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Two Decades of Interference Network (IN) Research

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(Society for the Promotion of Applied Computer Science, Reg. Ass.)

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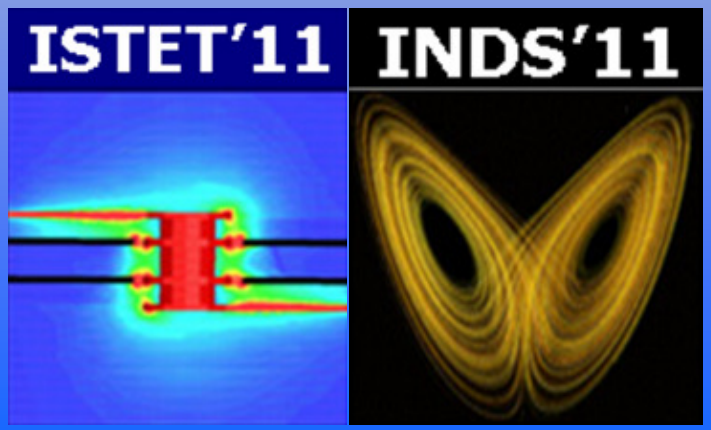


Relative Delay - Networks

- New theories based ever on new axioms
  - Nicolaus Copernikus: Not earth, sun is the center of universe
  - Albert Einstein: Constancy of light velocity, relativity of time

- Interference Network:

  Shift/movement of any signal/information in space needs time
  - Physical, delaying flow of information
  - Signal distribution needs time
  - Infinite high signal velocity forbidden

- Character: Race Circuits
  - Relative delay defines function
  - Signals carried by relative delay, not by wire

The Last Question of Informatics

- How is it possible, to understand "knowledge" in terms of firing nerve networks and waves?

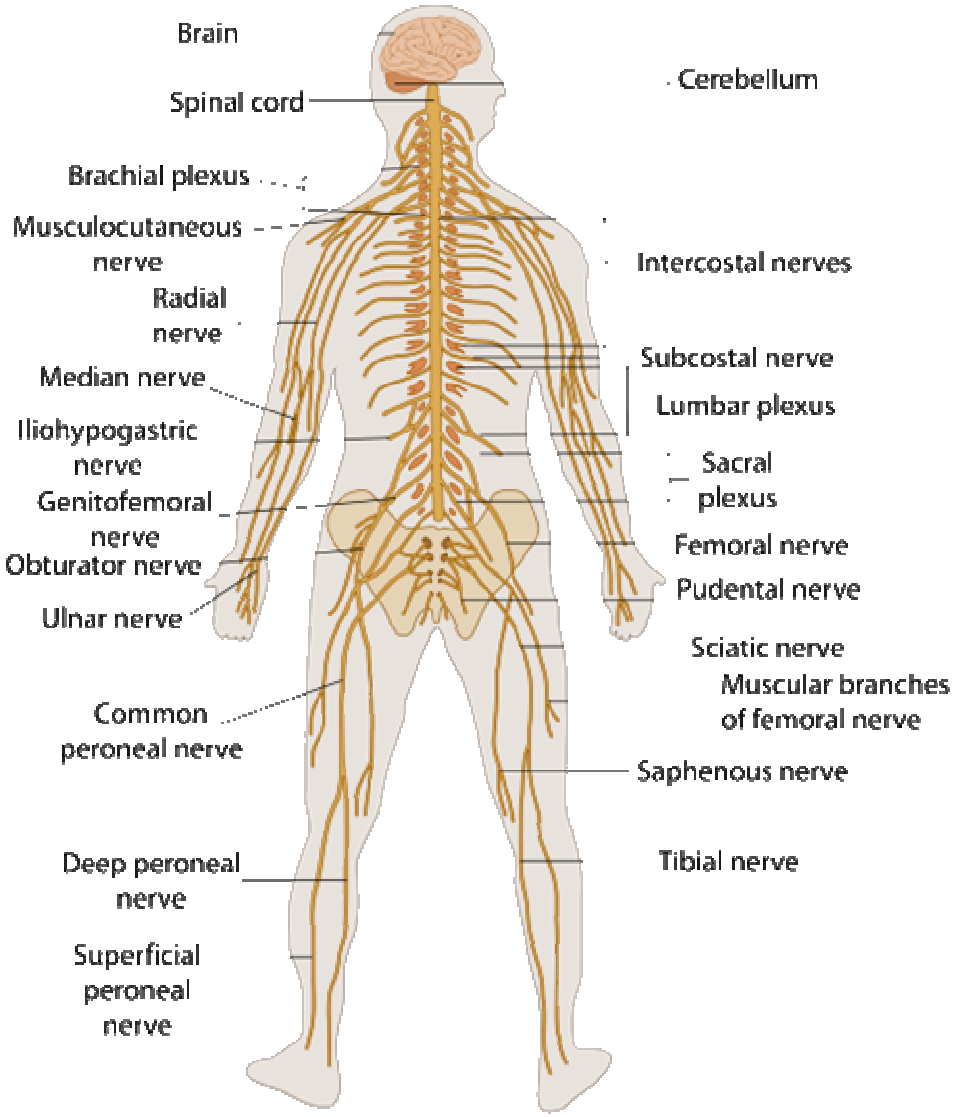
Source: National Resource for Biomedical Supercomputing, Pittsburgh, PA 15213 http://www.nrbsc.org/old/brainmovie/index.html

Failor Rate of Human Nerve System

- A nerve cell lives approx. 7 years
- How is it possible to construct a system with > 100 billion neurons that lives 80 years?
- Failor rate:
  1/(7 years) = 4 e-9/sec
  4e-9/sec * 100e9 = 400/sec
- Survival time of the whole system
  1/400 sec = 2,5 millisec (!)

Highlights:

- Spikes (0.1 … 1 ms)
- Floating potentials
- Short circuits over and over
- No clocks - asynchron
- Ionic velocities mm/s … m/s
  (<1e-6 of electric velocity)



Interference Network (IN) Background

Comparable properties between space and time in different theories abstractable on delaying time-functions in nets:

- Signal-processing
  - Filter theory (Digital filters – FIR, IIR)
  - Wireless transceivers
- Optical lense systems
- Supersonic Arrays A, B, M – Methods; Beam forming (acoustics)
- Global Positioning System (GPS)
- Radio Telescopes
  - Superimposition of I^2 (images) - VLA
  - Superimposition of time functions – SKA
- Acoustic Camera
- Fast Integrated Circuits
- Nerve System

I^2: Interference Integral

Special property on IN:

"Closed" solutions impractical

→ Networks of equations (IN)

Central Questions of IN Research

- What is a wave?
  → A complex solution of a differential equation or
  → A time function running in *n*-dimensional space?

- What is a physical (wave) image (a map)?
  → A mirroring map (lens system)?

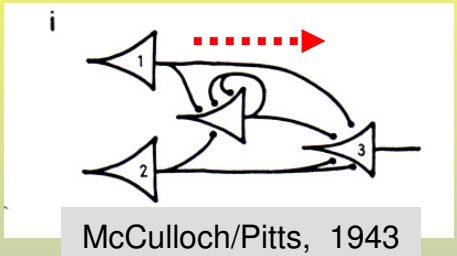
- Relations between time function, wave and map (image)?
  → Connections between Radar, Sonar, GPS, nerve, acoustic map and optical lens system

- Properties of cross-interference maps (to hear) and self interference maps (to see)

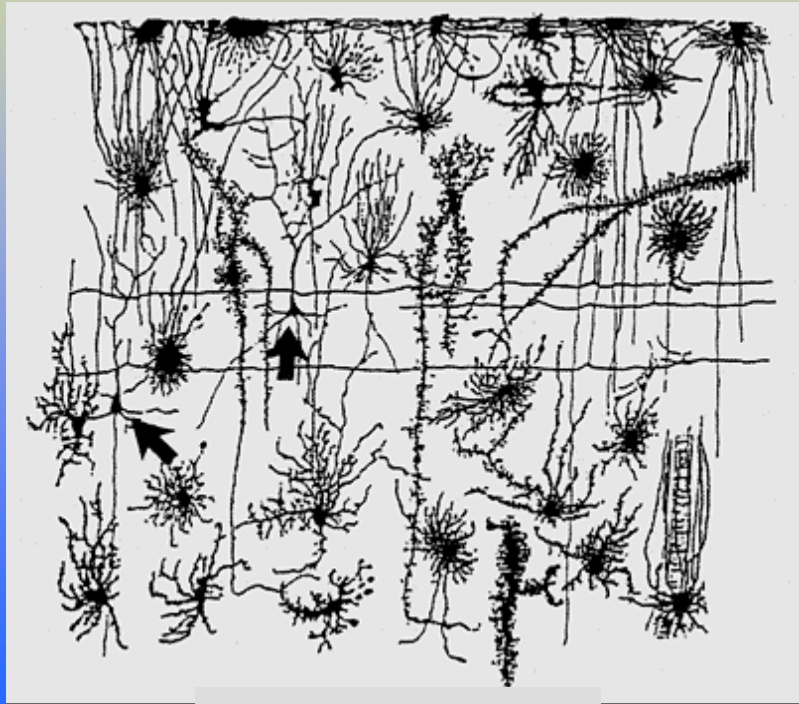
- Quality of maps: Relations between time-function type, channel number, conjunction type and tfc.-properties

Some Historical Dates

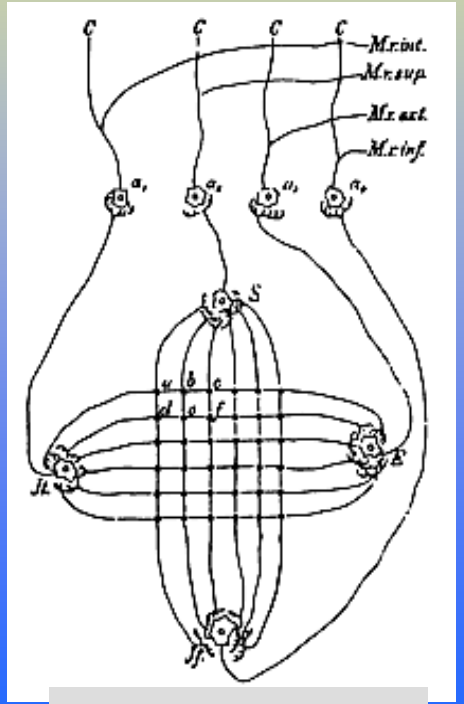
Only dead fishes swim
with the stream.
Bertolt Brecht



McCulloch/Pitts, 1943



Gustaf Retzius, 1890



Sigmund Exner, 1894

Relating Ideas

- **State machines** - world of integer delays:
  f(t-1), f(t-2),…f(t-n)
  - Leibniz 1703 "Arithmétique Binaire"
  - Boole 1854, Augusta Ada 1858
  - McCulloch/Pitts 1943 → Artifical Neural Nets
  - Moore, Mealy, Medwedjew 195x
  - TTL 1961, Petri-Nets 1962, Fuzzy Sets 1965
  - Intel i4004 1971…
- **Interference Systems**
  - Sigmund Exner 1894
  - Lloyd A. Jeffress 1947 — Place theory of sound localization (owl)
  - Shun Ichi Amari 1977 — Cognition networks
  - Karl Pribram 197x — Holomorphic memory
  - Mosche Abeles 198x — Synfire chains
  - Wolf Singer 198x — Synchronization in cats cortex
  - Mark Konishi 1993 — Place theory of sound localization
  - Andrew Packard 1995 — Color waves on skin of squids (Tintenfische)

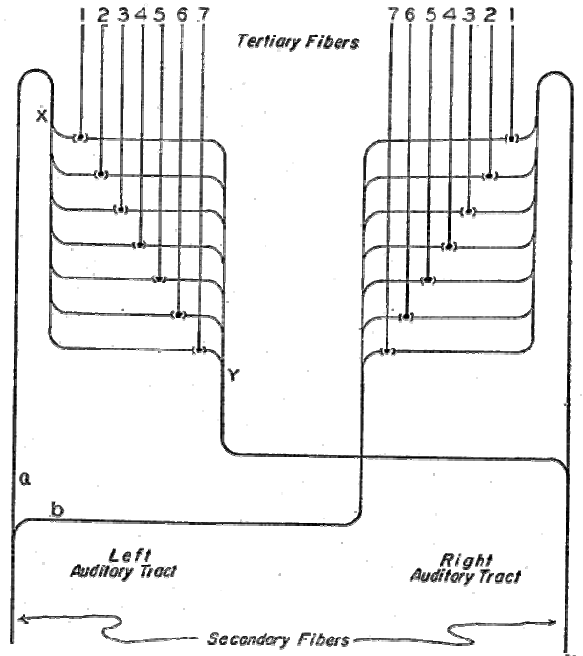


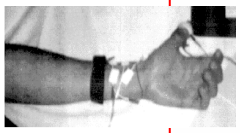
FIGURE 1. HYPOTHETICAL MID-BRAIN MECHANISM FOR THE LOCALIZATION OF LOW FREQUENCY TONES

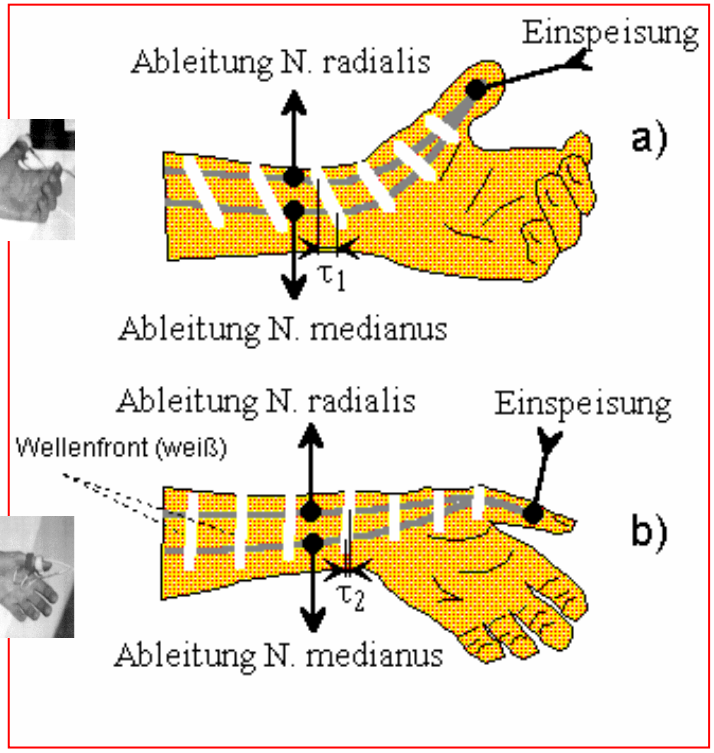
Before I could start:

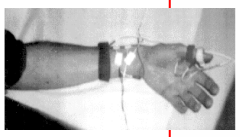
Nerves Waves (1992)

- "Thumb Experiment" (Griepentrog/Heinz, 12/1992)
- Waves can be inspected with NLG (EEG)
- 10x averaging

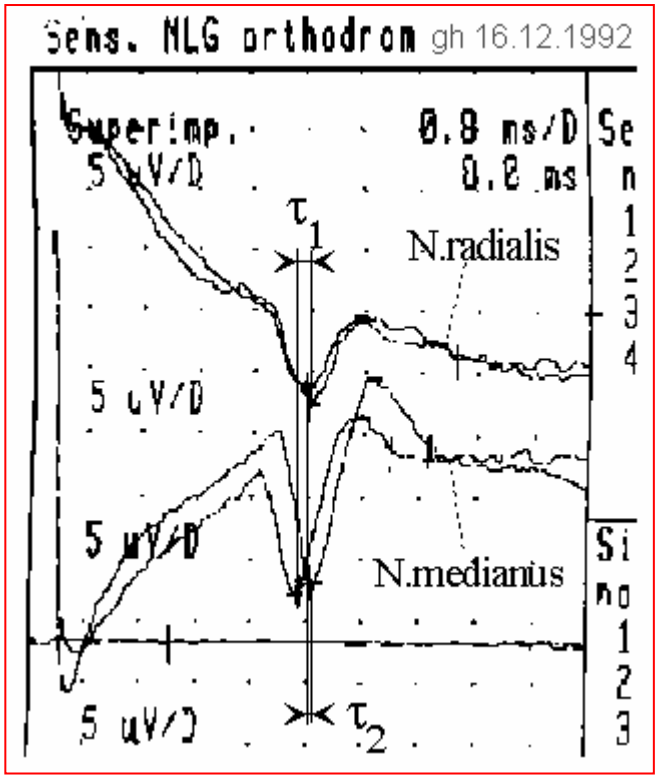
Arrangement:



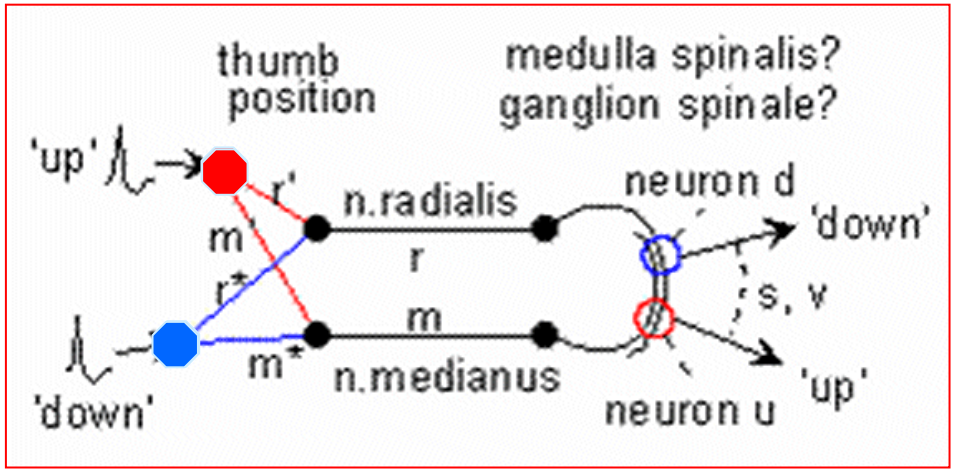




Result:



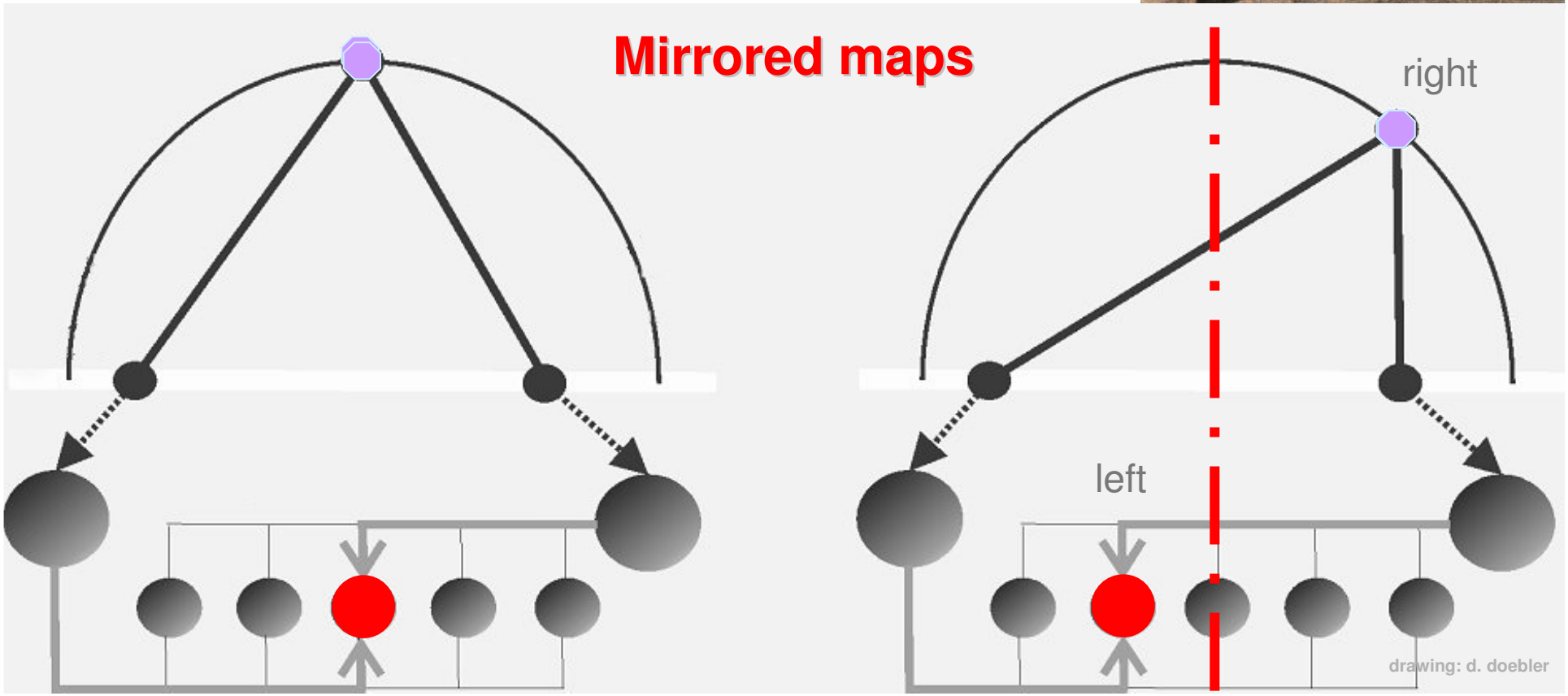
Interpretation:



Interference projection 1993

Konishi, Mazakazu: Die Schallortung der Schleiereule. Spektrum der Wissenschaft, Juni 1993, S. 58 ff.; (Biologist, Caltech Pasadena)

Jeffres L. A.: A place theory of sound localization. J. Comp. Physiol. Psychol. 41 [1948]: 35-39



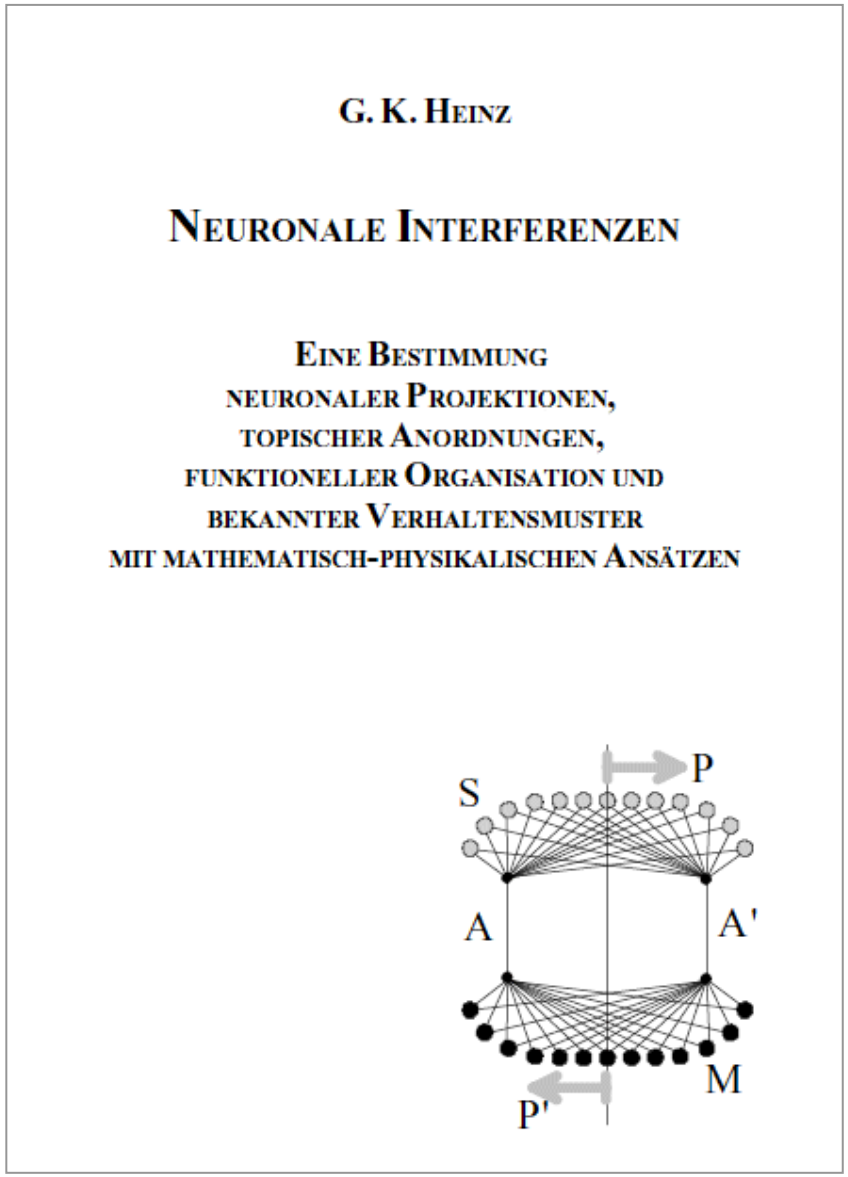
Manuscript "Neuronale Interferenzen" 1993

- Far away from ANN-mainstream: Acumulation of ideas (300 pages)

- Main content: categorization of nerve wave projections
- Zooming, Movement, …
- Hyperbolic, eliptic … projections
- Overlay, konjugation …
- Dermatome projections
- Biomodels: skeleton feedback control system …

- Download:

http://www.gfai.de/~heinz/publications/NI/index.htm

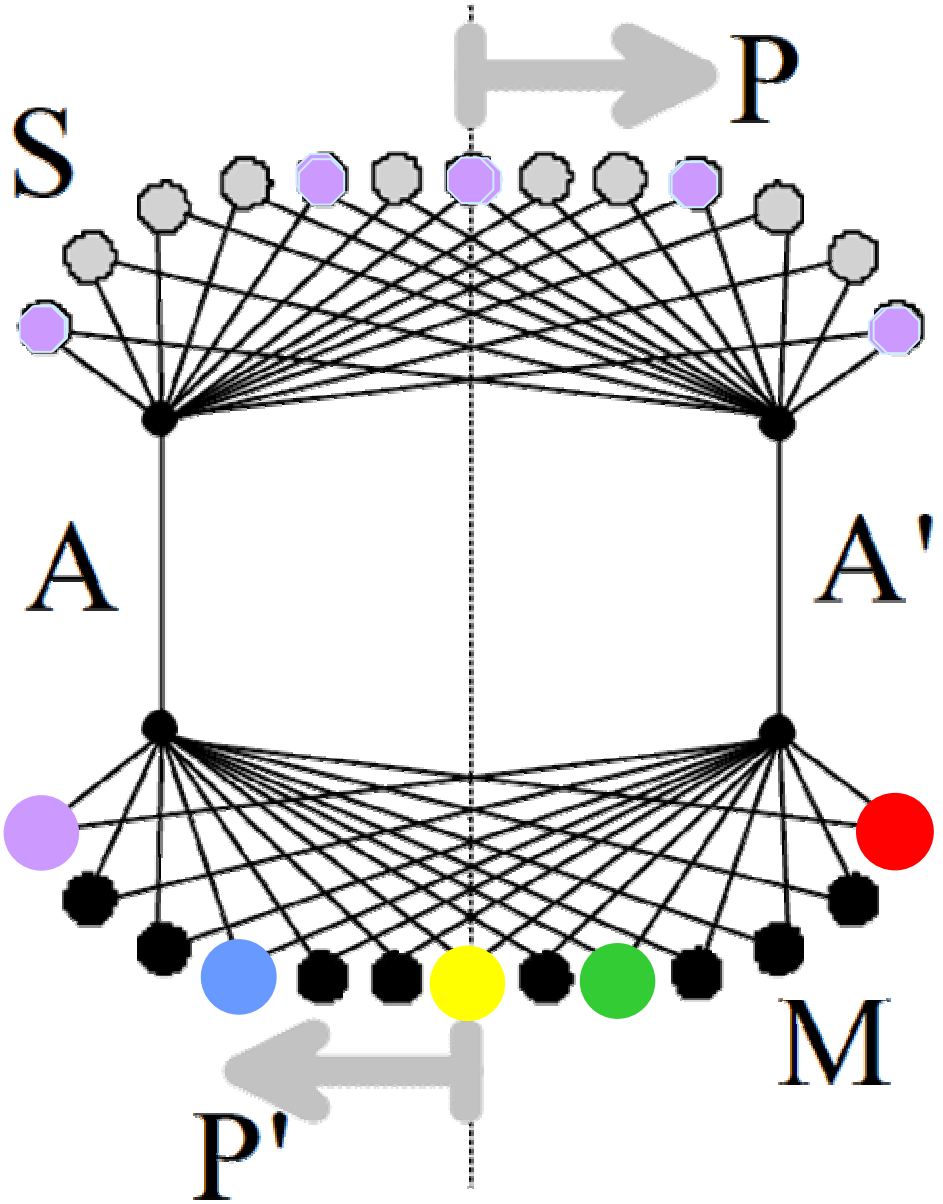


"Logik bestätigt lediglich die Errungenschaften der Intuition"
J. Hadamard

Nerve Projection 1993

- Signals meet at locations with identical delays from source
- (all other cases not drawn)
- Specific neurons begin to communicate (P <-> P') it seems, they are connected by a single wire
- Mirroring projections appear
- Not wires define the information flow
- Address relations between different locations are given by delays
- "Time codes location"

(only successful excitements drawn)



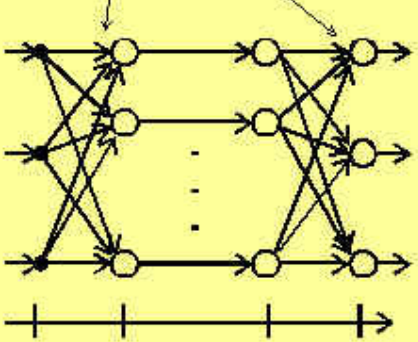
Source: Titelbild Heinz, G.: 'Neuronale Interferenzen' (1993)

ANN <-> IN (1996)

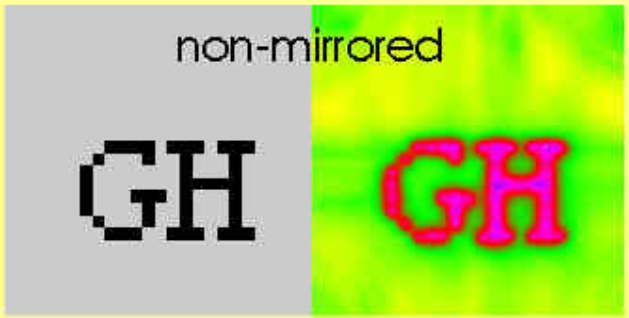
Views

'neural network'

weights & levels



discrete time

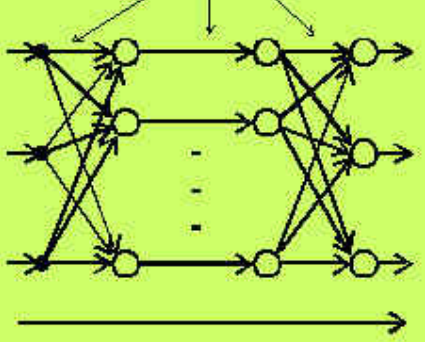


in out

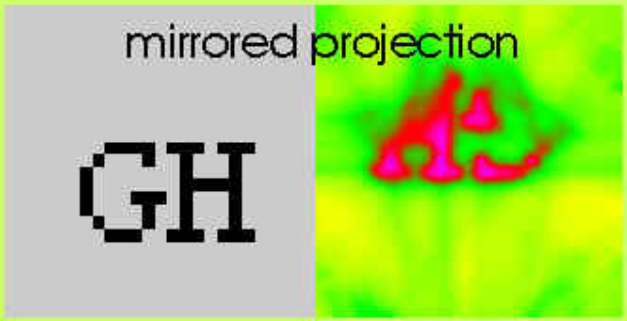
mathematical approach:
What is the value?

'interference network'

delays & spikes



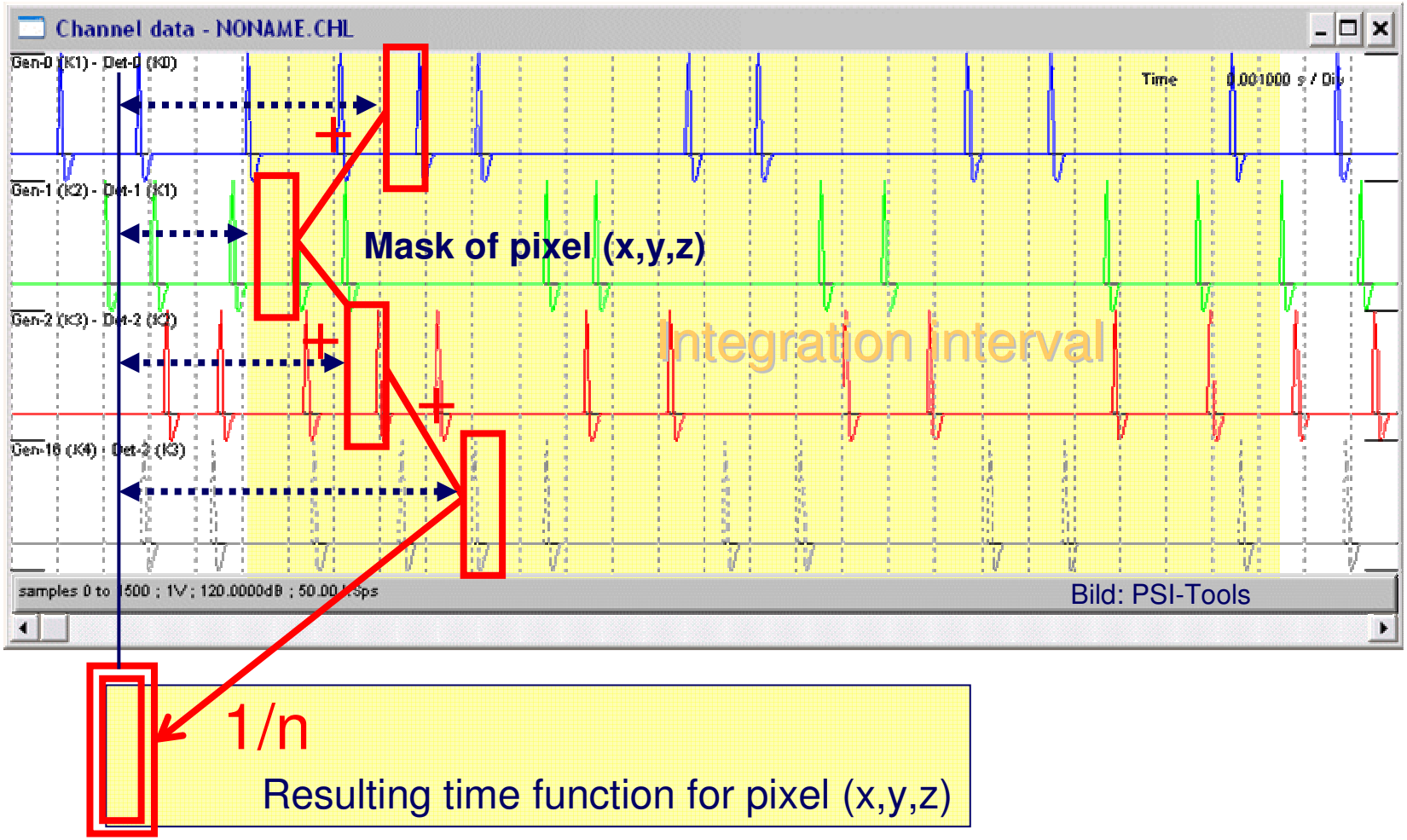
continous time



in out

physical approach: Where is the interference location?

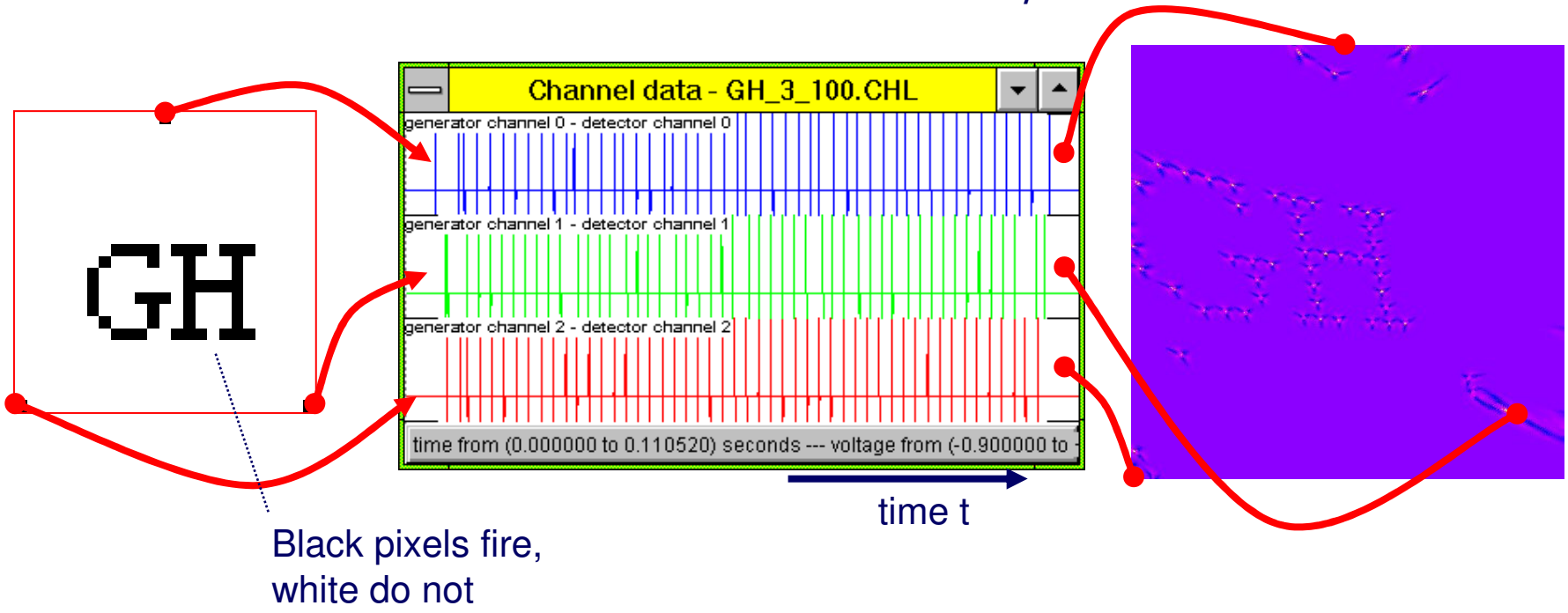
Mask-Algorithm 1993 → Acoustic Camera



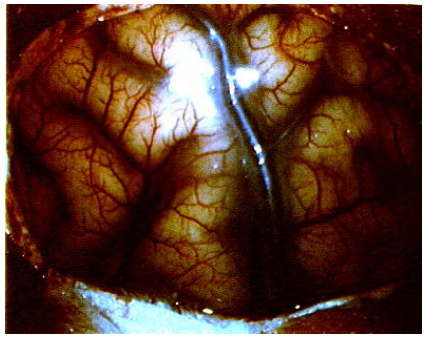
used for image reconstruction "Acoustic Camera"

Spike-Wave Image 11/1994

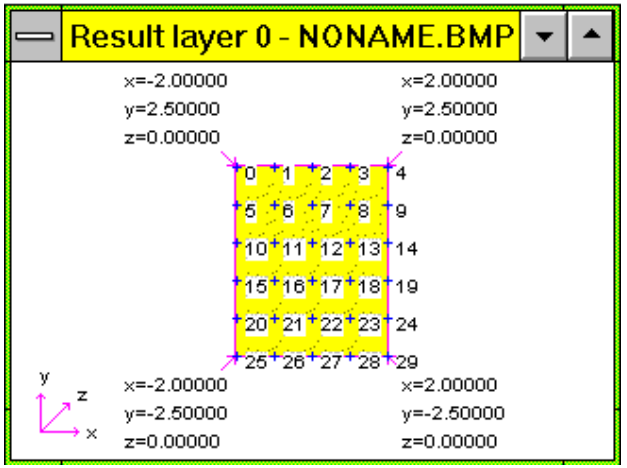
- High resolution interference reconstruction (type f(t+τ) Nov.14, 1994 (reconstruction with delay compensation)
- 3 channels, add-exp. Algorithm, 400x400 pixel
- Software PSI-Tools, written by Sabine Höfs
- Calculation time ~ 17 hours on Intel i386 33MHz/ i486 25MHz

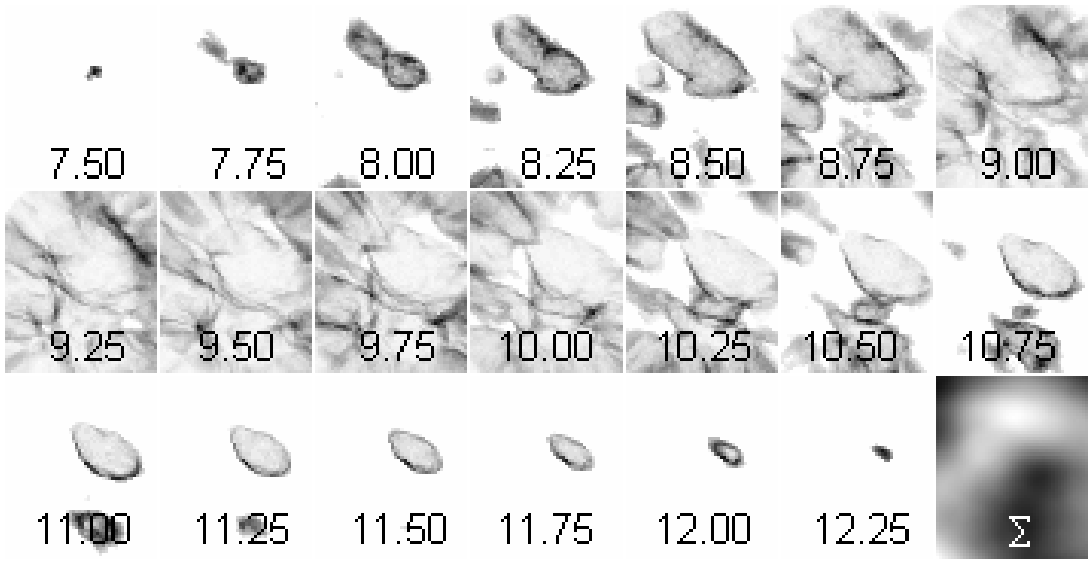


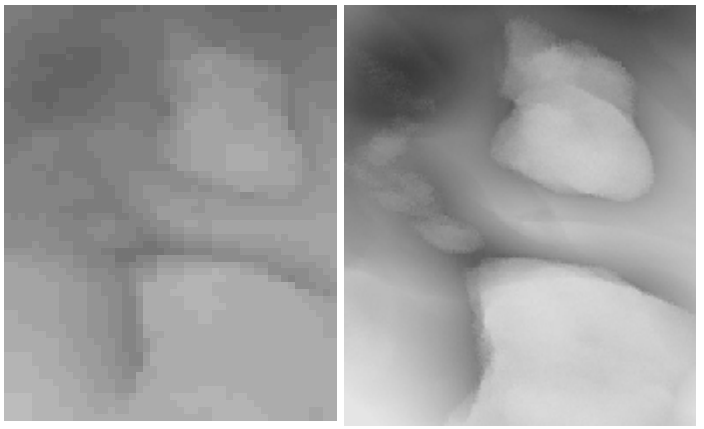
NLG-ECoG Maps 9/1995



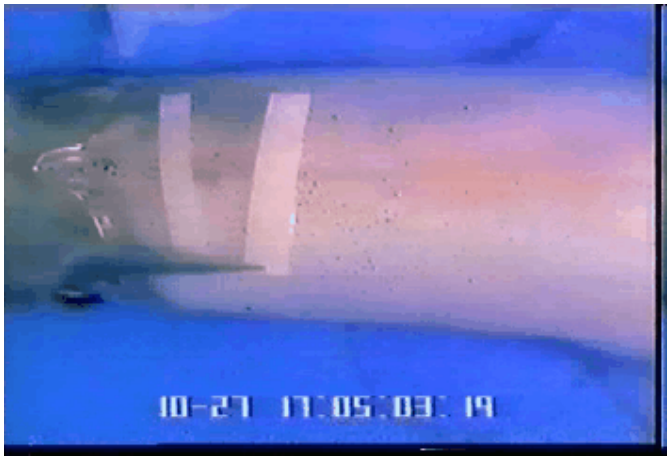
- Interference reconstruction of electro-corticograms (ECoG)
- Data sets with 30 channels from Charite,
  PD Dr. Bartsch, Hr. Krüger
- Result was sometimes not noise, see images
- Not published, further investigations necessary
- Some documents on the www

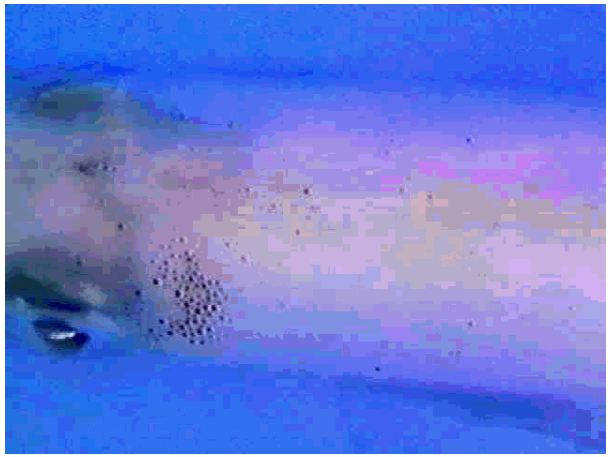






Waves on Squids: Andrew Packard 10/1995

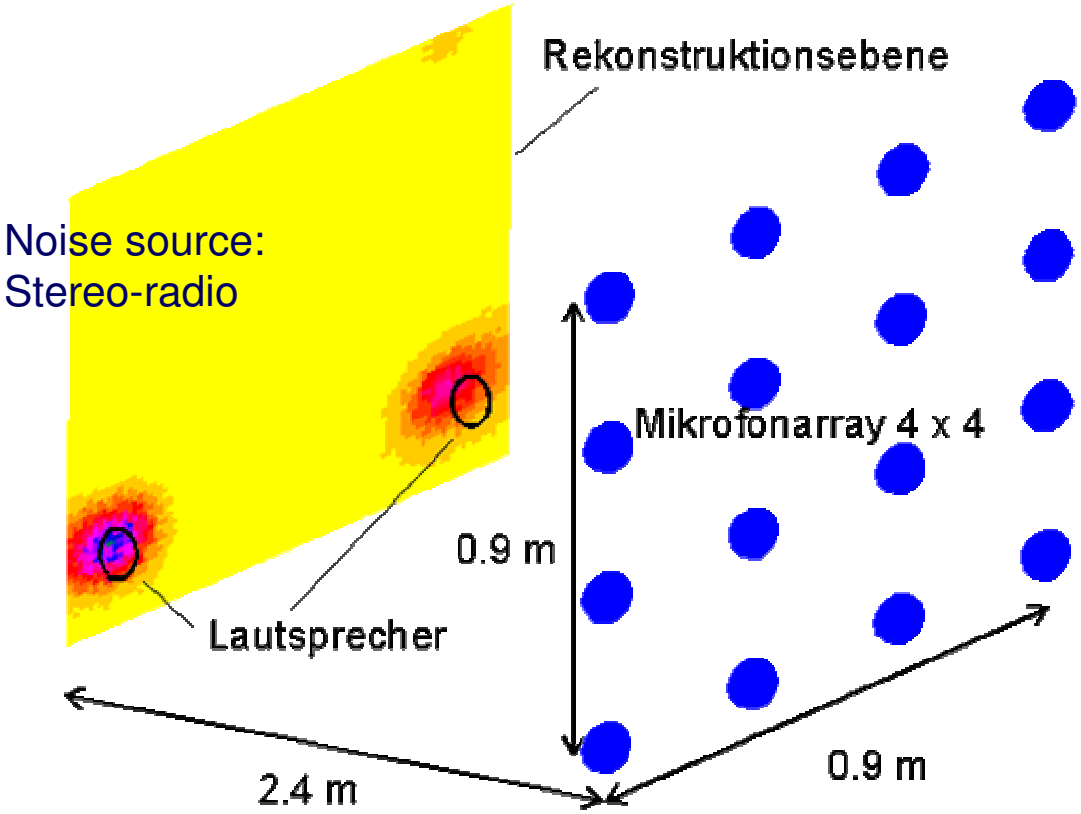


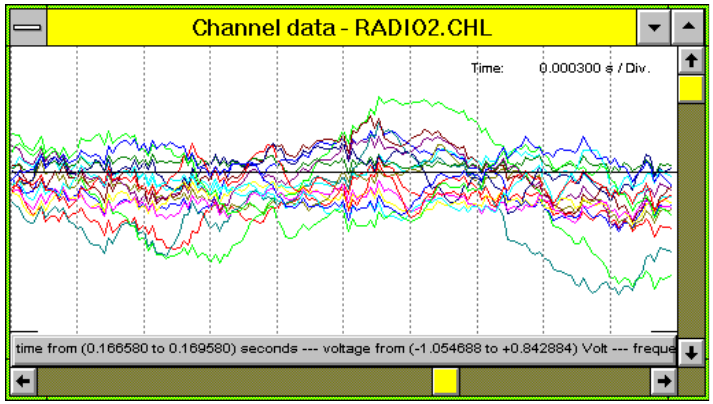



- Packard, A.: Organization of cephalopod chromatophore systems: a neuromuscular image-generator. In Abbott, N.J., Williamson, R., Maddock, L., *Cephalopod Neurobiology*, Oxford University Press, 1995, pp. 331-367
- Packard, A.: A 'neural' net that can be seen with the naked eye. In Backhaus, W. (ed) 2001 International School of Biocybernetics (Ischia): *Neuronal coding of perceptual systems*: pp. 397-402. World Scientific, Singapore, New Jersey, London, Hong Kong
- See www.gfai.de/~heinz/historic/biomodel/squids/index.htm

First Acoustic Photo 1994

- Pressboard-plate with 16 microphones
- Data recorder with 16chl. 50 ks/s UEIDAC WIN30DS
- 3 days calculation with PSI-Tools
- debugging the software waves occured (!)





Erste Bilder, erste Filme

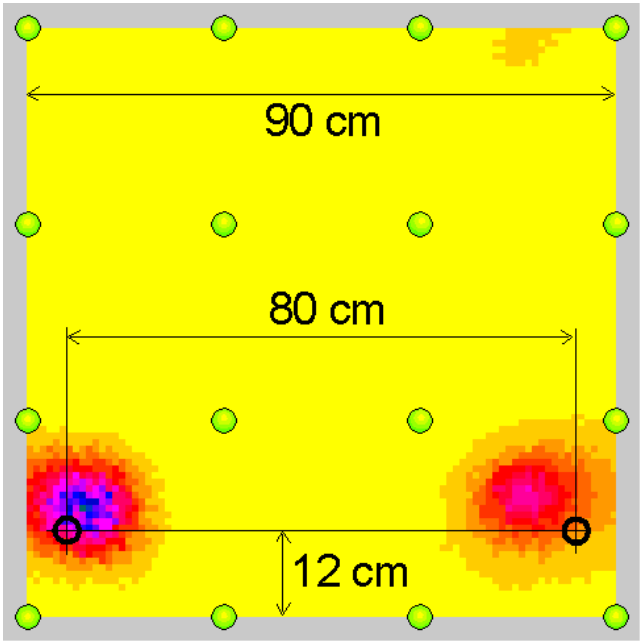
(a) Stereo-loudspeakers, 16 chl., 2.40 meter, 1996

(b) Film: Motorbike, 16 chl., 1x1 m array 1997

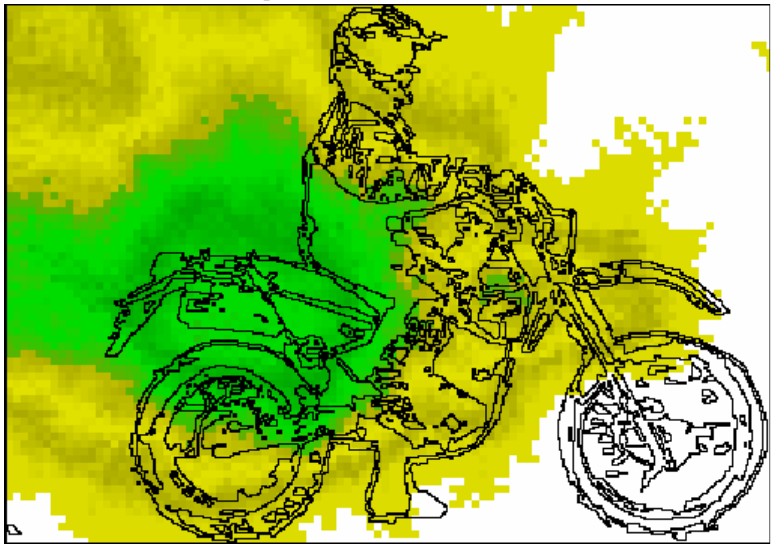
(c) Line scan, 16 chl., 1x1 m array 1998 (first at MBB, 1993)

(Software Sabine Höfs, Hardware Carsten Busch, Bilder: GH)

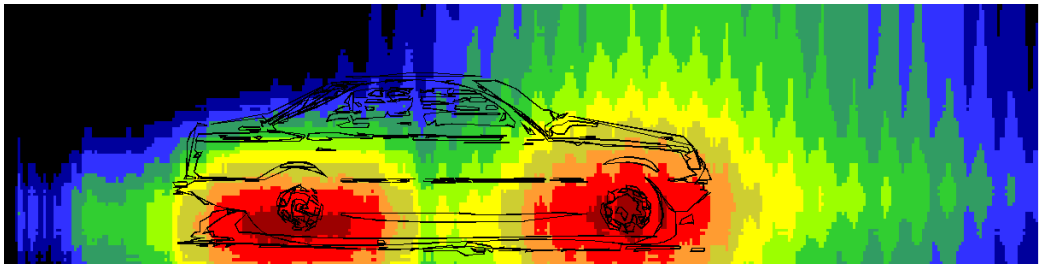
(a)



(b)



(c)



First Visualization of Mirroring Noise 1997

GEO전망대

소리를 찍어 내는
음성 사진기

기술

마이크 열여섯 개와 컴퓨터

소프트웨어를 이용해 소리가 발생하는 위치를 매우 정확하게 알아낼 수 있게 되었다. 인간 두뇌의 신경 활동을 연구하던 독일의 국소전자 공학자인 게르트 하인스는 무심코 뇌전극 대신에 마이크를 충전기에 연결했다가 과학사에 커다란 획을 긋는 음성 사진기를 탄생시켰다.

이러한 '음성 사진' 촬영은 음성 사진기와 특별한 컴퓨터 프로그램에 의해 가능해진다. 사진기는 정사각형 모양으로 배열된 열여섯 개의 마이크다. 이 사진기는 엄밀하게는 소리를 인식하는 일종의 대물렌즈 역할을 한다. 이 마이크가 포착한 소리 음파가 컴퓨터로 전송되면 컴퓨터는 사물의 '소리 영상'을 보여 주게 된다. 소리가 큰 지역은 컴퓨터 모니터에 파란색이나 연보라색으로 나타나고, 소리가 약한 곳은 빨간색이나 초록색, 노란색으로 표시된다. 소리의 발생지를 찍은 사진과 음파의 강도를 표시한 색깔이 서로 겹쳐지면 비전문가들도 어디에서 소리가 들려오는지 정확히 알 수 있다.

컴퓨터에 내장한 특수한 프로그램은 정보학자 사비네 호프스가 개발했다. 이 소프트웨어는 소리가 발생지에서부터 마이크 하나하나에 도달하기까지 음파의 차이를 기록하는데, 이것은 인간의 두뇌가 소리의 발원지를 찾아 내는 것과 비슷하다. 눈을 감고 있어도 소리가 어디에서 들려오는지 알 수 있는 것처럼 음성 사진기도 소리의 근원지를 찾아 기록하는 것이다.

단지 차이점이라면 음성 사진기가 사람보다 훨씬 더 정확하게 위치를 파악한다는 것이다.

기어를 중립에 놓은 자동차에서 소음이 나면 사람들은 으레 엔진에 이상이 생겼다고 생각한다. 하지만 음성 사진기는 엔진은 비교적 적은 소리를 내며, 엔진 아래 놓여 있는 소음기와 이 소음기의 소리를 되울리는 아스팔트가 정본인이라는 것을 금세 알아 낸다. 하인스와 동료들은 이 사실을 간단한 관찰을 통해서 확인했다. 즉 눈이 많이 쌓인 곳에서 달리는 자동차는 비교적 소음이 적다. 이는 눈이 소음기의 소음을 삼켜 소리를 더 적게 내기 때문이다. 음성 사진기를 통해 잔디 깎는 기계가 내는 시끄러운 소리 역시 타이어의 벨브가 원인이라는 사실도 확인되었다.

많은 공학자들은 이러한 원리를 이용하면 소음이 심한 공장에서도 그 원인을 쉽게 찾을 수 있어 소음을 줄이는 게 가능할 것으로 전망하고 있다. 이제 음성 사진기 기술은 소리가 나오는 곳이라고 해서 무조건 소음이 가장 심한 것은 아니다. 흔히 비행기의 소음기가 굉장한 굉음을 낸다고 생각하지만 실제로는 아스팔트가 여객기의 소음을 강하게 반사해 더 큰 소음을 낸다는 것을 알 수 있다(왼쪽). 형광빛을 발하는 해파리종이 엽록체 내부를 참히 비추고 있다. 이 실험으로 지금까지 알려지지 않았던 식물의 엽록체 사이에 연결관이 존재하고 있음이 밝혀졌다(아래).

사진을 한장 한장 찍는 원초적 수준에서 벗어나 연속 촬영이 가능할 정도로 발전했고, 초당 5만 장까지 찍어 내는 고속촬영법도 개발되었다. 이를 바탕으로 음성 필름까지 만들어질 수 있게 됨으로써 이제 엔진이나 연동기의 소음을 획기적으로 줄일 수 있게 될 전망이다.

상호 연락을 취하는 녹색 발전소
'엽록체'

세포생물학

지구상에서 벌어지는 거의 모든 생물의 탄생 과정은 태양을 중심으로 이루어지고 있다. 특히 식물은 햇빛의 도움으로 광합성 작용을 해 유기물이나 산소를 생성해 낸다. 식물 세포의 에너지 공급을 담당하고 있는 엽록체는 서로 긴밀하게 정보를 교환하고 있다. 지금까지 사람들은 식물의 '녹색 발전소'라는 별명을 가진 엽록체가 서로 아무런 접촉도 하지 않는다고 생각했다. 하지만 최근 실시된 실험에서 엽록체의 대부분이 미세한 관을 통해 서로 연결되어 있음이 밝혀졌다.

미국의 코넬 대학 생물학자 모린 핸슨 연구팀은 나팔꽃의 일종인 페튜니아와 담배 세포에 있던 엽록체를 현미경에 비춘 뒤 좀더 자세히 관찰하기 위해 해파리종 유전자를 투입했다. 엽록체 안에서

(Korea)
GEO 지오
1997 11

1997년 11월호 / 통권 제57호
1997년 11월 1일 발행

등록번호 공보 라 - 06182
등록일 1992년 3월 13일
발행인/편집인 서정권

기자 조은주/이혜원/박영숙/송수진/정영호
디자인 강윤희/황진희
자료수집 Heidrun Reinhardt
편집지원 오은경/이은경/정호정/홍석현
해외섭외 명종옥/이의도/송문영
마케팅 김인섭/조영권/나선택
독자봉사 손영숙/차은미/김영이
광고 이혜원/이창수/권순억
영업 김경우/홍성용/한현우/송병석
경리 문용대/김현섭/박은정/전미현

발행처 주식회사 두비
대표이사 서정권
이사 송영진
최택호(전무)
이억일(상무)
박용진

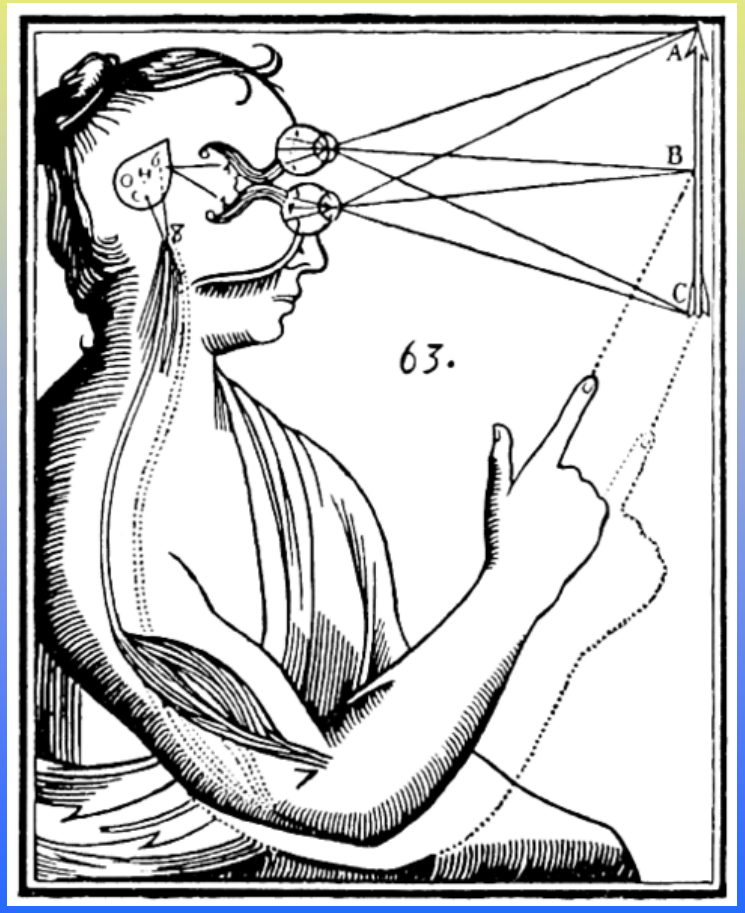
전화 (02)776-4100(代)
(02)319-4471(편집부)
(02)775-4034(독자봉사부)

팩시밀리 (02)755-9860(代)
(02)775-4037(편집부)

Boeing 737-400
16 chl. 1x1 m array
30 m distance
mics: MK250 Gefell

Theoretical Background

Any intelligent fool can make things bigger, more complex, and more violent.
Albert Einstein



Mind-body vision of
René Descartes
(1641)

What is an Event?

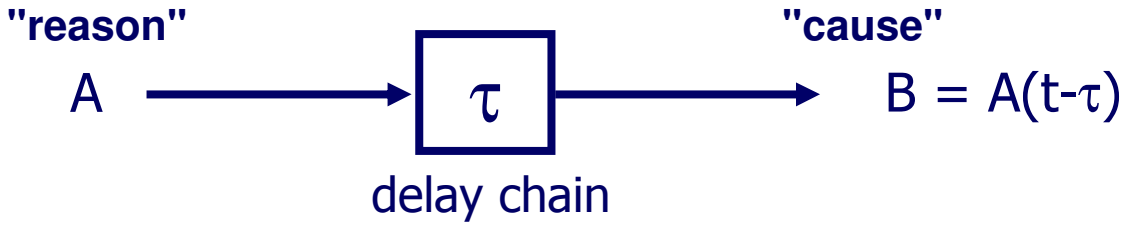
- Together (Greek: syn-)
- in the same time (Greek: chronos)
- At the same place (Greek: topos)

Examples for Synchrotopy:

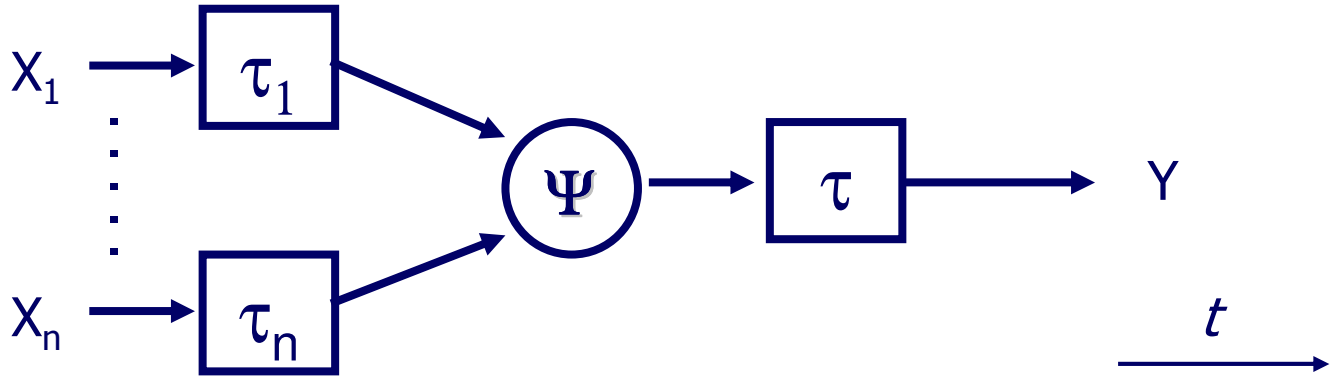
- Traffic accident (airplane-heli crash)
- Chemical reactions
- Combination of Timefcts.:
  Radar, Acoustic Camera, Optics

Causality

- Arthus Schopenhauer: "Any reason A produces a cause B"

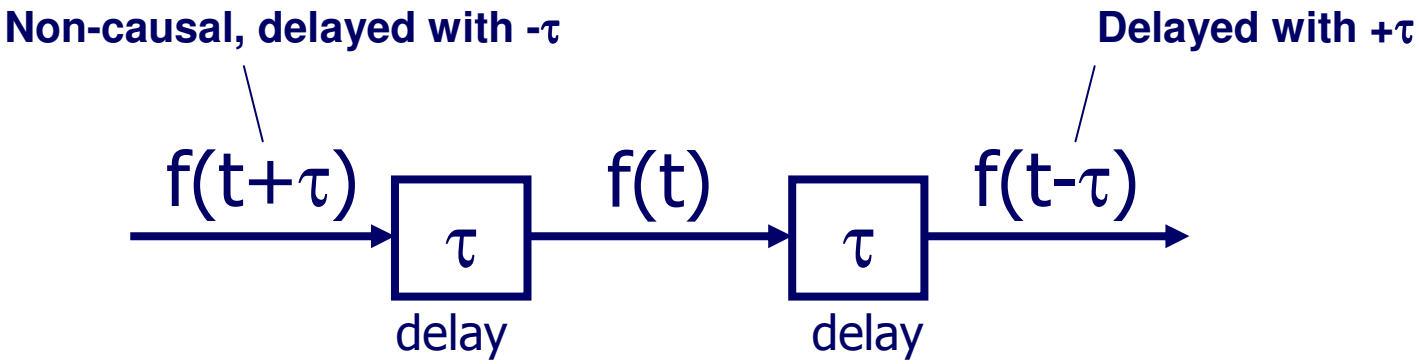


- Schopenhauer's case is a delay chain – a trivial case
- Interference systems: X_1 combined with $X_2 \ldots X_n$ causes Y



Delay and Time Function

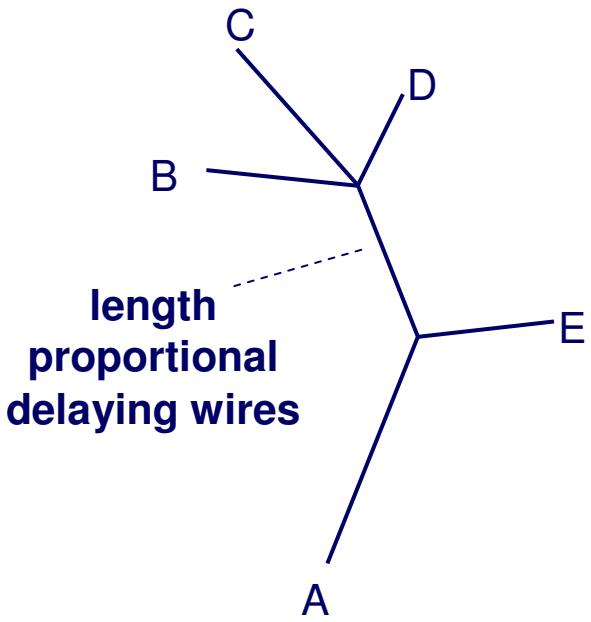
- time function delayed by +τ: f(t-τ)
- time function back-delayed by -τ: f(t+τ) -> non-causal
- Delays are not integer -> float numbers (!)

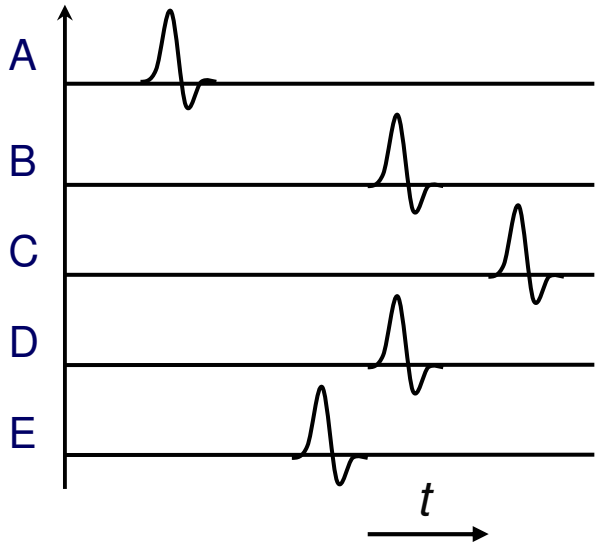


- Time function visualization is confusing:
  time-axis is x-axis (oscillogram)
- we can not look on the time, only on locations

Connection Scheme produces Timing Scheme

Distance dr —velocity→ **Delay dt**



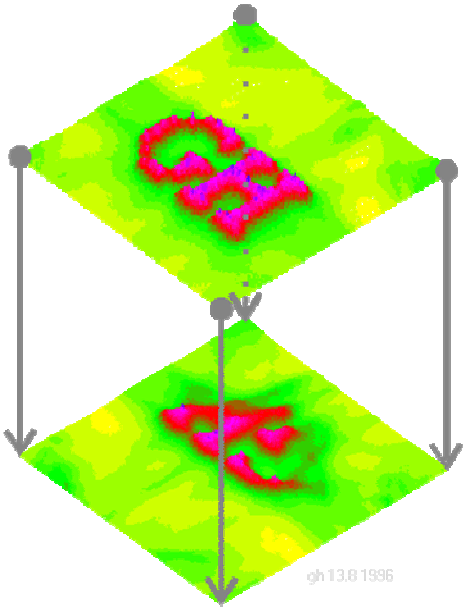


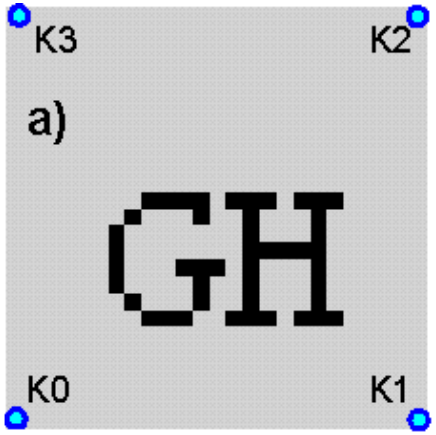
How to get syncausality in large systems?

- Integrated circuits: connection scheme dominates the timing scheme
- Nerve system: dito
- Radar, Sonar, Acoustic Camera, optical lense systems: dito

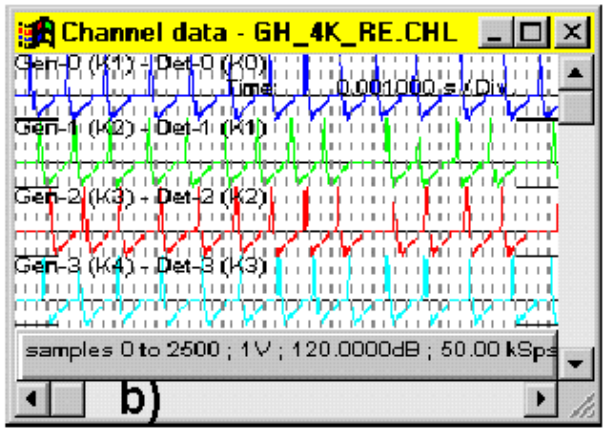
I²-Tasks

- Reconstruction of generating field
  - → Acoustic Camera task
  - → Non-causal delays $f(t+\tau)$
  - → Time fct. inversion $-f(t)$
- Projection into a detecting field
  - → Nerve type $f(t-\tau)$

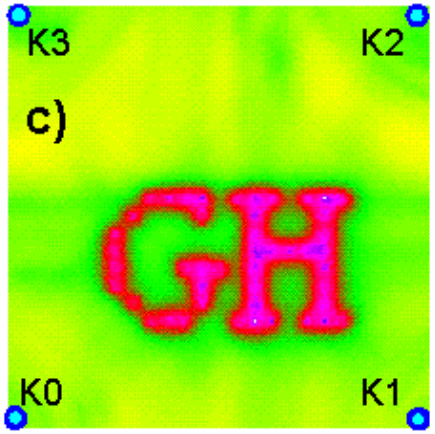




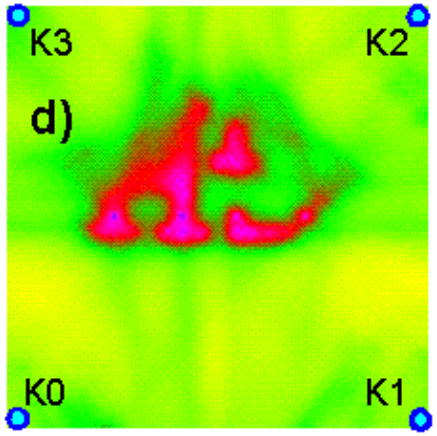
Generating field



Time functions



Reconstruction



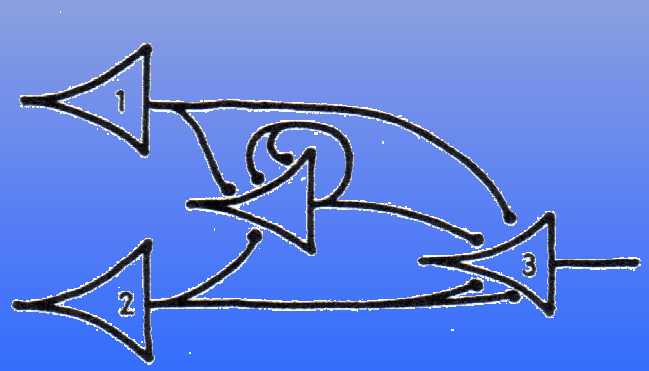
Projection

If theory should wait on experience,
it would never exist.
Friedrich von Hardenberg

Time Functions in One Dimension

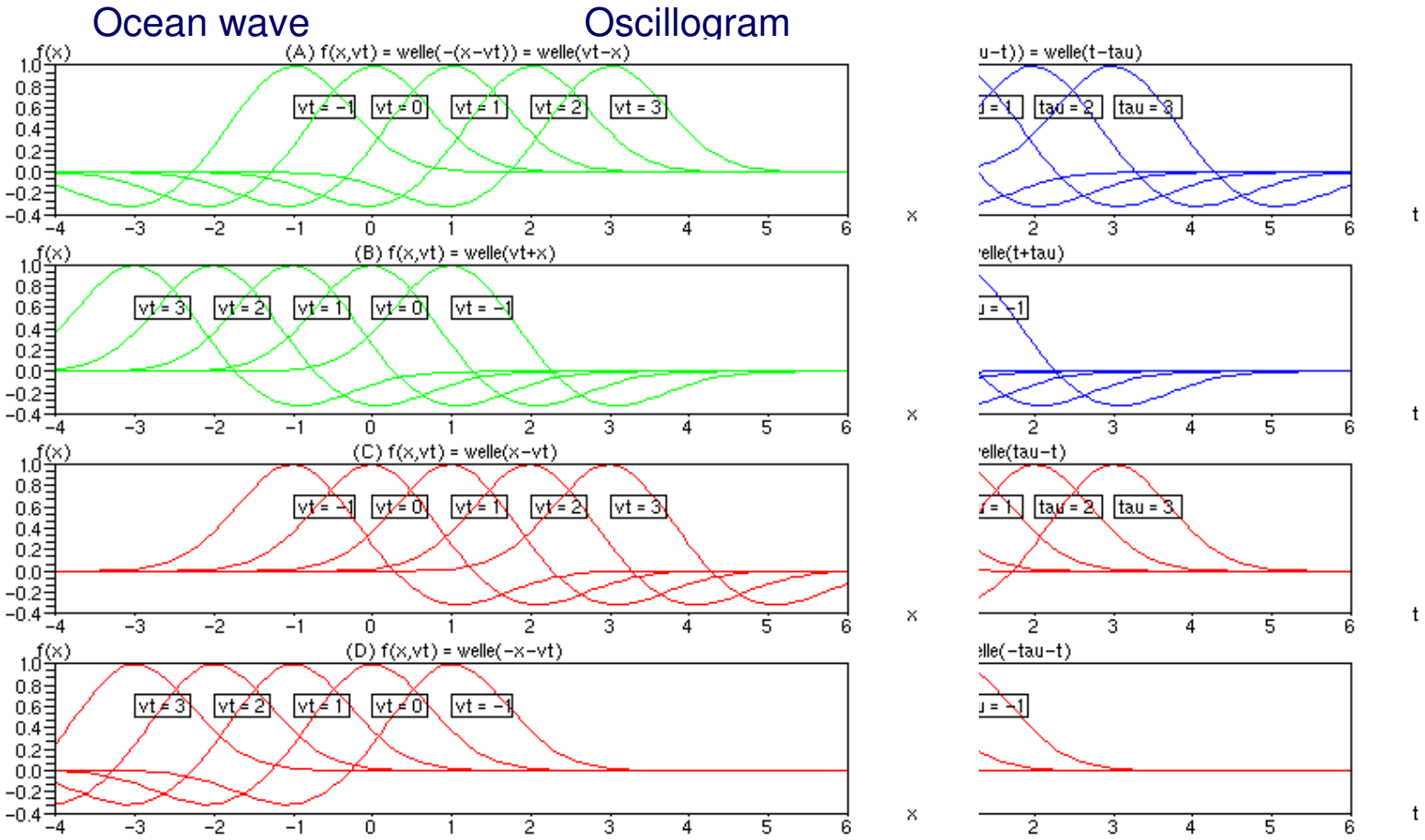
"d' Alembert Waves"

- Space- and time functions
- Interference integral

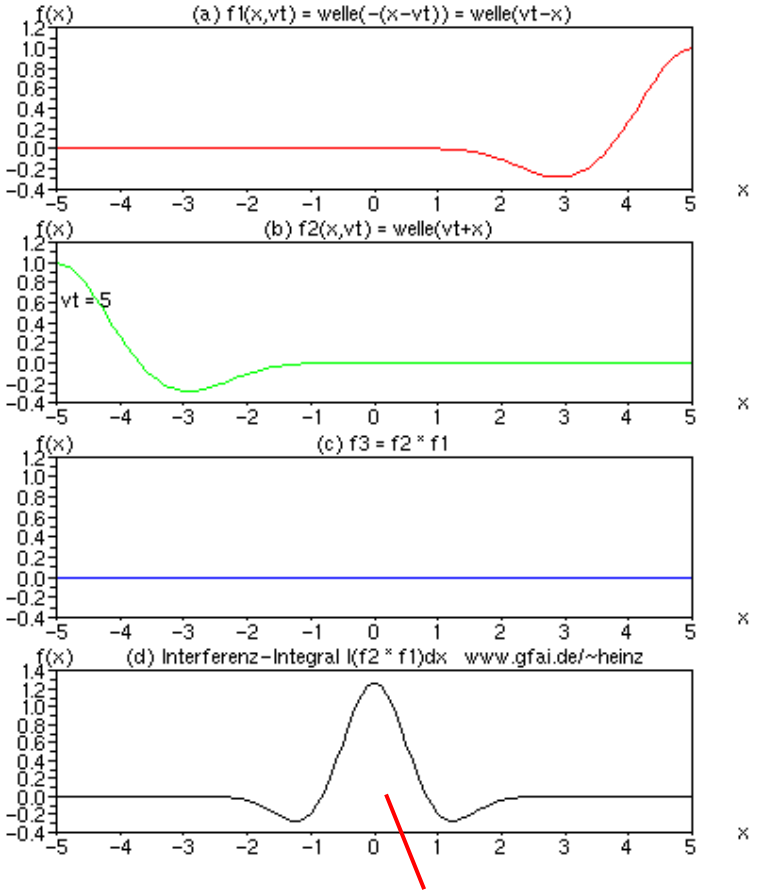


Space- and Time- Function

- Dual views: Space function (fixed time) or time function (fixed location)
- Substitution x = vt ←→ t = x/v



Interference Integral (I^2)



"Interference Integral (I^2)"

```
// Scilab function definition:
deff('y=gauss(u)','y=exp(-(u)^2)');
deff('z=welle(w)', 'z=gauss(w) - .3*gauss(w-2)');
//                      (wave peak)      (wave tail)
```

First wave:

f1 = welle(vt-x);

Second wave:

f2 = welle(vt+x);

Multiplication (or addition):

f3 = f1 * f2

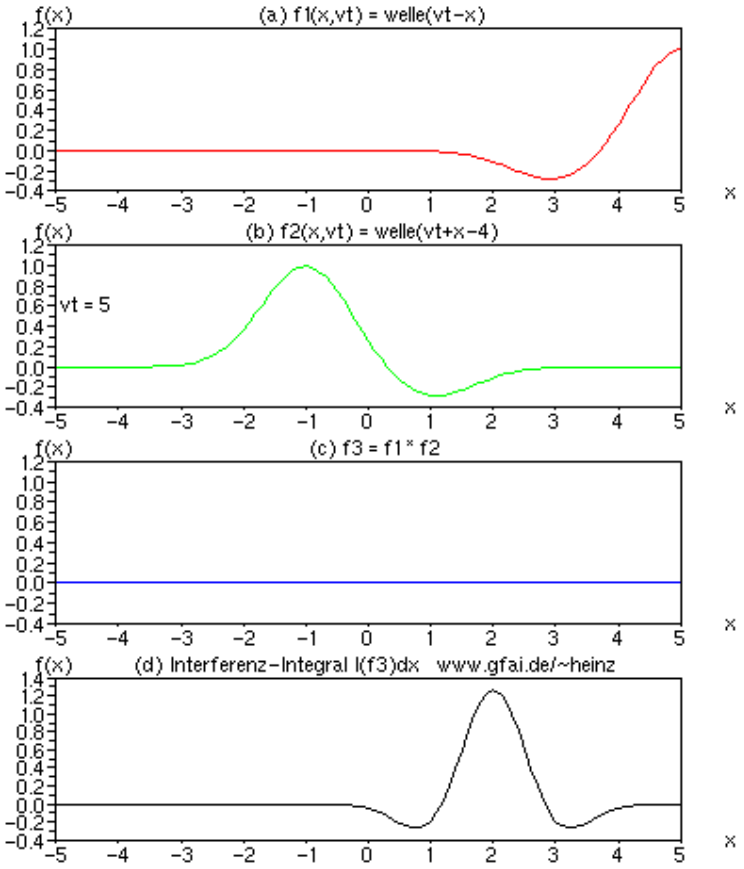
Integration:

f4 = f4 + f3

initial = 0

See Scilab-sources at http://www.gfai.de/~heinz/publications/animations/index.htm

Movement of I²




```
// Scilab function definition:
deff('y=gauss(u)','y=exp(-(u)^2)');
deff('z=welle(w)', 'z=gauss(w) - .3*gauss(w-2)');
//                      (wave peak)      (wave tail)
```

First wave:

f1 = welle(vt-x);

Second wave delayed:

f2 = welle(vt+ (x-4));

Multiplication (or addition):

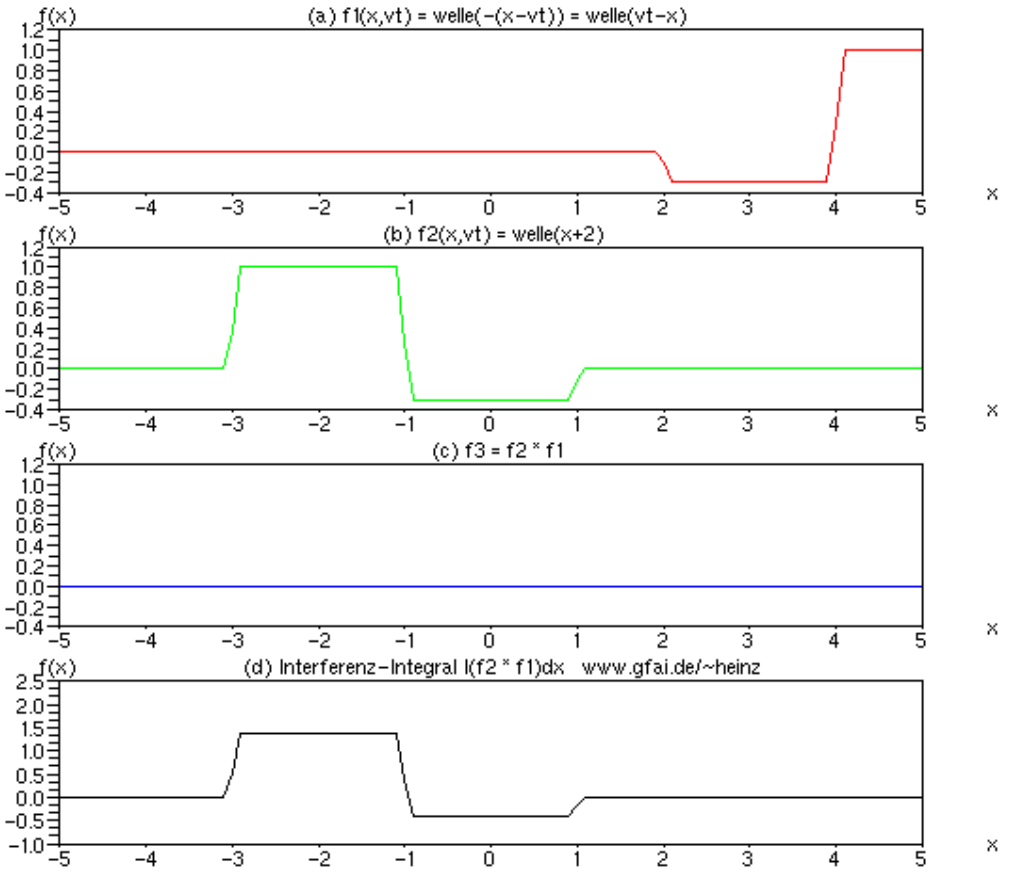
f3 = f1 * f2

Integration:

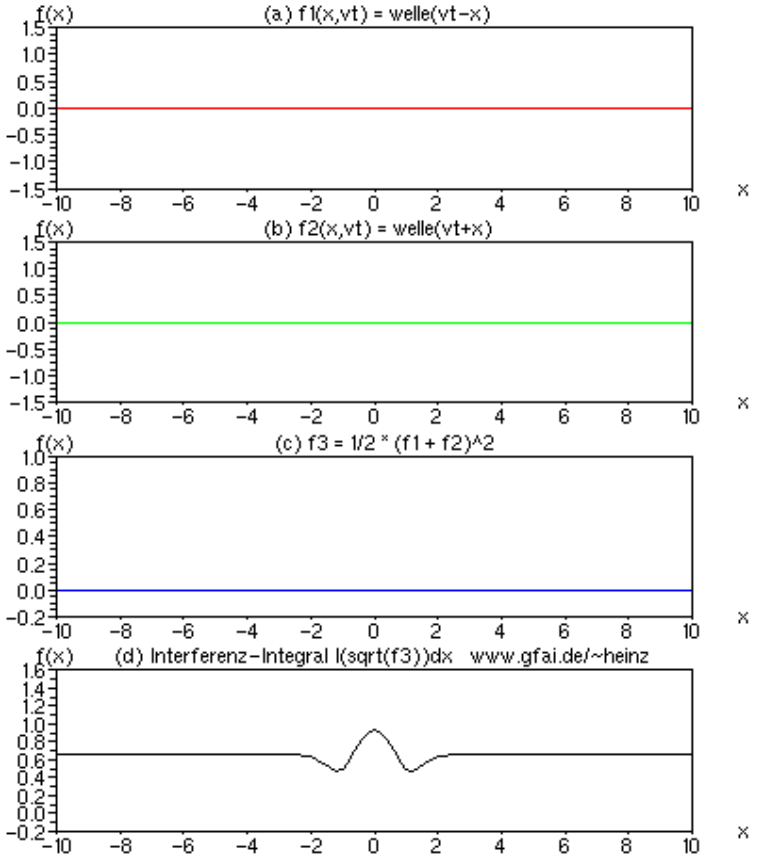
f4 = f4 + f3

Result: (x-r) produces shift by r/2

Mult Square Waves

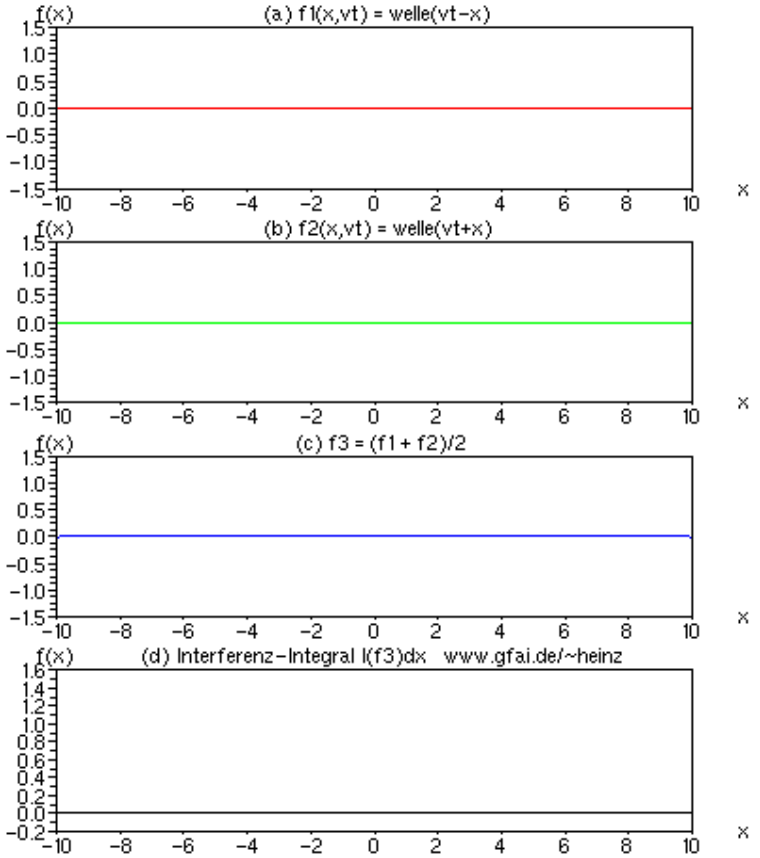


Add Effective Value



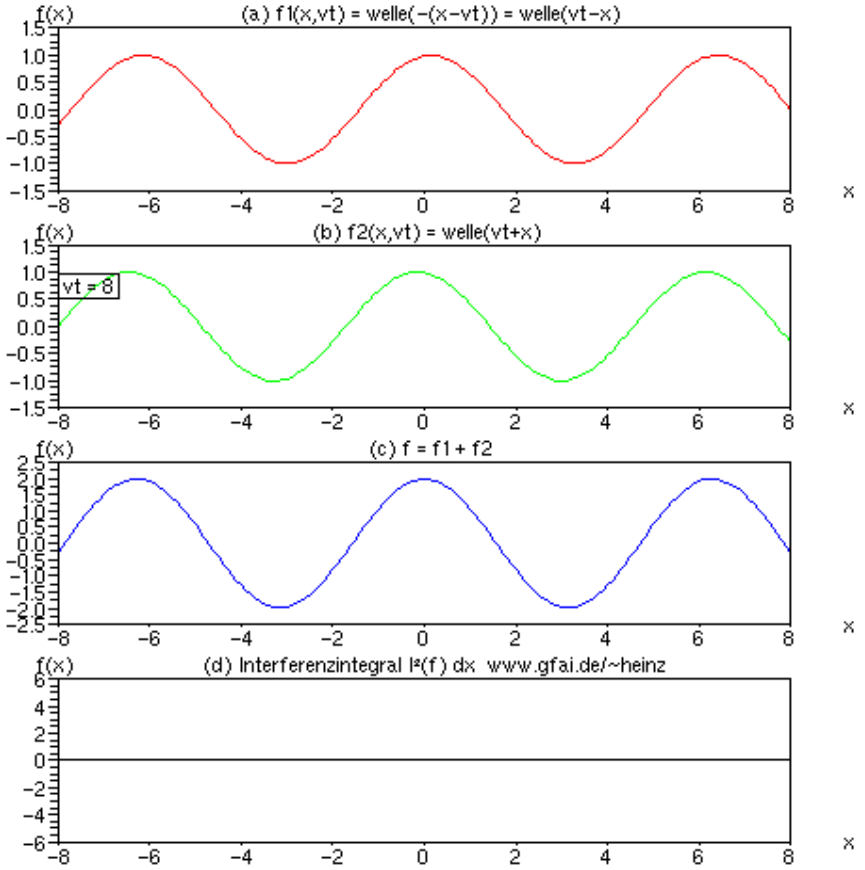
Add (pure)

- Interference Integral (I^2) disappears after excitement
- Rule: I^2 is zero or divergent



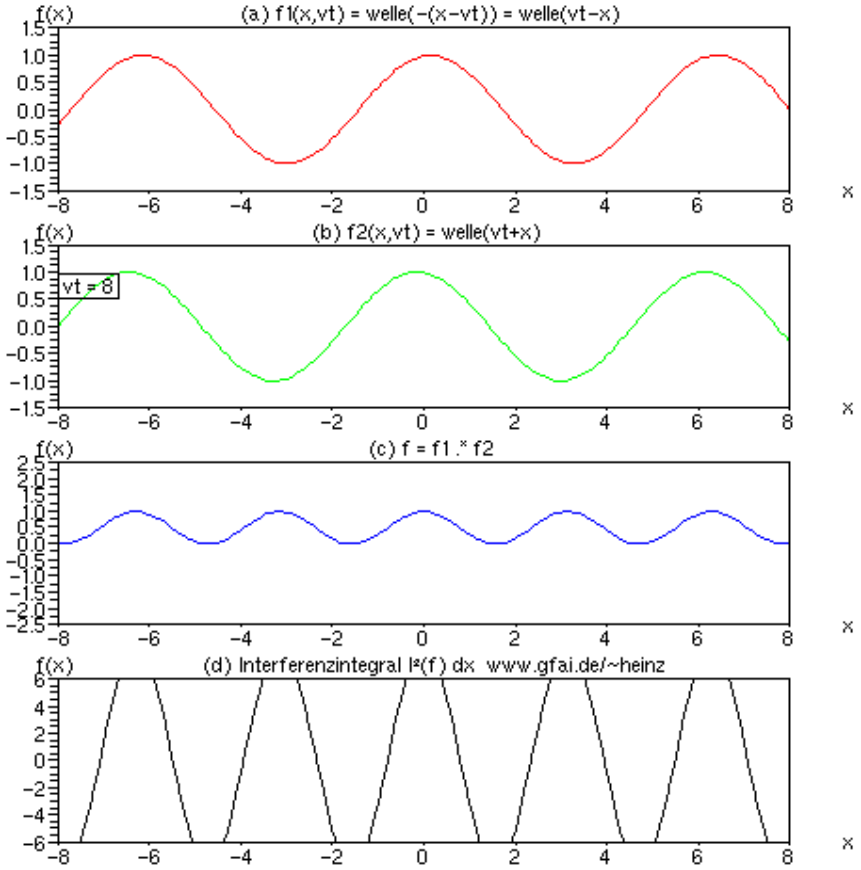
Add Sinus

- I^2 is zero



Mult Sinus

- I^2 is divergent
- Interference integrals grow to infinite (divergent) or stay zero
- Stop conditions:
  - Photographic film: shutter
  - Nerve: pulse reset



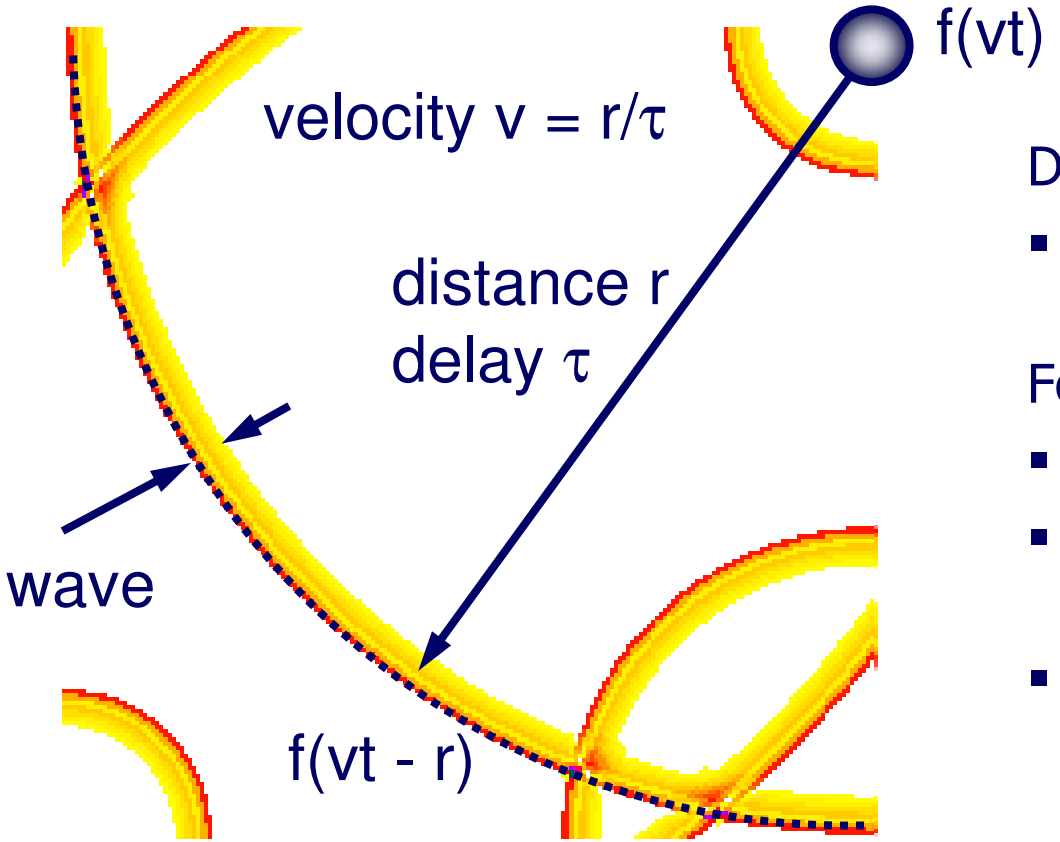
All great discoveries are made
outside the temples of science.
Carl Ludwig Schleich

Time Functions in Space

Up to now we calculated each sample (1D);
Calculating each pixel (2D, 3D) means:

Time function becomes a Wave Function

Time Function Wave



Delaying 2d-/3d- spaces:

- Time function becomes a non-physical wave

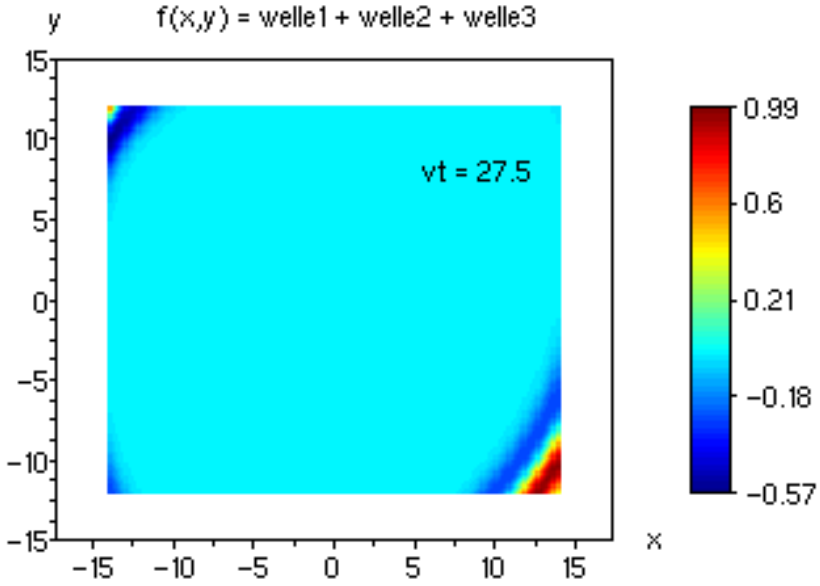
Forms:

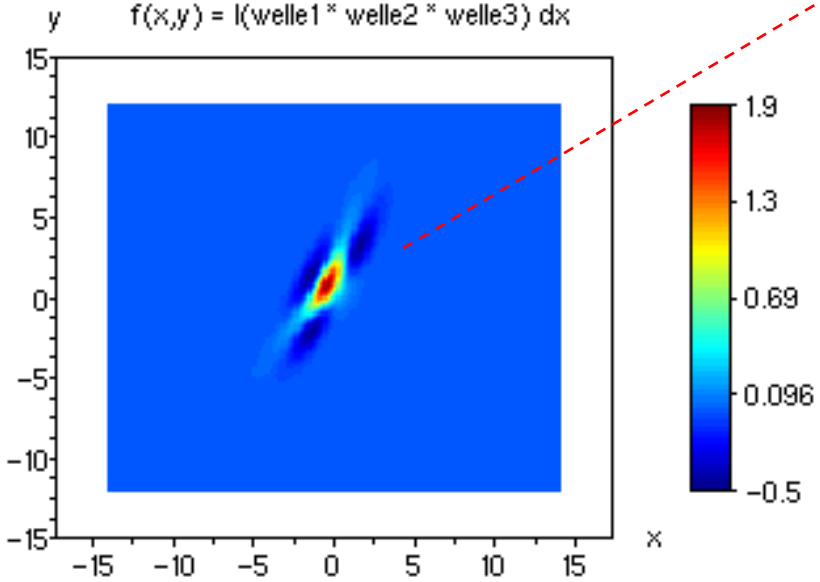
- time function f(t ± τ) →
- wave function g(v t ± r)
  velocity v: τ = r/v
- running paramter *vt* :
  waves come in motion

Time Function
→ Wave Function

- each pixel has individual delay τ to source
- points on circle have the same delay τ to origin of that wave
- each point can overlay different waves from different origins

Example 2d-Wave





Scilab (Matlab) function definition:

```
deff('y=gauss(u)','y=exp(-(u)^2)');
deff('z=welle(w)', 'z=gauss(w) - .3*gauss(w-2)');
welle1 = welle(vt - sqrt((x-x1)^2 + (y-y1)^2));
welle2 = welle(vt - sqrt((x-x2)^2 + (y-y2)^2));
welle3 = welle(vt - sqrt((x-x3)^2 + (y-y3)^2));
                        // (distance → tau)
```

Waves:

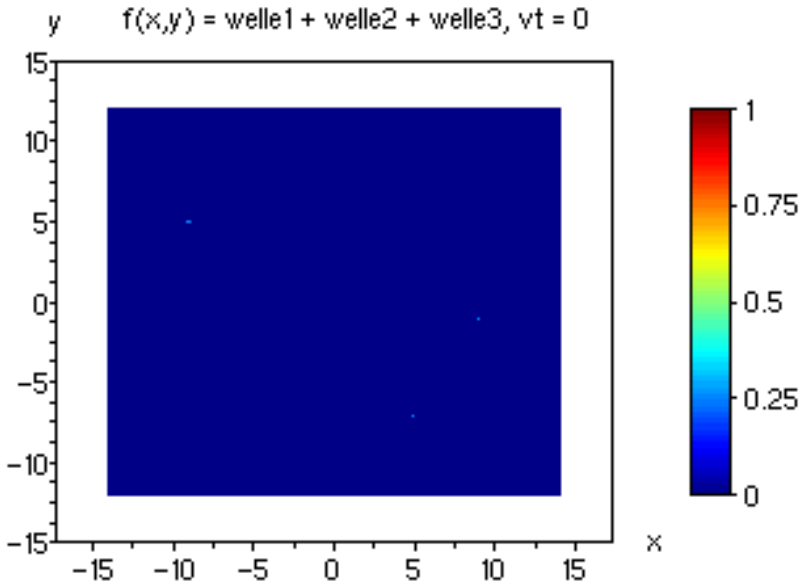
```
f(ix,iy) = welle1 + welle2 + welle3;
```

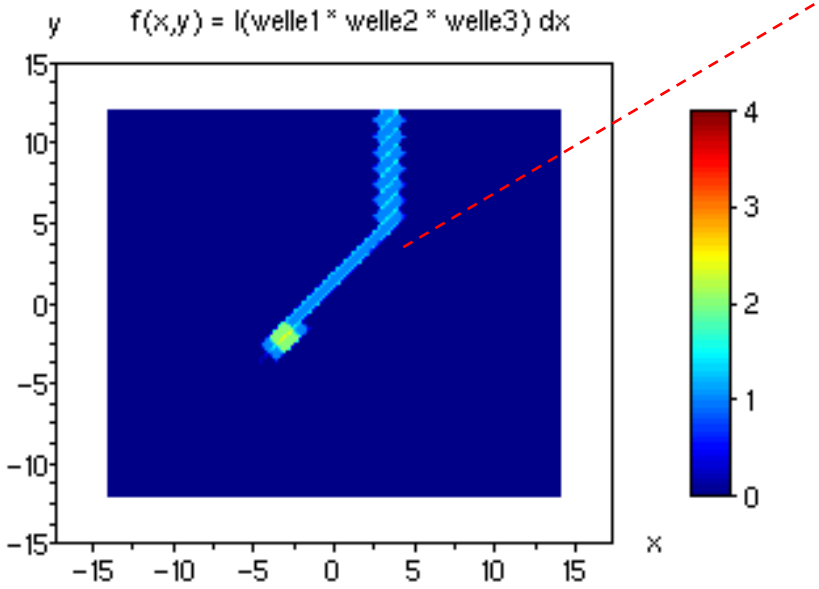
Interference Integral shows points of **synchrotopy**

Integration (Summation):

```
i(ix,iy) = welle1 * welle2 * welle3;
g = g + i;              // integral
                        // initial g = 0
```

Non-Euclidian Space





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deff('z=welle(w)', 'z=gauss(w) - .3*gauss(w-2)');
welle1 = welle(vt - abs((x-x1) + abs(y-y1)));
welle2 = welle(vt - abs((x-x2) + abs(y-y2)));
welle3 = welle(vt - abs((x-x3) + abs(y-y3)));
                        // (distance → tau)
```

Waves:

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

Interference Integral shows points of **synchrotopy**

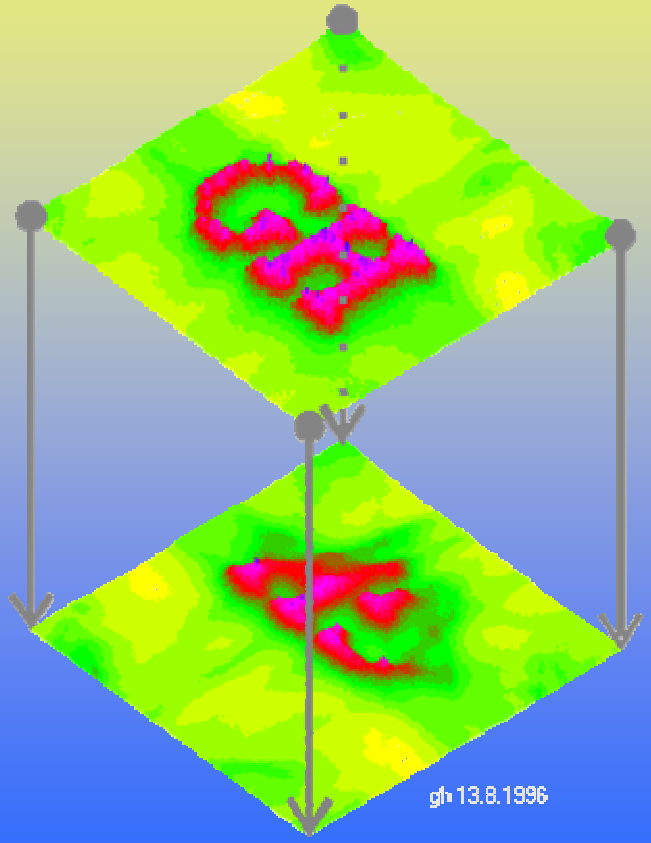
Integration (Summation):

```
i(ix,iy) = welle1 * welle2 * welle3;
g = g + i;              // integral
                        // initial g = 0
```

Properties of Interference Integrals (I^2)

The trouble with the world is
that the stupid are sure
and the intelligent are full of doubt
Bertrand Russell

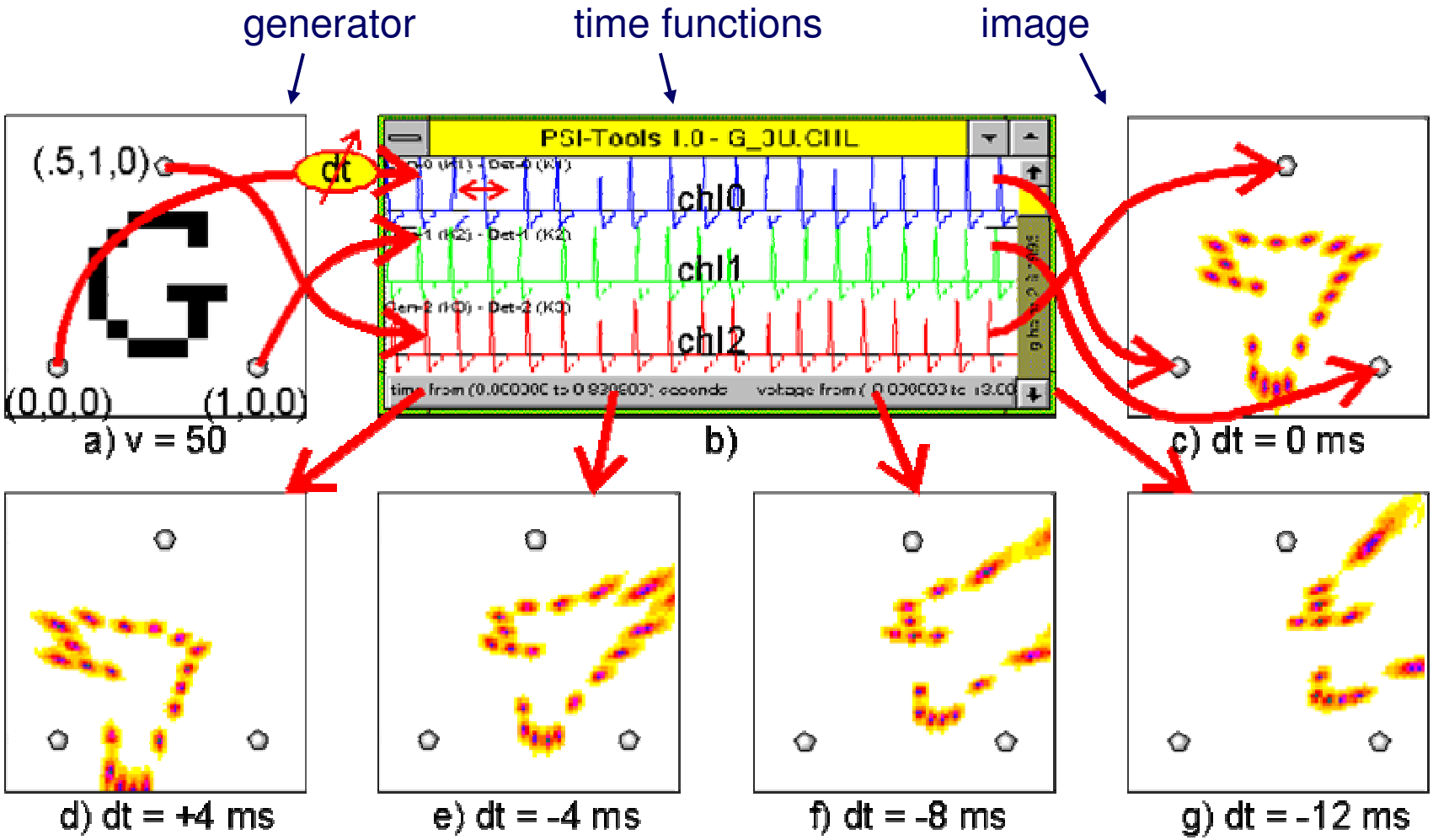
- Movement
- Zoom
- Distortion
- Self- and Crossinterference



(all Simulations: PSI-Tools, Heinz 1994…96)

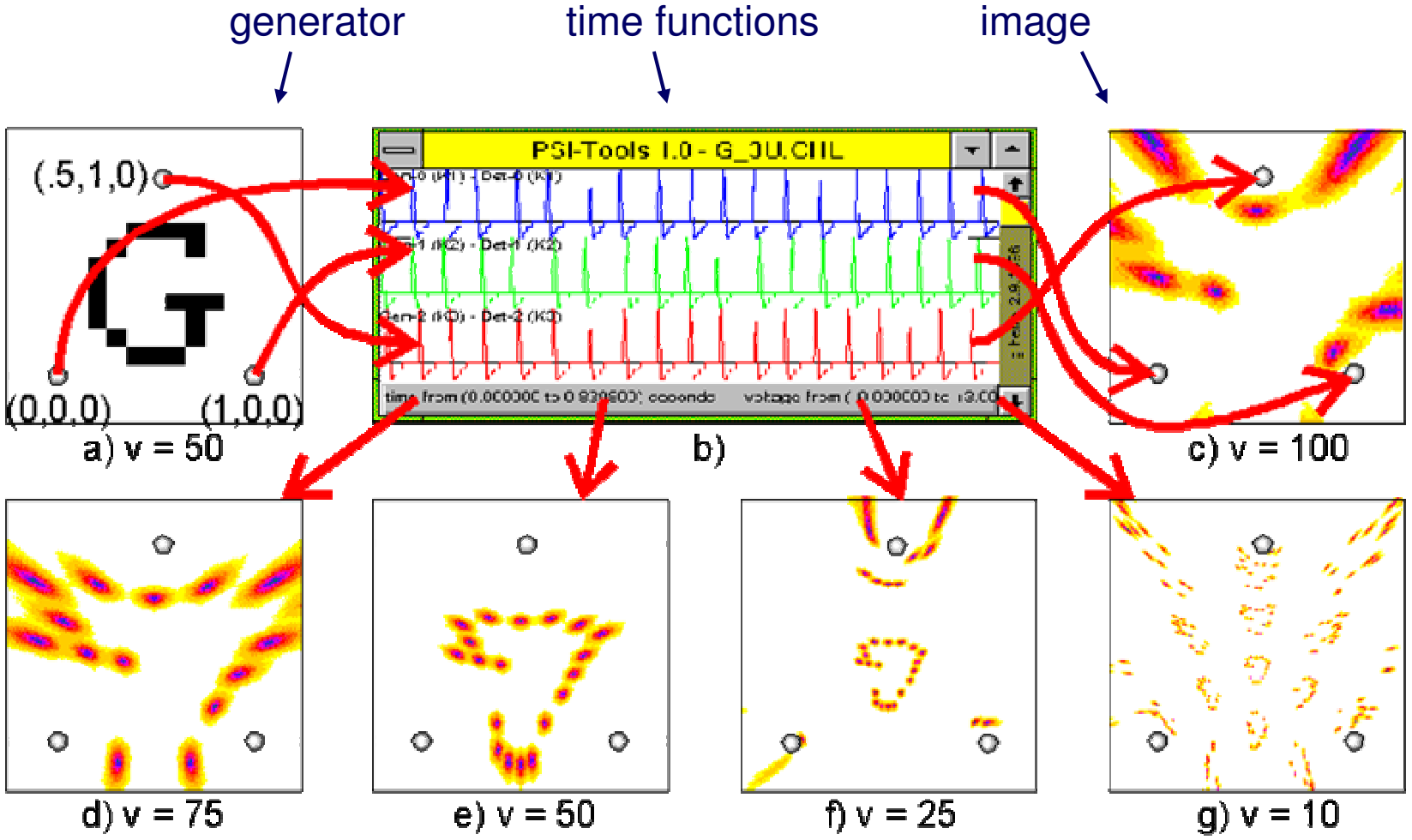
Moving Int.-Integral (I^2) in 2D-Space

- one channel is delayed with dt



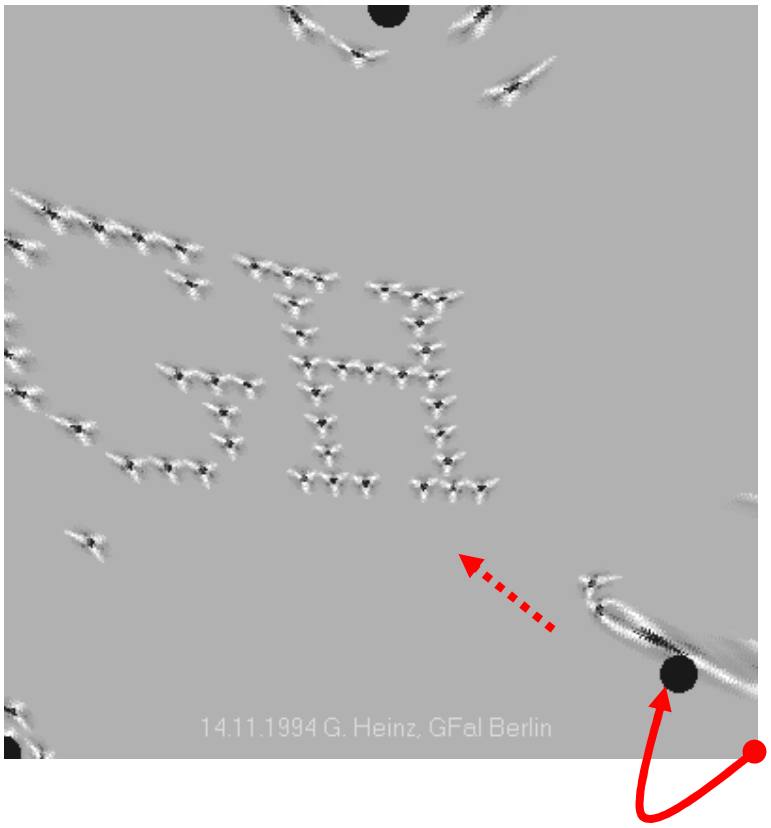
Zooming I² in 2D-Space

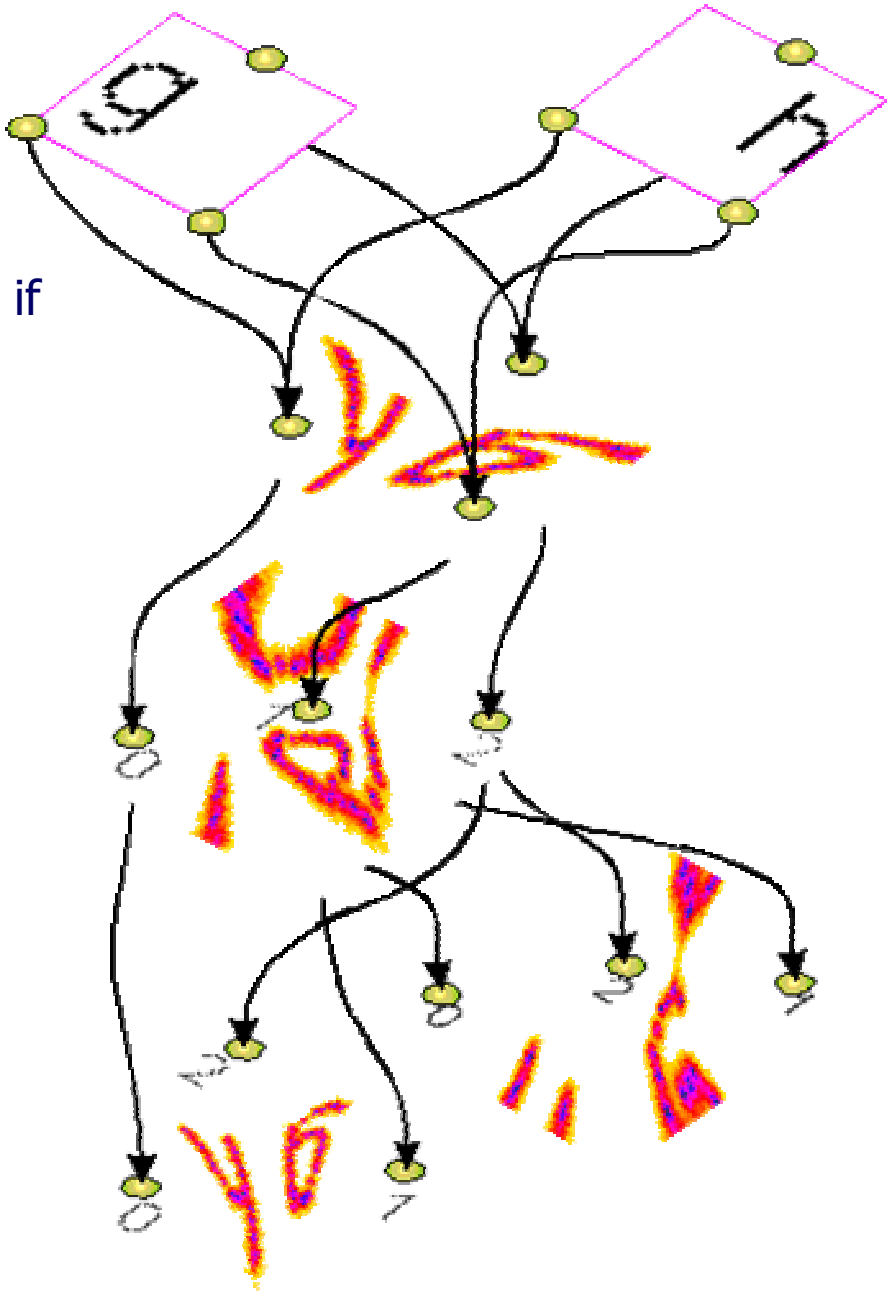
- Variation of background velocity v



Distortions

- Interference integrals stay together, if we move source points in space

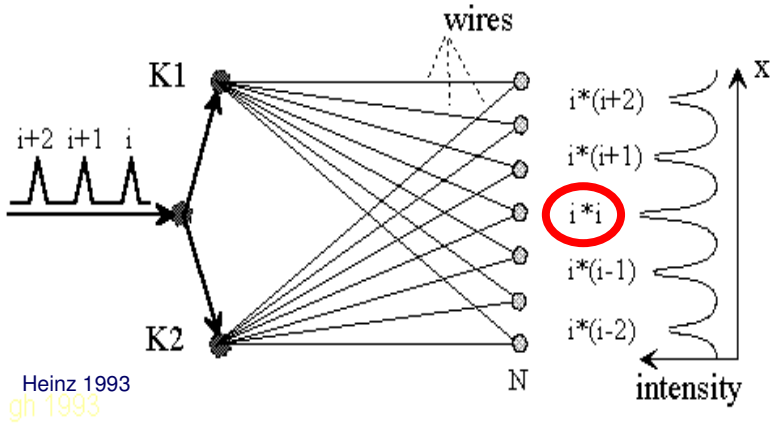


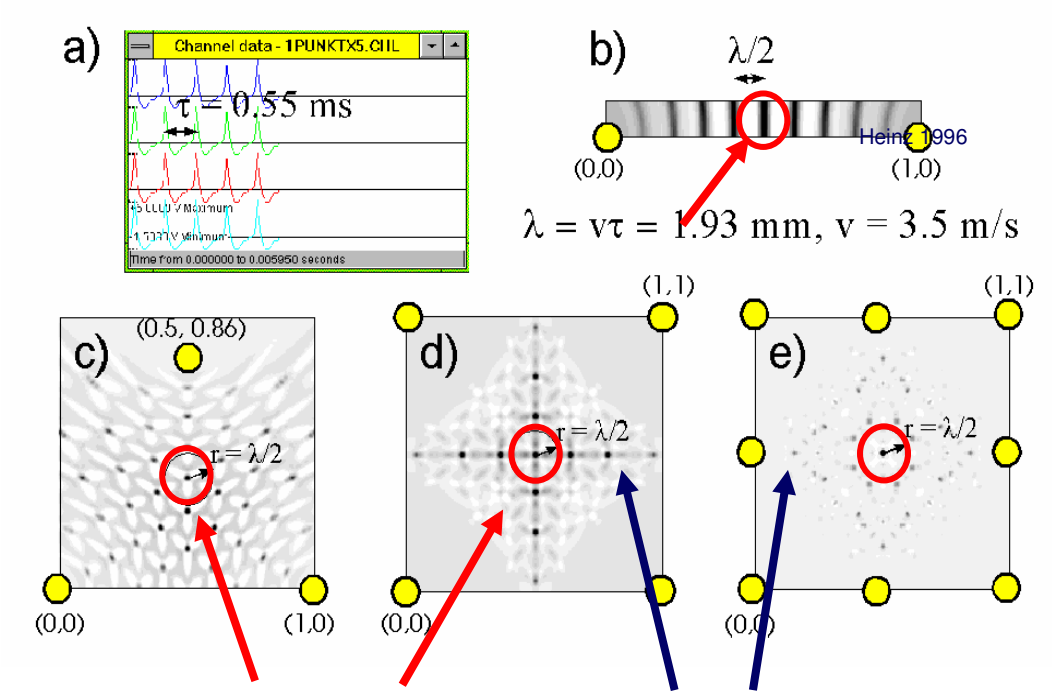


Cross-Interference

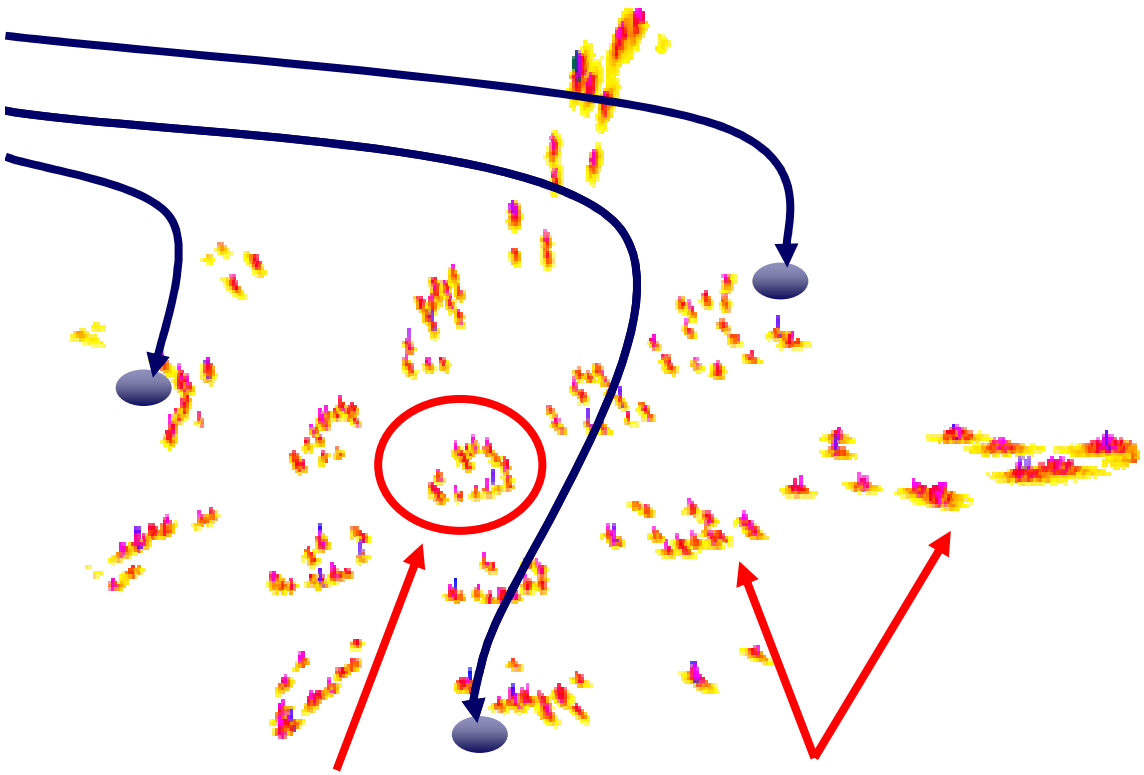
- Interferenceintegrals between waves of different origin (wave number)

Youngs double-split experiment as IN





Self- and Cross-Interference



Self-interferences **Cross-interferences**

SI + CI intrinsic connected,

Parameters: firerate, time-function type, channel number, wavelength

Self-Interference-Integrals

Wave i meets wave i

- Somato-topical maps
- Projektions: images, films
- Source location (Dolphin)
- Optics, Acoustic Camera, GPS, Radar, Sonar

-> **To See**

Cross-Interference-Integrals

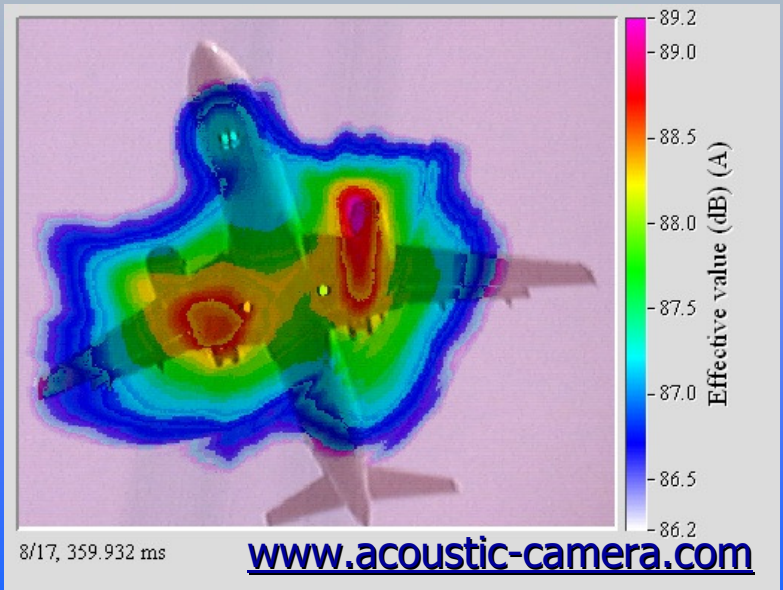
Wave i meets i+n or i-n

- Space-time maps
- Frequency mapping (FFT)
- Auditorical maps
- Code- and behaviour maps
- ...

-> **To Hear**

Um ein tadelloses Mitglied einer
Schafherde sein zu können,
muß man vor allem ein Schaf sein.
Albert Einstein

Acoustic Camera



Acoustic I²

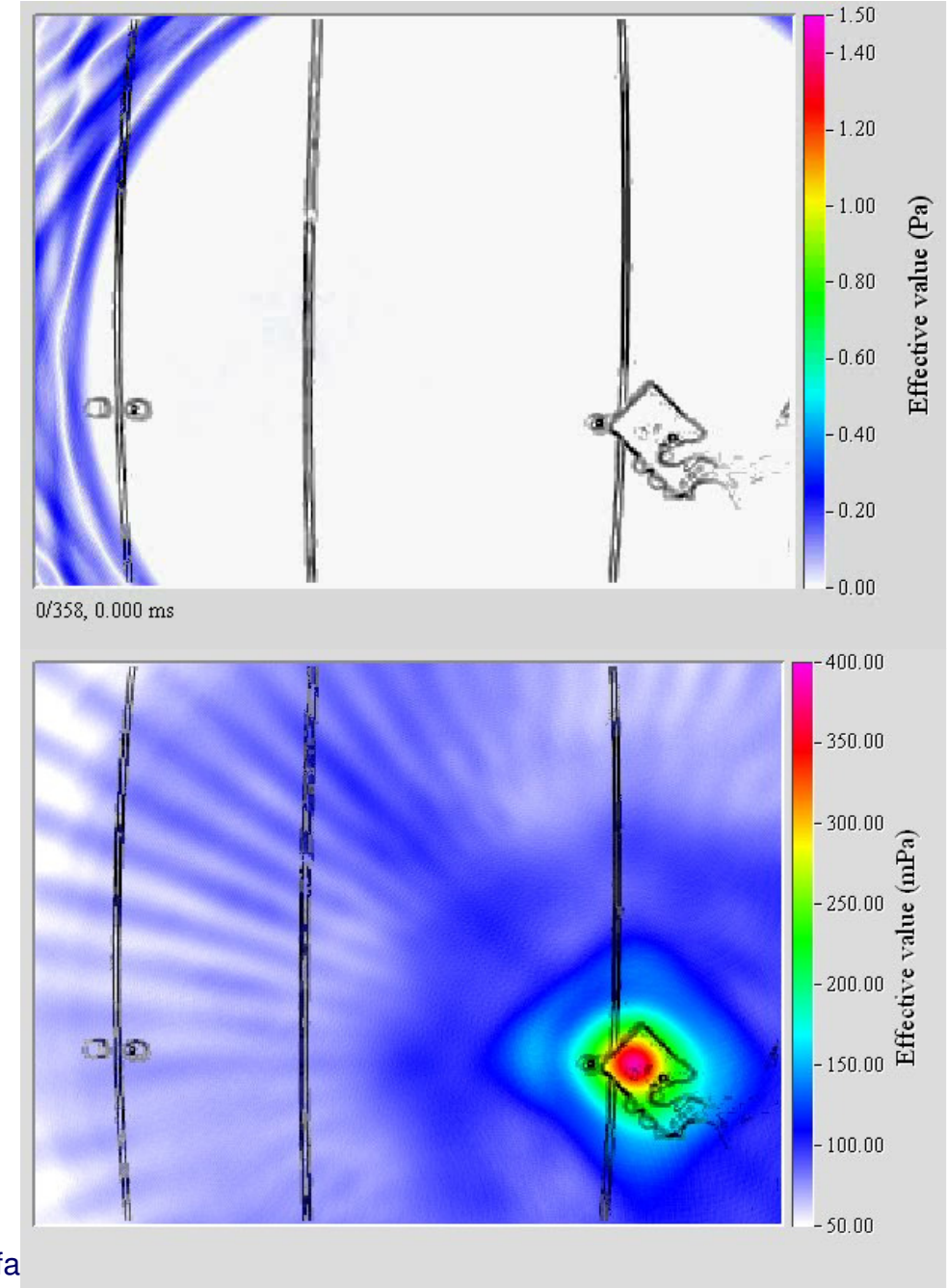
Wave field --->

- Finite velocity
- Many channels (here 32)

Interference integral --->

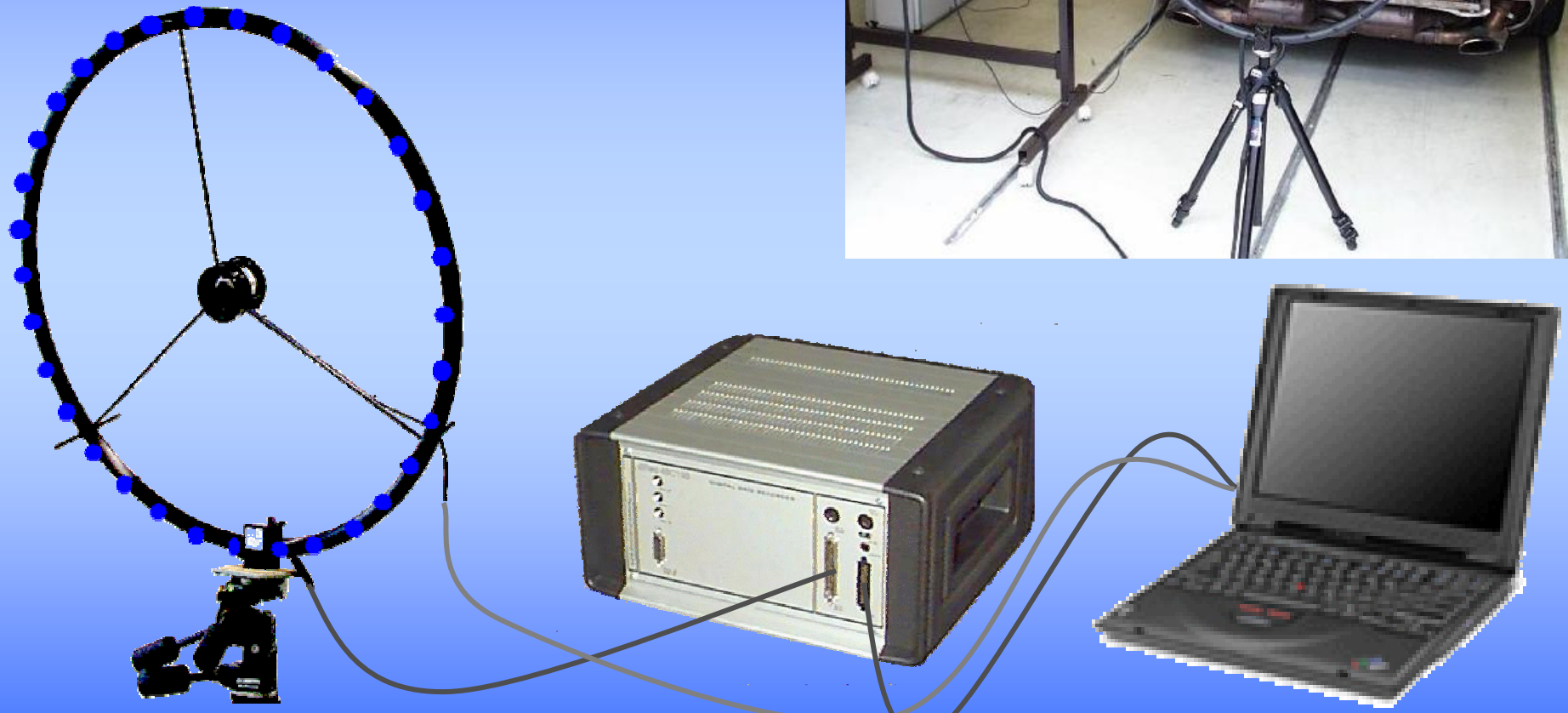
- Integration for each pixel
- High values at correlating points "interference locations"

(example: Acoustic Camera)



Hardware

Start NoiseImage – example: money sorter

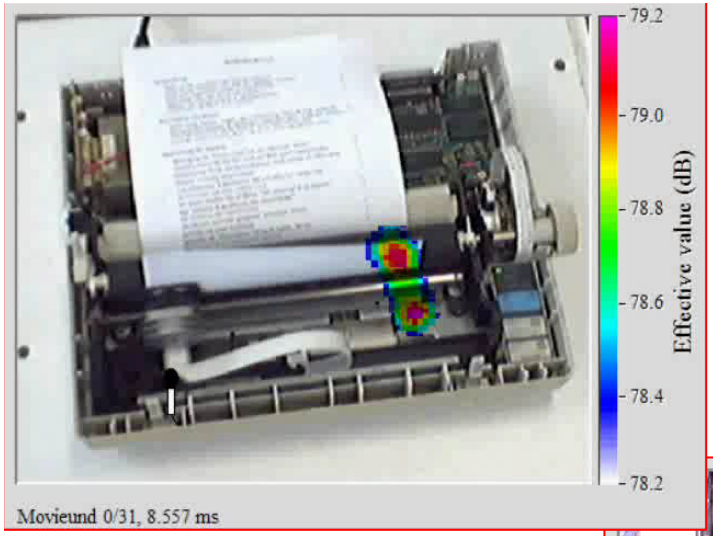


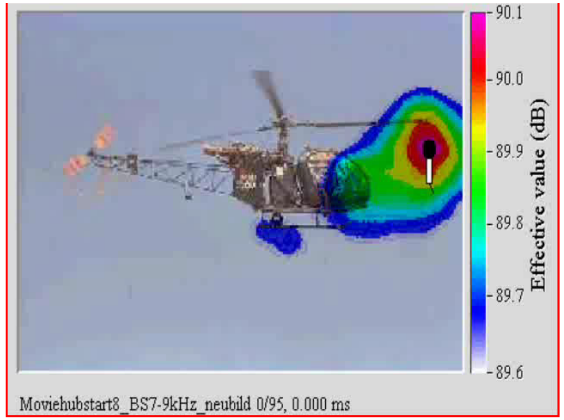
Microphone array with video camera

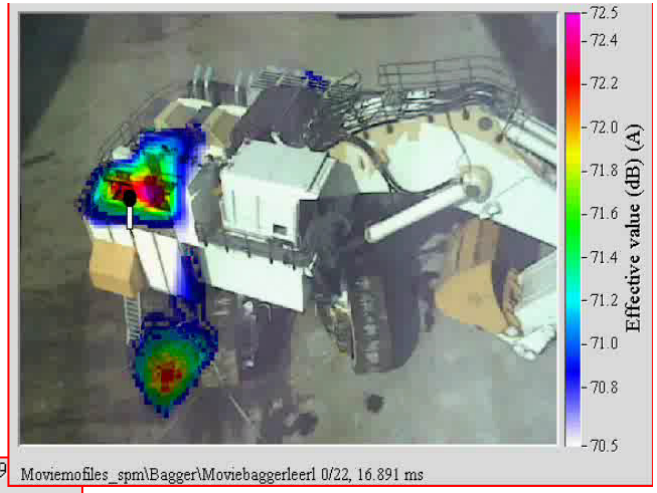
Data recorder

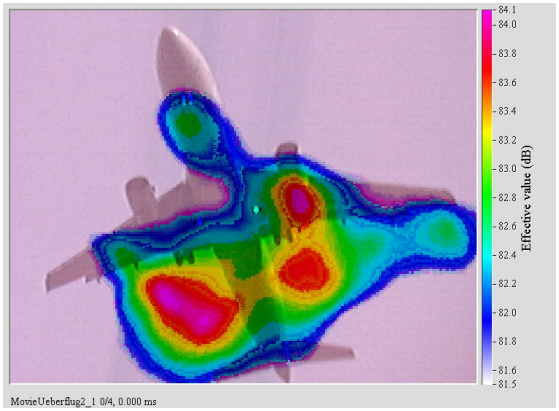
Notebook

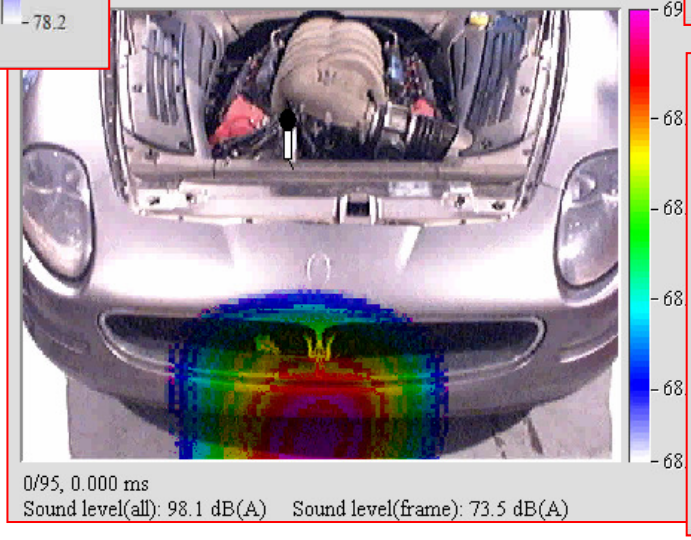
www.acoustic-camera.com

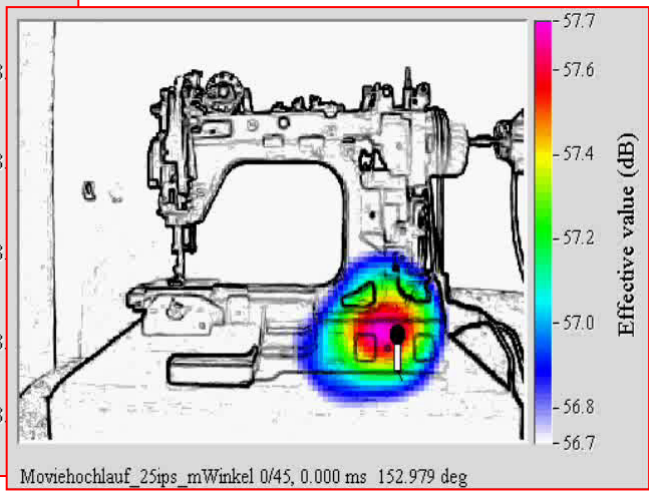

79.2
79.0
78.8
78.6
78.4
78.2
Effective value (dB)
Movieund 0/31, 8.557 ms

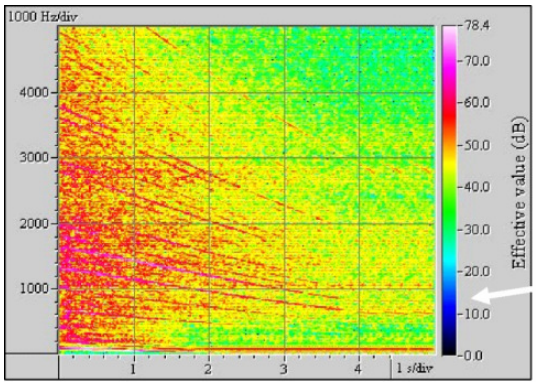

90.1
90.0
89.9
89.8
89.7
89.6
Effective value (dB)
Moviehubstart8_BS7-9kHz_neubild 0/95, 0.000 ms

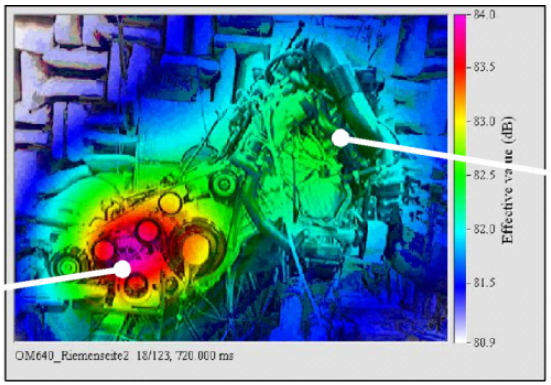

72.5
72.4
72.2
72.0
71.8
71.6
71.4
71.2
71.0
70.8
70.5
Effective value (dB) (A)
Moviemofiles_spm\Bagger\Moviebaggerleerl 0/22, 16.891 ms

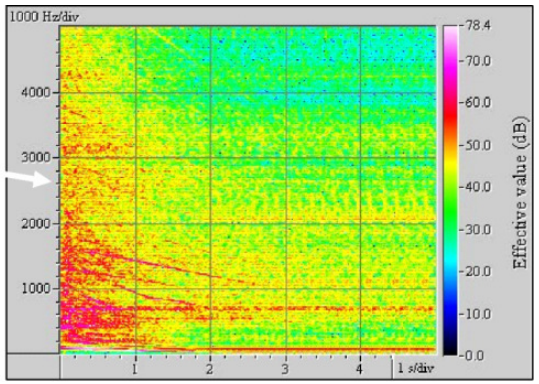

Effective value (dB)
MovieUeberflug2_1 0/4, 0.000 ms


0/95, 0.000 ms
Sound level(all): 98.1 dB(A) Sound level(frame): 73.5 dB(A)

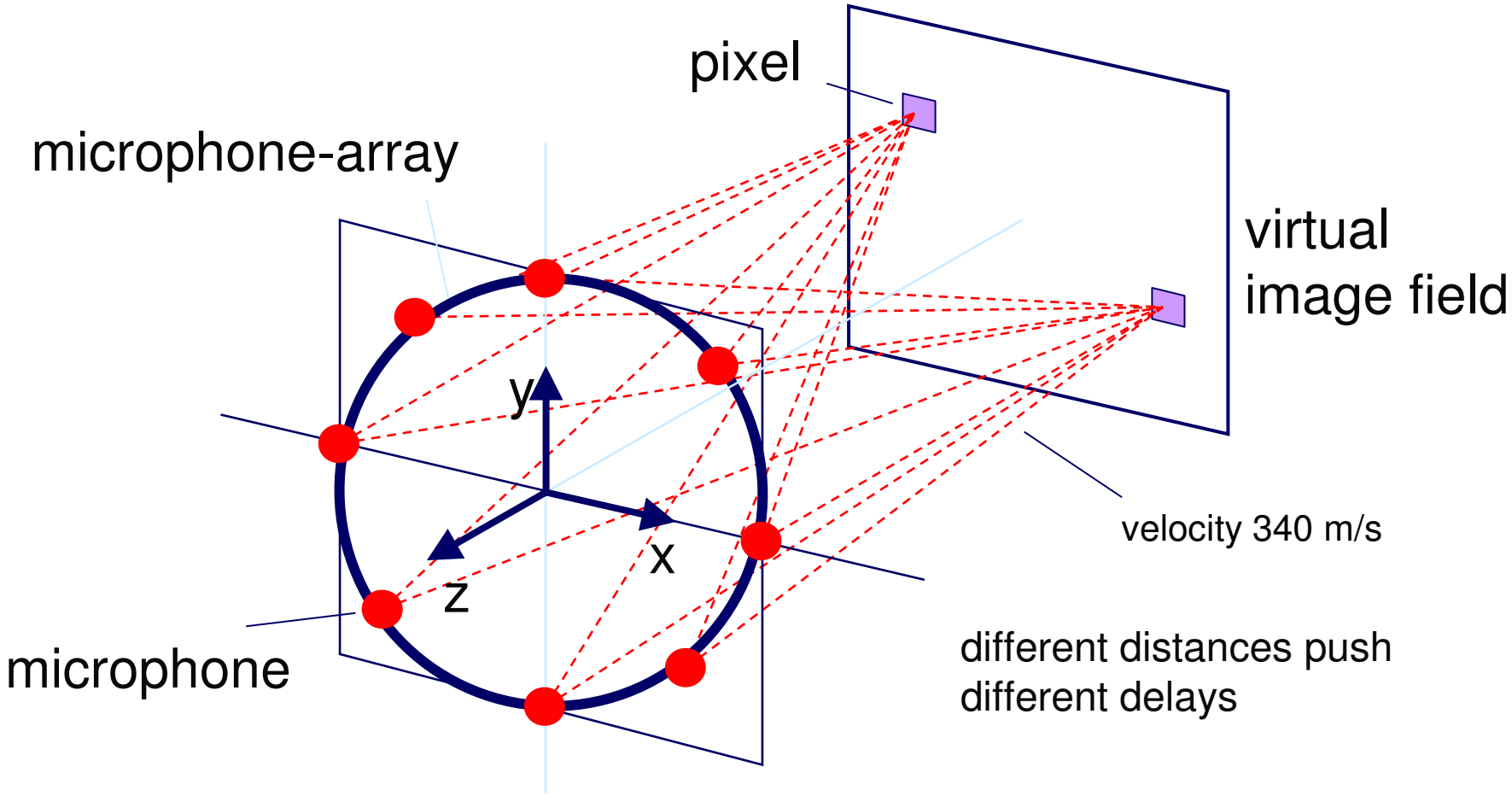

57.7
57.6
57.4
57.2
57.0
56.8
56.7
Effective value (dB)
Moviehochlauf_25ips_mWinkel 0/45, 0.000 ms 152.979 deg


1000 Hz/div
4000
3000
2000
1000
78.4
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
Effective value (dB)
1
2
3
4
1 s/div

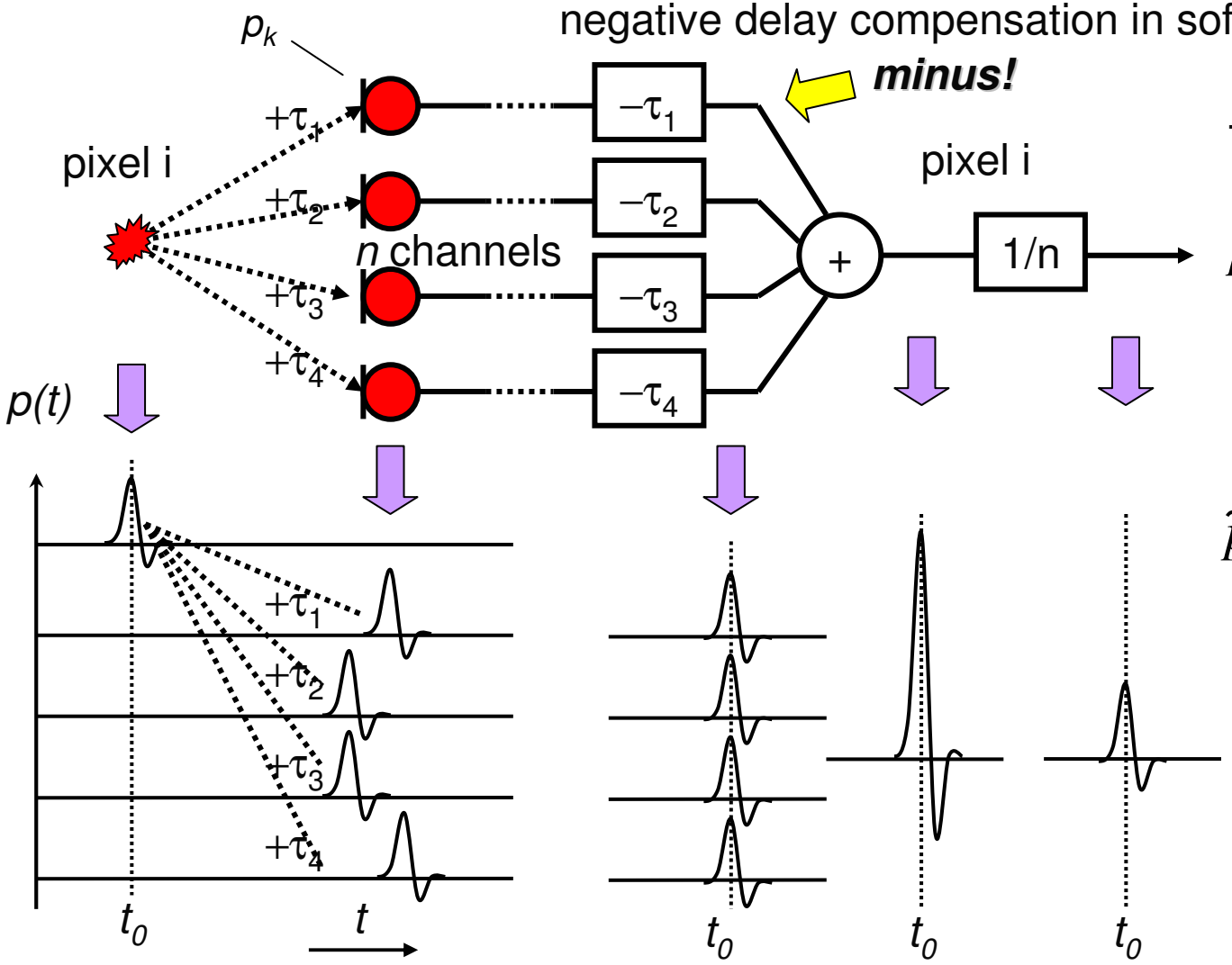

OM640_Riemenseite2 18/123, 720.000 ms


1000 Hz/div
4000
3000
2000
1000
78.4
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
Effective value (dB)
1
2
3
4
1 s/div

Basics: Distances and Corresponding Delays



Interference Reconstruction



Time function of pixel i:

$$p_i(t) = \frac{1}{n}\sum_{k=1}^{n} p_k(t+\tau_{ik})$$

plus!

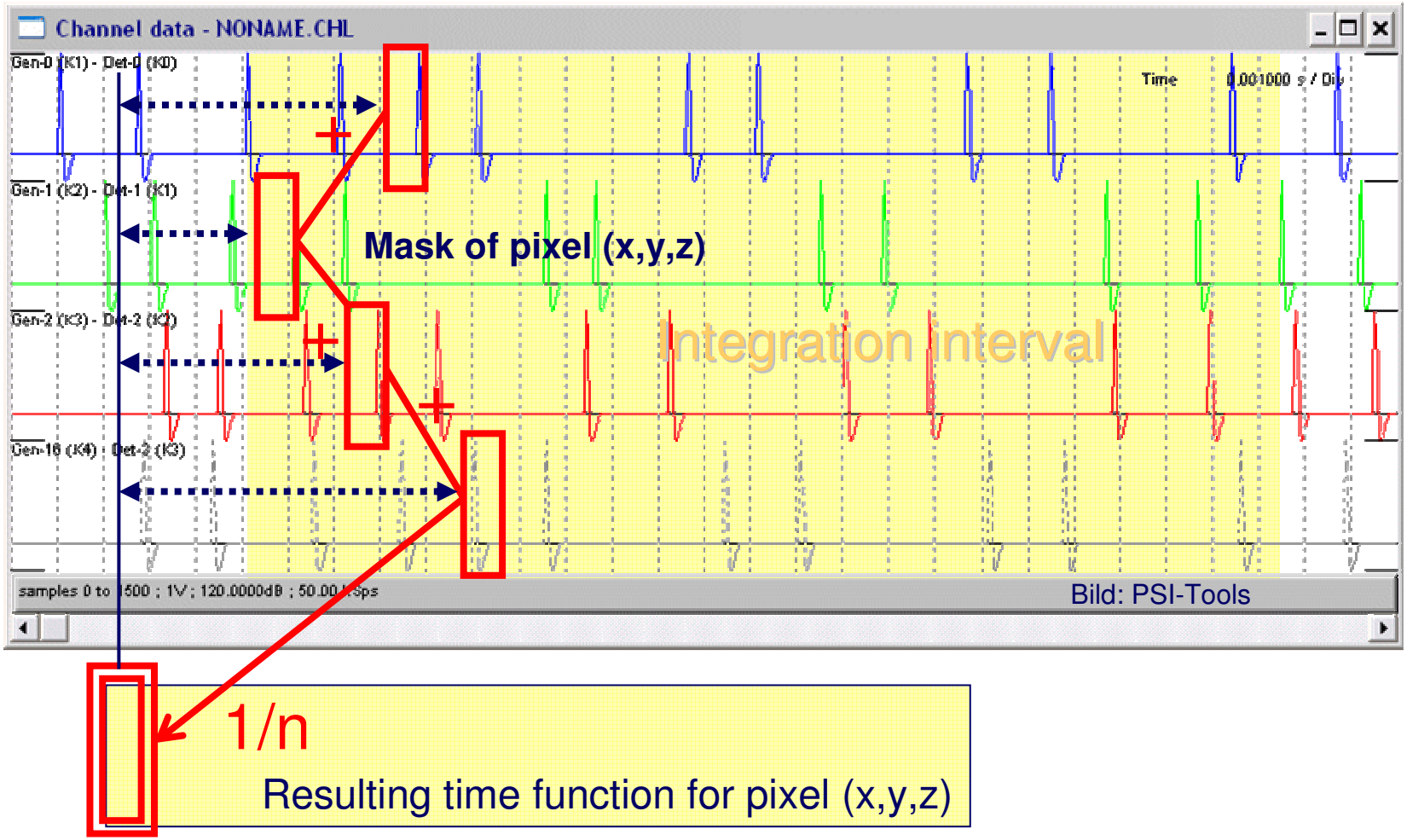
Integration:

$$\tilde{p}_i(t) = \frac{1}{T}\int_{-T/2}^{T/2} \sqrt{p_i^{\,2}(t)}\, d\tau$$

Principle history:

Heinz' Interferenz-Transformation (HIT), 1993

Mask-Algorithm 1993 → Acoustic Camera



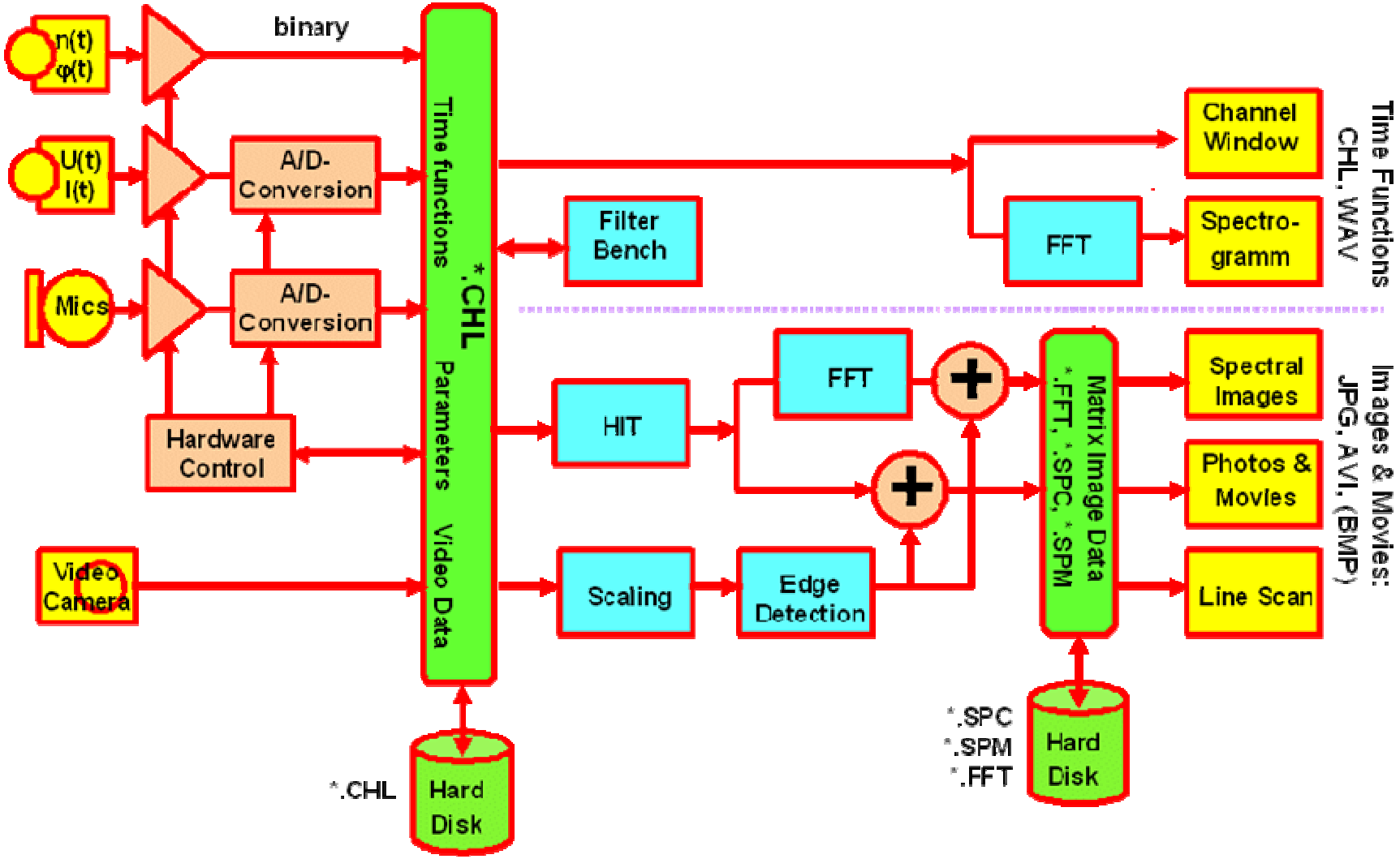
used for image reconstruction "Acoustic Camera"

Mikrophon-Arrays

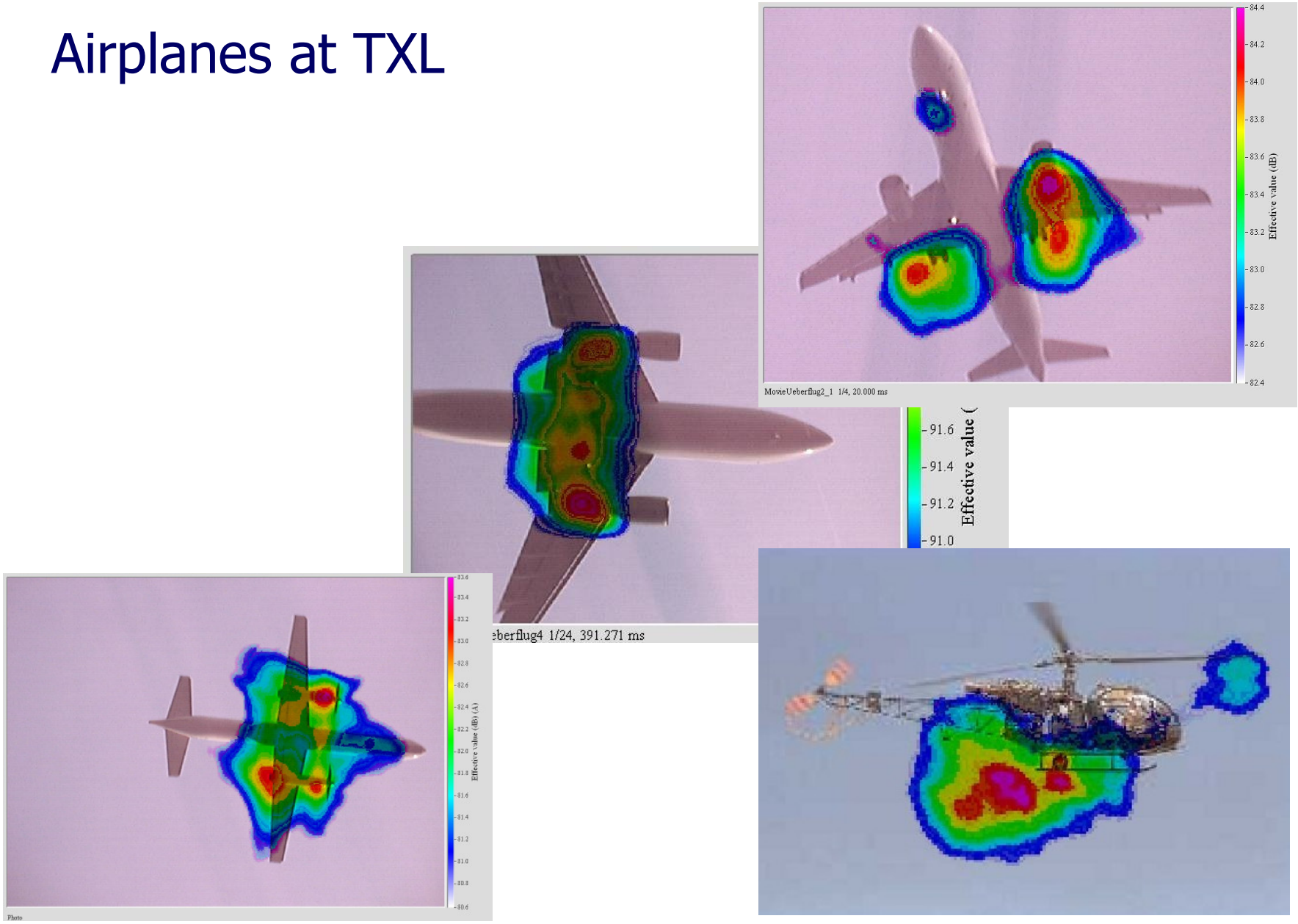
Compatible Arrays (MicBus)

Disc	Cube	Ring	Star
32 chls	32 chls	32…120 chls	36 chls
Ø 35 cm	Ø 35 cm	Ø 35…70…140 cm	Ø 3 m
Interior, 2D	Interior, 3D	Engines LN/STD	Outdoor
30…100 cm	30…100 cm	1…3 m	10…300 m

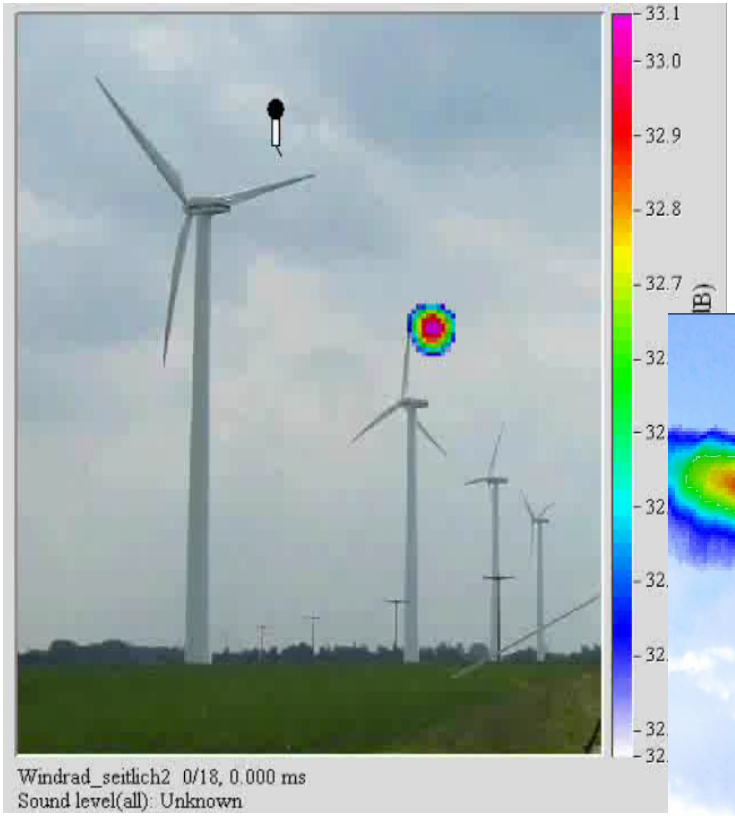
Structur Acoustic Camera

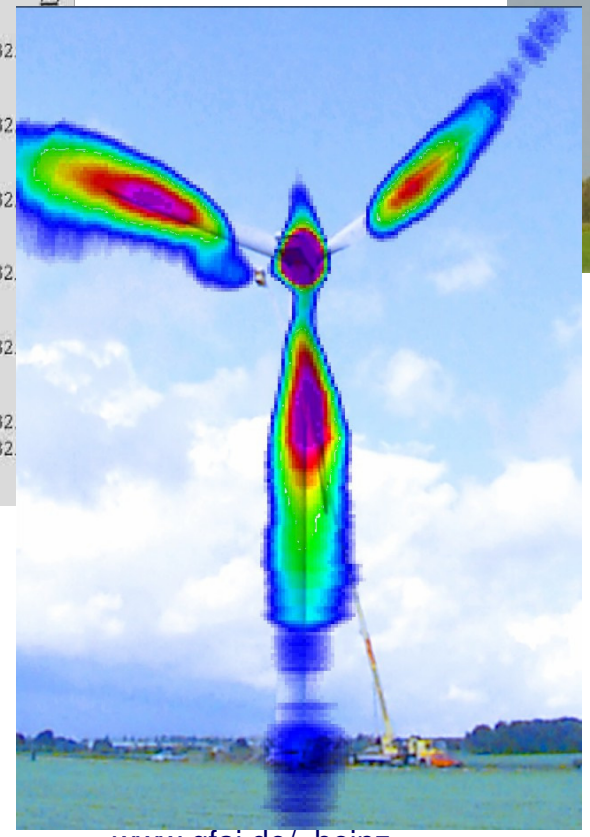


Airplanes at TXL



Blinking Wind Power Station



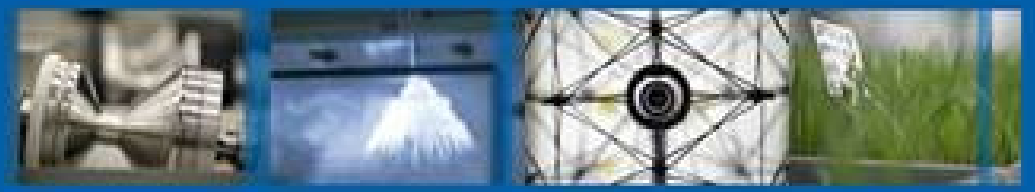


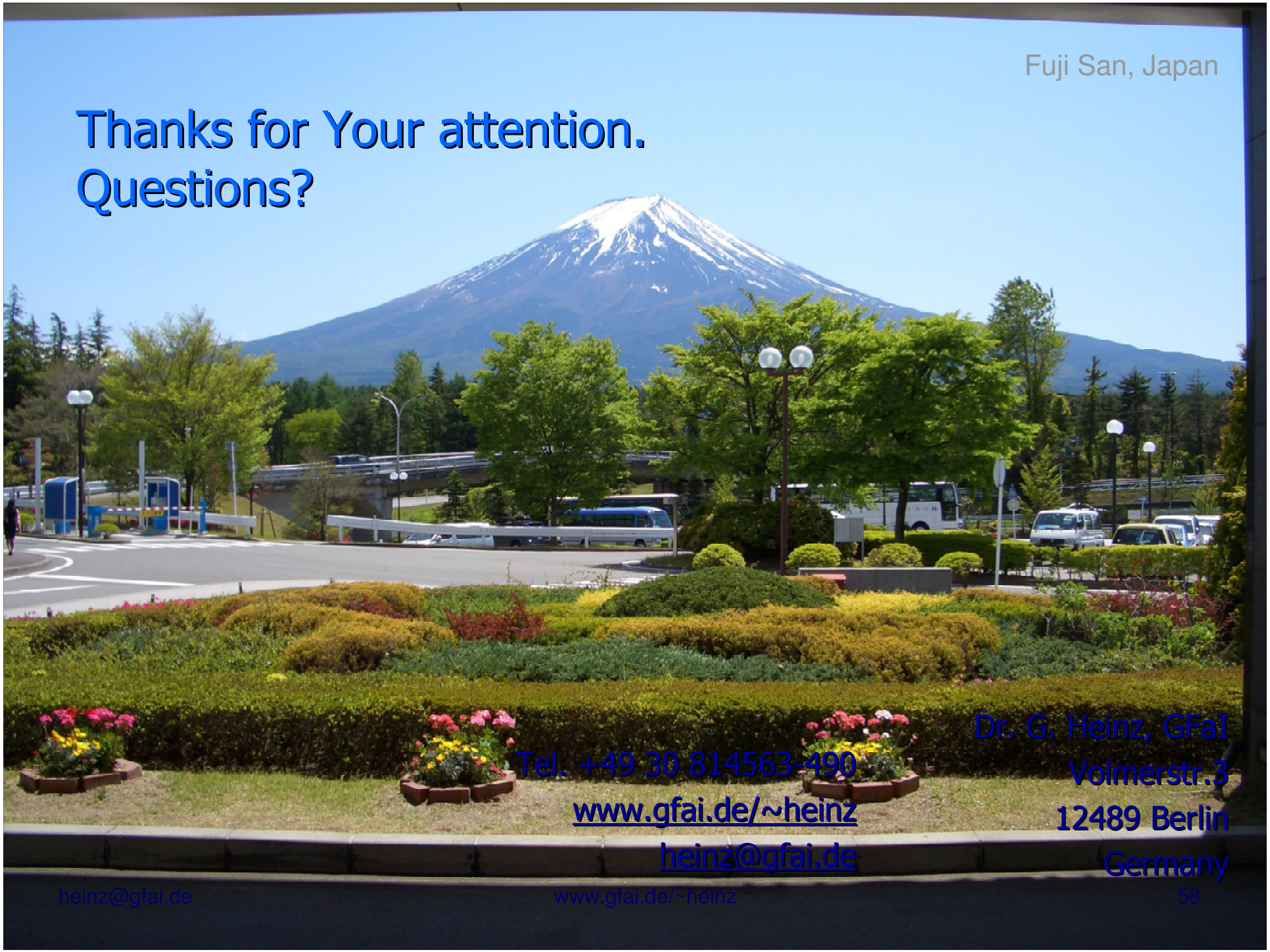
Nomination of Acoustic Camera for German Future Award 2005

http://www.deutscher-zukunftspreis.de

DEUTSCHER ZUKUNFTSPREIS
Preis des Bundespräsidenten
für Technik und Innovation

http://www.gfai.de/~heinz/publications/presse/index.htm





Thanks for Your attention.
Questions?

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