Conference Poster

Investigation of fallacies in focused ultrasound transducer acoustic modeling

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BACKGROUND AND MOTIVATION

- transcranial focused ultrasound (tFUS) is a promising therapeutic approach (non-invasive neurosurgery, tumor ablation, DBS, neurostimulation,...)
- modelling is required for treatment planning & optimization
- typical transducer modelling isn’t physically correct:
  - constant pressure / velocity boundary condition on transducer surface
  - heuristically adapted curvature to match effective focus location

→ even modelling validated against experimental hydrophone data in water is not generalizable to inhomogeneous / complex setups
→ significant such differences (focus position, size, side-foci) were in fact observed in our measurements, illustrating the importance of proper source modelling

APPROACH

- systematic study of modelling pitfalls using FDTD, full-wave acoustic modelling in Sim4Life [2]
- sensitivity analysis
- comparison against experimental data:
  - 3D hydrophone measurements
  - precisely positioned skull obstacles (pig, sheep)
  - CT based modelling of skull inhomogeneity

OBSERVED PITFALLS AND CORRECTION

- manufacturer provided geometry / curvature information is wrong (modifed to reflect effective focus position in water)
  → measure and simulate correct geometry
- internal transducer construction is not considered
  → model piezo-element as source & curved transmission element as acoustic material (identify correct properties)
- account for vibrational mode and transducer wall impact (mechanical simulation / aperture function)
- consider tissue heterogeneity
- CT-based (HU) skull property maps [1] (large variability and uncertainty is found in literature for the mapping function)

RESULTS

- typical modelling is unable to reproduce transcranial sonication results and fails to capture predicted secondary foci in water
- corrected approach is successful in reproducing focus location and shape with and without skull obstacles
  → quantification using gamma method ongoing [3]
- piezo element depth and matching material speed of sound are most sensitive parameters; attenuation dominates intensity predictions; aperture function affects secondary foci
- no universal HU-property mapping (attenuation) found across different species
  → investigate non-linear mappings further or assume constituent-based inter-species variability

CONCLUSIONS

→ careful transducer modelling, accounting for the internal transducer structure and vibrational modes, is crucial for reliable FUS treatment modelling; typical approaches are unsuitable
→ experimental validation is an important step towards predictive, clinically applicable treatment planning tools
→ modeling must be complemented by systematic uncertainty assessment [3]

REFERENCES