SINTEF

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The DREAM Toolbox - theory and implementation

Sjur Urdson Gjerald

The Norwegian University of Science and Technology (NTNU), Medical Faculty

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MOTIVATION

1. We have a task: What is the pressure field (signal) at a point in space? (Averagely and at a specific point in time)
2. We have a tool: A software package called DREAM
3. We have a question: How does it work?
4. And yet another question: Is it any good?

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THE HUYGENS PRINCIPLE

- Every point on transducer emits spherical wave
- Described by the Rayleigh integral

$$\phi_N(r,t) = \frac{1}{2\pi} \iint_{S_0} \frac{v_n(t - \frac{R}{c_0})}{R} \mathrm{d}S_0$$

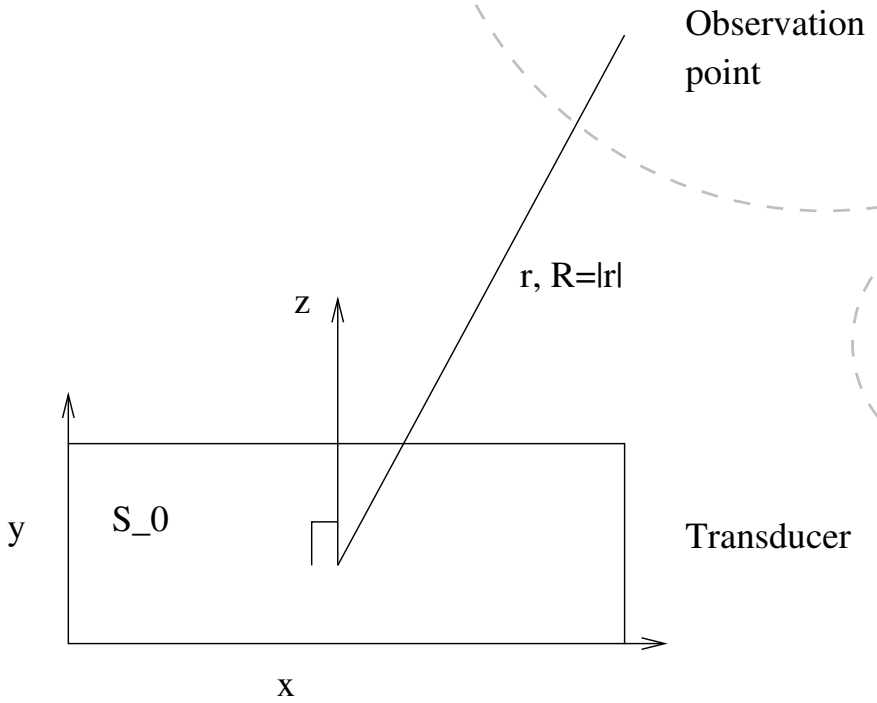

Figure: Coordinates

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IMPULSE RESPONSE

Assume space-time separability of pulse ($v_n = v_{n0}\xi_0(x, y)$)

$$\phi_N(r, t) = \int_{-\infty}^{\infty} v_{n0}(\tau) \iint_{S_0} \frac{\xi_0(x, y)\delta(t - \frac{R}{c_0} - \tau)}{2\pi R} \mathrm{d}S_0 \mathrm{d}\tau$$

The ubuquitous impulse response

$$h(r, t) = \iint_{S_0} \frac{\xi_0(x, y)\delta(t - \frac{R}{c_0} - \tau)}{2\pi R} \mathrm{d}S_0$$

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THE PROBLEM

- We know: the Huygens principle
- A fact: A point does not have an area
- Problem: How to cover a finite area by points?

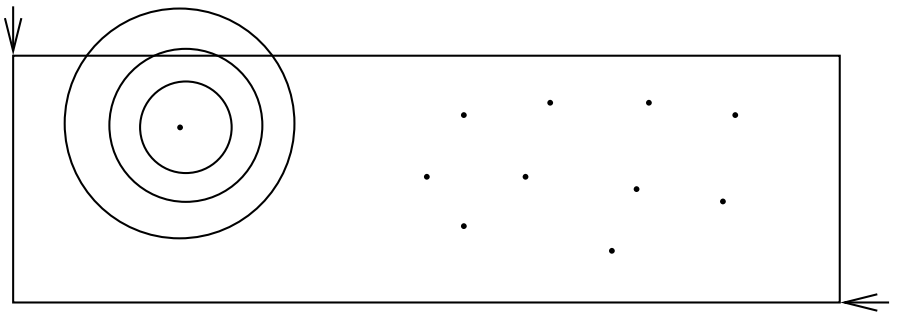

Figure: Points cannot cover a plane

THE DREAM WAY

1. Chose a subset of points (sampling)
2. The signal from every point source arrives at observation point at different times
3. The signal is recorded at time intervals
4. Coordinate time and space sampling
5. SOLUTION: USE THE AVERAGE SIGNAL STRENGTH IN A SAMPLING INTERVAL

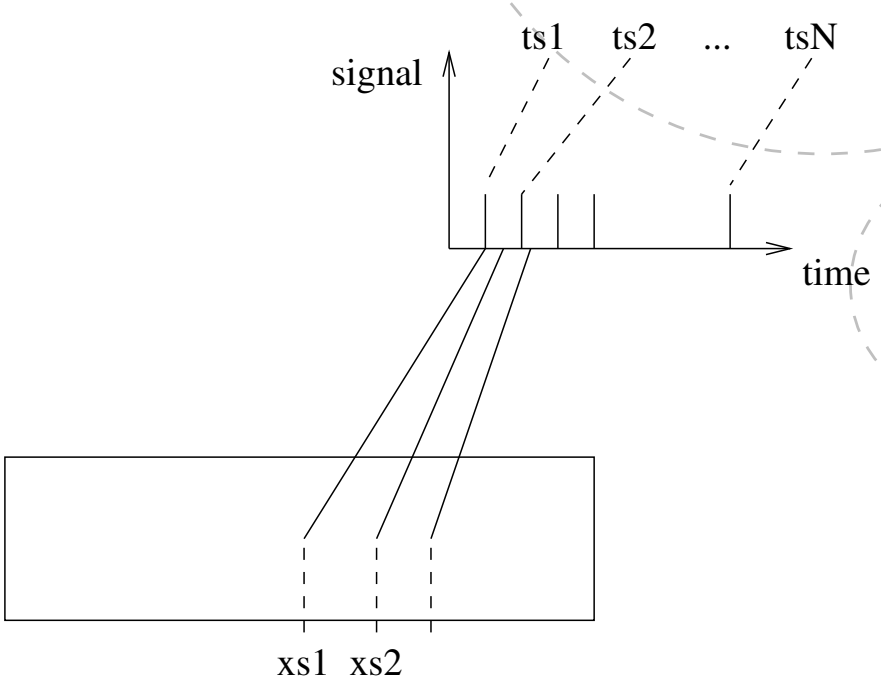

Figure: Sampling

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DREAM: SHOULD IT WORK?

- Similar to definition of (Riemann) integral
- High temporal frequency: average → exact solution
- High spatial frequency (transducer sampling): sampled → average solution

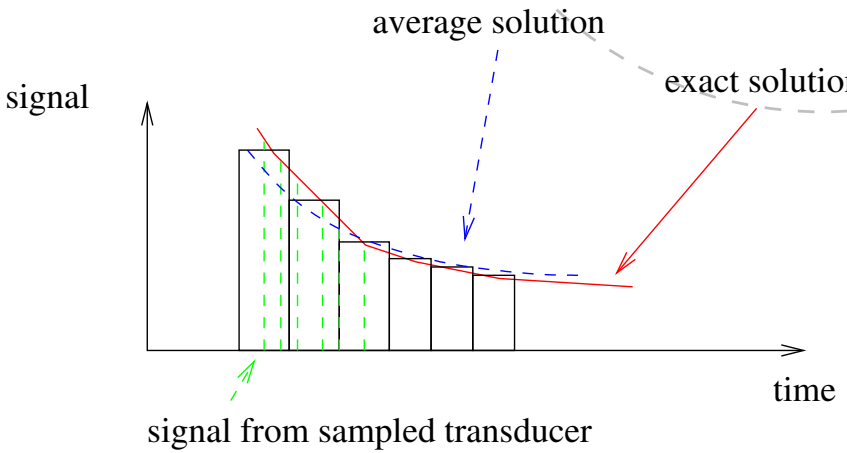

Figure: Averaging

DREAM: THE TRICKS

- Fourier transform of the impulse gives signal for all frequencies (spectral analysis)
- Emitted pulse is not an impulse $\Longrightarrow$ highest frequencies disappear
- There is a highest frequency $\Longrightarrow$ limits on sampling frequency
- Just remember Nyquist's sampling theorem

$$\Delta t \times f_{\mathrm{max,pulse}} \leq \mathrm{constant}_1 < 0.5$$

$$\frac{\Delta x}{\lambda_{\mathrm{min,pulse}}} \leq \mathrm{constant}_2 < 0.5$$

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DREAM: THE ACCURACY VS COMPUTATION SPEED

- No additional approximations about observation points
- Accuracy depends on discretizations only
- Calculation speed depends on transducer discretization only
- Higher accuracy $\Longrightarrow$ slower calculation speed

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DREAM VS FIELD2

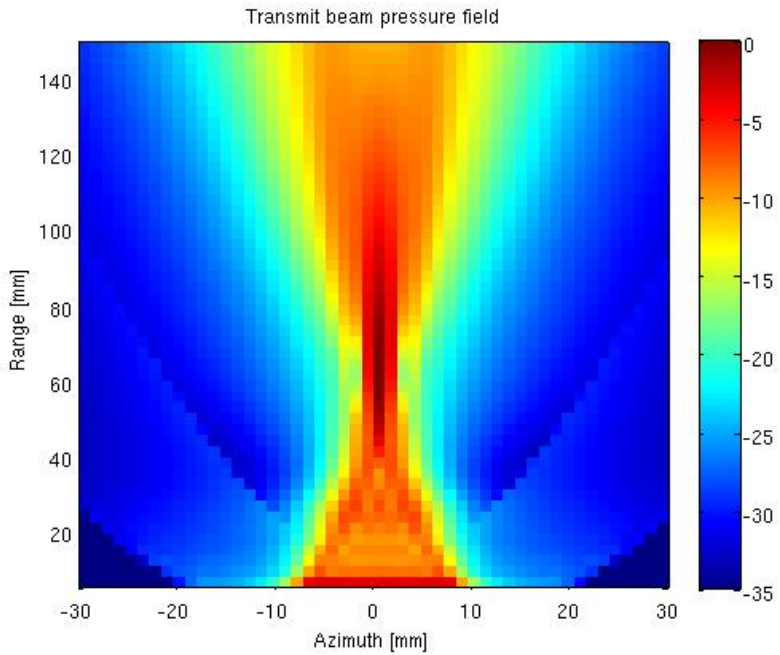

Figure: Dream: 2.52 seconds for impulse response

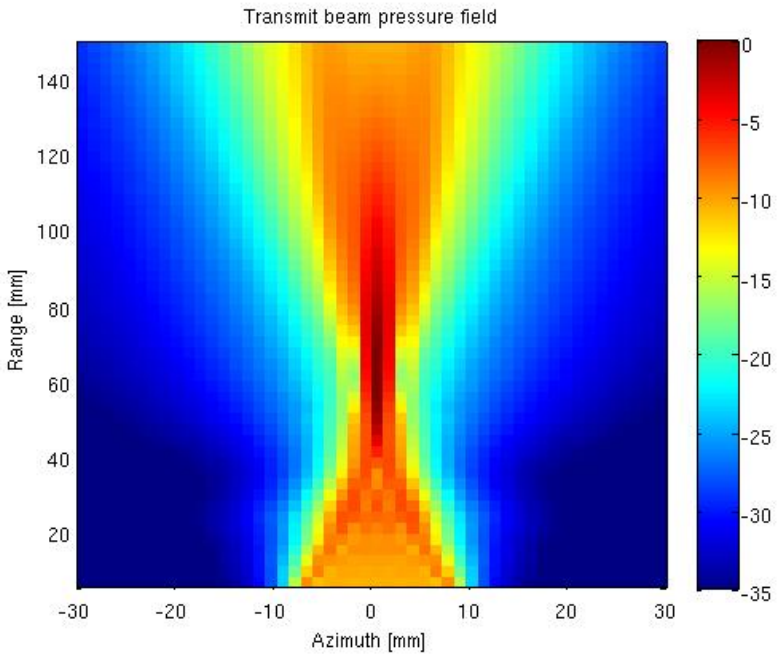

Figure: Field: 5.79 seconds for impulse response

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DREAM VS FIELD2 DIFFERENCES

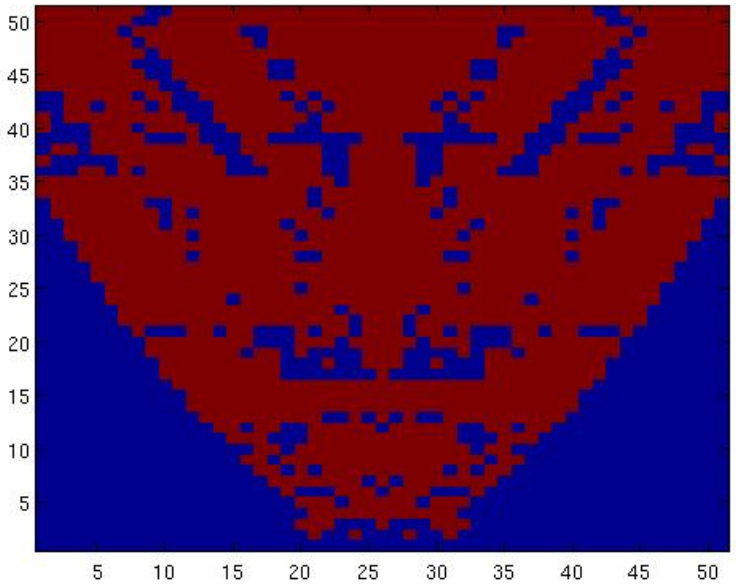

Figure: Area for less than 1 per cent difference

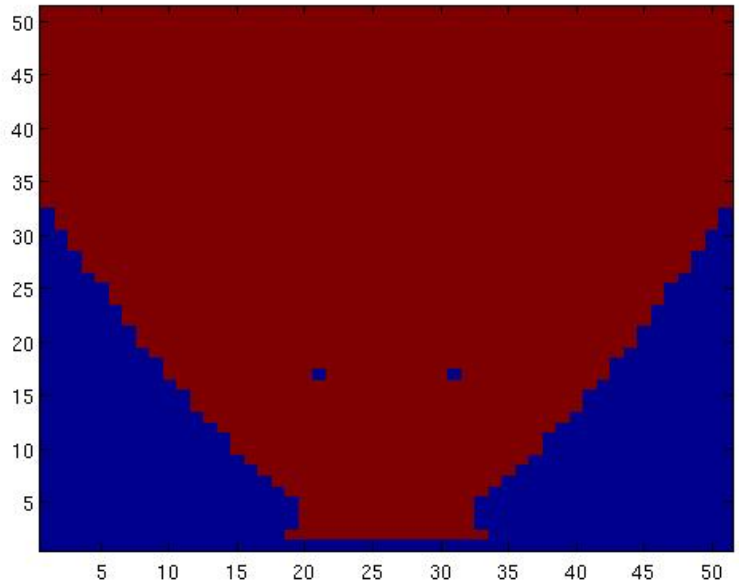

Figure: Area for less than 5 per cent difference

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DISCUSSION

- DREAM is supposed to require higher sampling
- DREAM does not support elevation focus such as Field (but: 2D array)
- DREAM supports parallelization multi-core cpus
- DREAM does not require far-field approximation as Field does
- The articles on Field are better written...

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