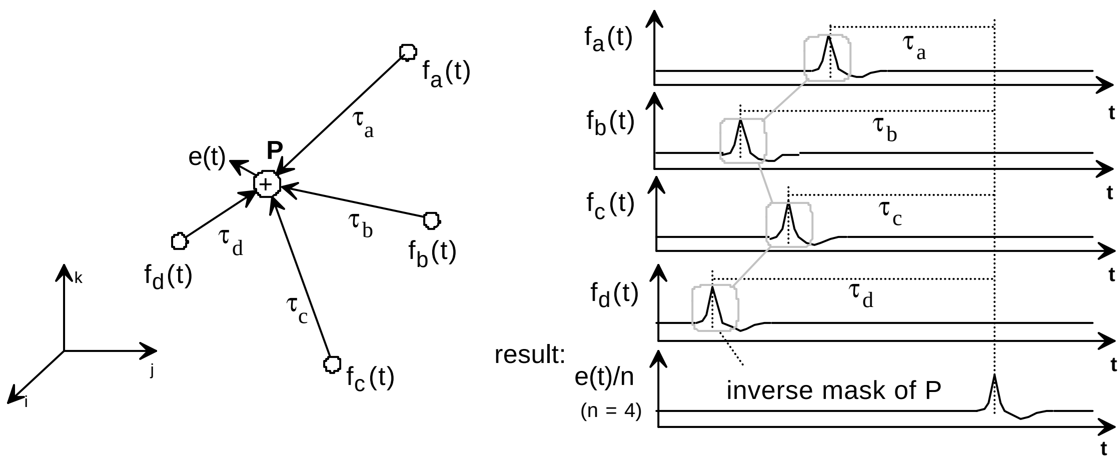


**Fig. 4: Interference to a location. Maximum excitement appears if the mask of pulses in the channel data stream is inverse to the mask of the location (time direction of delays can be seen to be inverse)**

time function :

$$e(t) = \frac{1}{n} \sum_{v=1}^{n} f_v(t - \tau_v) = \frac{1}{n} \sum_{v=1}^{n} g(t - \frac{r_v}{v_v}$$


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# Two Neural Fields Connected with some Fibres, Interference Transformation (HIT)

Distance between any two points $a$, $b$ $\quad \tau_{ab} = \frac{1}{v} \left| \sqrt{(x_a - x_b)^2 + (y_a - y_b)^2 + (z_a - z_b)^2} \right.$

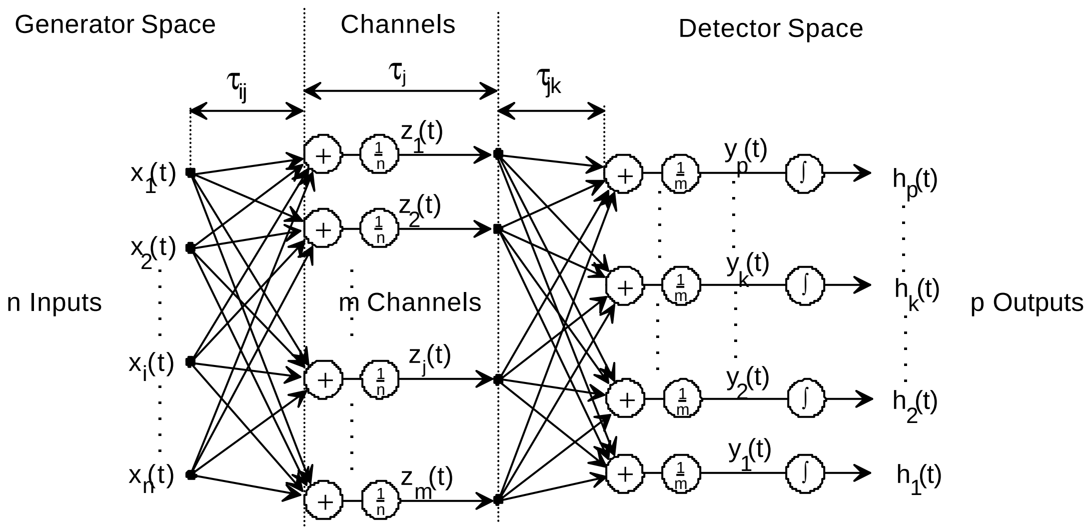


**Fig. 5: PSI model of two neural fields, connected via some axons. We suggest that each neuron of generator- and detector space has a direct or indirect, length-proportional connection to channel axons.**

*Transformation Generator Space into Channels:*

$$z_i(t) = \frac{1}{n}\{x_1(t-\tau_{1i}) + x_2(t-\tau_{2i}) + ... + x_n(t-\tau_{nm})$$

$$z_j(t) = \frac{1}{n}\sum_{i=1}^{n} x_i(t-\tau_{ij} \qquad (1)$$

*Transformation Channels into Detector Space:*

$$y_k(t) = \frac{1}{m}\{z_1(t-\tau_1-\tau_{1k}) + z_2(t-\tau_2-\tau_{2k}) + ... + z_m(t-\tau_m-\tau_{mk}$$

$$y_k(t) = \frac{1}{m}\sum_{i=1}^{m} z_j(t-\tau_j-\tau_{jk} \qquad (2)$$

$$h_k(t) = \lim_{T\to\infty} \frac{1}{T}\int_0^T \theta(y_k(t))\,dt. \qquad (3)$$

*Resulting Transformation Generator to Detector:*

$$y_k(t) = \frac{1}{m}\sum_{i=1}^{m} z_j(t-\tau_j-\tau_{jk}) = \frac{1}{mn}\sum_{i=1}^{m}\sum_{i=1}^{n} x_i(t-\tau_{ij}-\tau_j-\tau \qquad (4)$$


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# Properties of Self Interference Projections

## Grey Pictures

$\lim_{n,m\to\infty} y_k(t) = \frac{1}{mn} \sum_{i=1}^{m} \sum_{i=1}^{n} x_i(t - \tau_{ij} - \tau_j - \tau_{jk}) =$ *central boundary (5)*

## Condition for Self-Interference

$\tau_{ijk} = (\tau_{ij} + \tau_j + \tau_{jk})$

$\boxed{\tau_{i1k} = \tau_{i2k} = \ldots = \tau_{ijk} = \ldots = \tau_{imk}}$ *self interference (6)*

## Projectivity

$y_k(t) = \frac{1}{mn} \sum_{i=1}^{m} \sum_{i=1}^{n} x_i(t - \tau_{ijk}$ *total sum (7)*

$\boxed{y_k(t) = x_i(t - \tau_{ijk})}$ *projectivity (8)*

$F : \{X\} \to \{Y\}$ or $(x, y) \in F$

## Boundary to Fremd-Interference

$max(space\_delay) < max(\tau_{ijk})$ *diagonal condition (9)*

# Properties of Projections in Fremd-Interference (Outside-Interference)

## Boundary to Self-Interference

$max(space\_delay > max(\tau_{ijk})$ *diagonal condition (9)*

## Condition for periodical Fremd-Interference

$\boxed{y_k(t) = x_i(t - \tau_{ijk} \pm qT),\ q \in N}$ *fremd-interference (10)*

periodical functions: $qT = \frac{q}{f}$ with $q \in N$


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# Results

### Moving Projections

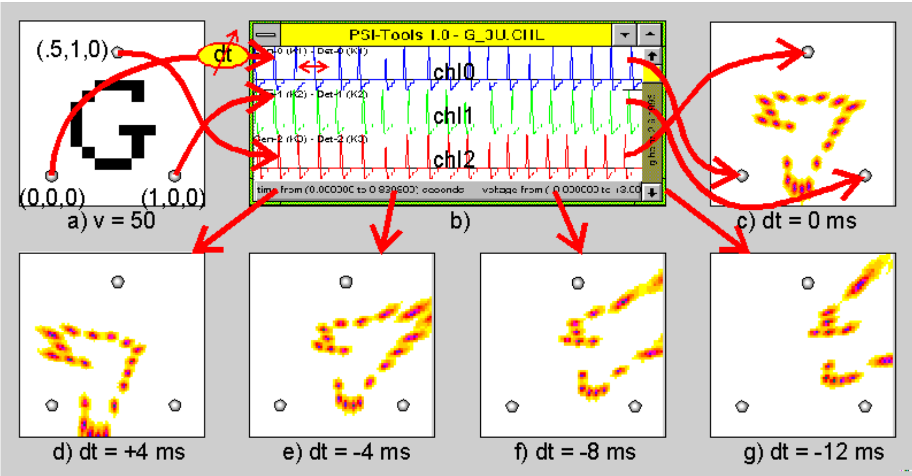


**Fig. 6:** **Moving interference projections. Moving projections occur by variation of the delay of one channel. a) Synthetic generator space; b) Channel data; c)...g) Reconstructions with delayed left channel**

### Zooming Projections

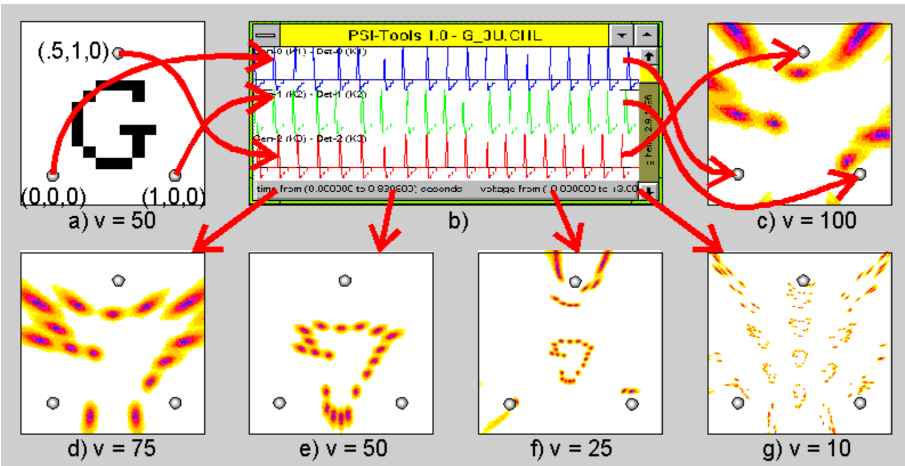


**Fig. 7:** **Zooming interference projections. a) Synthetically generator space with speed v=50, black pixels fire one for one; b) channel data; c)...g) projections with different velocities v (normalized unit system)**

# Conjunctive Projections

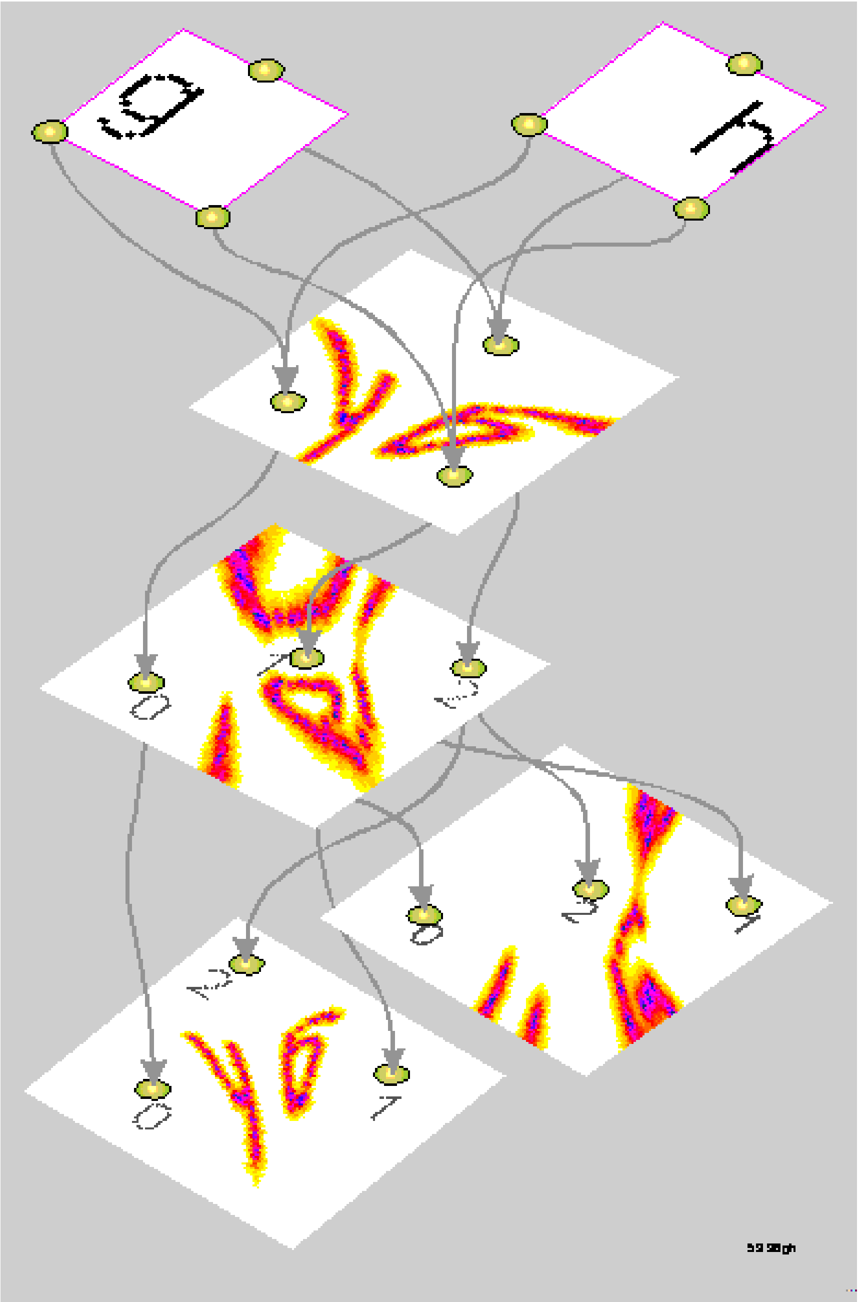

**Fig. 8: Conjunction of different neural excitement maps into one field. In relation to the channel source points the projections appear distorted, the interference locations vary.**

# Spectral Coding

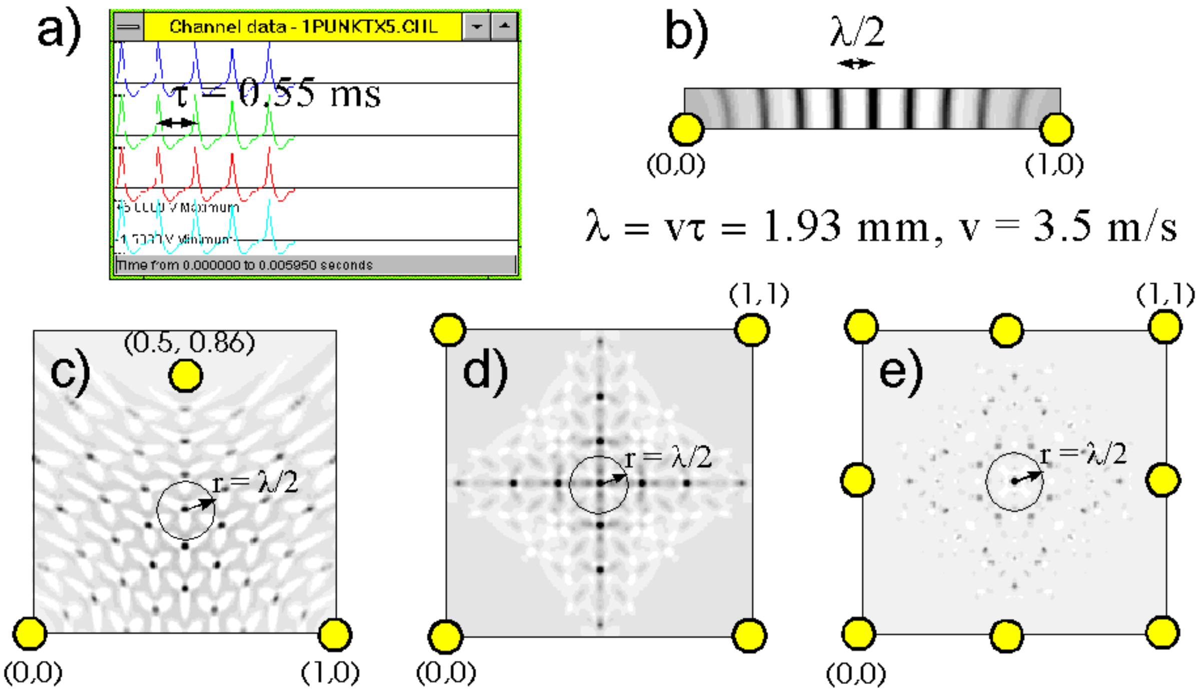


**Fig. 9:** **Neural spectra of different channel arrangements in 2-dim. space. Electrode positions are marked. The higher the channel number, the higher is the peak of the central interference: b) 2-chl.; c) 3-chl.; d) 4-chl. with channel data in a); e) 8-chl. arrangement (PSI-Tools).**

# Wave Fields (Movies)

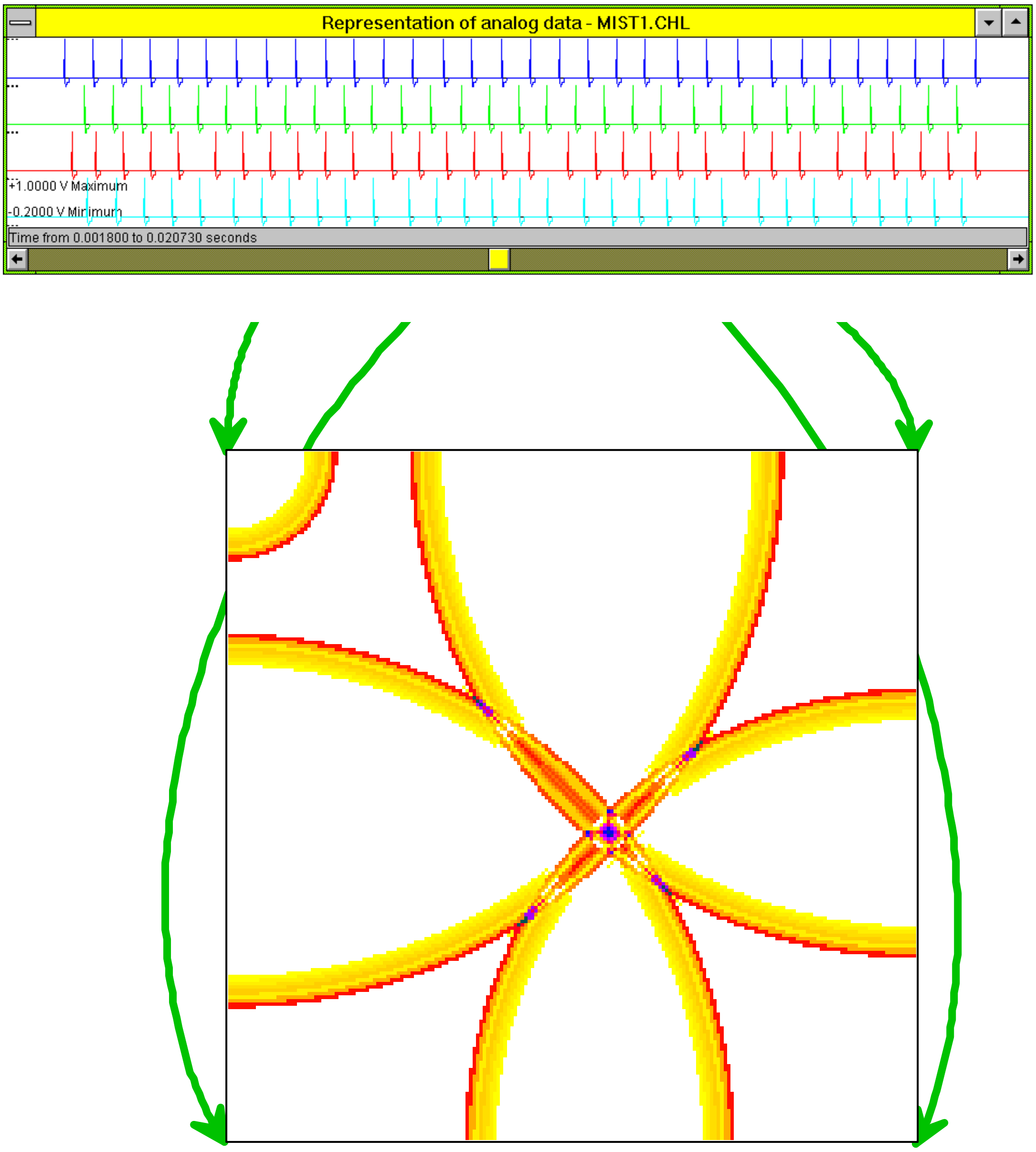


**Fig. 10: Wave field as an interference transformation (HIT) with four channels. The picture shows a calculation of all pixel interference values for one time step. Centrally an interference appears between four waves. Channel sources lie in the corners (PSI-Tools)**

# Projection, Reconstruction and Direction of Time Axis

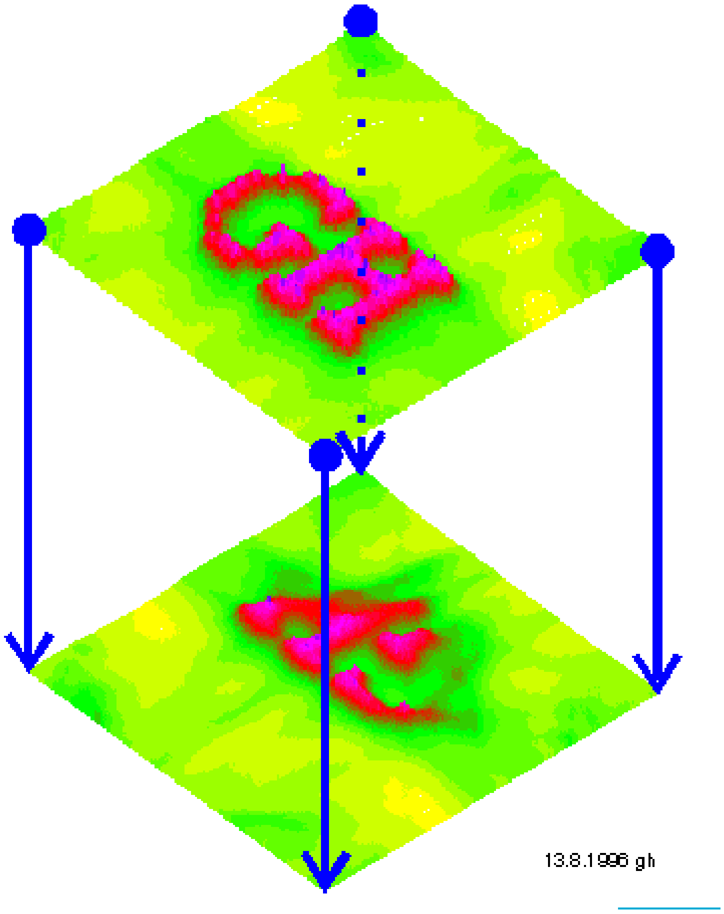


**Fig. 11: Comparison of a reconstruction (top) and a projection (bottom) of the same channel data stream. The projection is over-defined with highest interference qualities in the central region. The picture symbolizes a 'wired' projection between two neural fields, connected via four channels (axons), source [6]**

# Summary and Discussion

- incremental correct delay calculations in pulse-propagating networks
- instead to follow a single signal flow we investigate multiple signals, location of superimposition appears as the data address
- geometry of a net defines relative timing and locations of projections
- shape of a nerve net defines functional properties
- interferences can clear the role of special drugs, changing the velocity
- *interference nets map without modifications of synaptic weights*
- by varying dynamic parameters, such as velocities or diameters of nerves, we are able to modify the functionality of interference networks
- *interference networks appear as a second group of learning networks* behind synaptic learning networks.
- interference circuits can move and zoom projections in space, overlay different projections and mix spectral components with image parts
- addressing data in stochastic (chaotic) switched networks:
- delay-code of bursts as static addresses of data
- moving and zooming as a form of dynamic addressing
- *a neuron can only excite a neuron with an inverse delay mask. But identical geometries exclude inverse masks nearly complete*. A simple *interference provides self-excitement and short-cuts between nearest neighbourly neurons* which are multiple connected.
- interference projections appears mirrored between generator and detector space, while non-interferential projections appears non-mirrored
- delay measurements have impact on understanding pulse processing in bio-neural networks
- PSI-Tools [10] is a simple measuring and simulating system
- interference can be the method to locate mechanical events with fibres having large receptive areas [17]

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