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Laboratoire d'imagerie biomédicale multimodale

Aberration correction in transcranial ultrasonic imaging using CT data and simulation-based focusing algorithms

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- Presentation of the CIVA platform
 - Principles of Dynamic Ray Tracing (DRT) model
 - Application to pressure field and delay law computation in complex structures

• Simulation based Transcranial imaging

- Full matrix capture
- Total Focusing Imaging
- Description of the set-up
- Experimental results on several targets
- Conclusion and perspectives







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- In France, every year 130,000 people suffer from stroke
- Essential to distinguish as soon as possible its origin since
 - time is a key factor to protect brain
 - since ischemia and hemorrhages require radically different treatments.
- X-rays and MRI brain imaging are diagnosis techniques currently used
 - not easily applicable in the emergency field.
 - access for patient monitoring can be very complicated.
- Ultrasonography is a more flexible and less expensive modality
 - Emergency diagnosis : brought into the vehicle carrying the patient.
 - Continuous monitoring in intensive care units
- Beyond early or continuous diagnosis, improvement of US brain imaging could be of great interest for neuroscience.





- Aims : create a breakthrough in the field of brain imaging
 - Improve brain images quality by counteracting ultrasonic wavefront aberration due to human skull
 - significantly improve the understanding of brain pathologies, brain trauma and physician diagnosis.
- Means : Adapt the simulation-based imaging tools developed by CEA-LIST for Non-Destructive Testing (NDT) applications
 - Programmable ultrafast ultrasound device Aixplorer[™] (Supersonic Imagine, Aix en provence, France)
 - Full Matrix Capture (FMC) acquisitions
 - Total Focusing Method (TFM) imaging
 - CIVA simulations tools to calculate field propagation through the skull
 - Skull geometry provided by a previously acquired 3D CT scan of the patient.







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NDT simulation

Multi-techniques, NDT Oriented Environment, Modeling using fast Semi Analytical Models or Hybrid FEM strategy, Parallelization, metamodeling and statistical tools



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UT INSPECTION SIMULATION PRINCIPLE

EXTENDE CIVA

1. Emission and propagation:

Computation of the incident field on the defect : ray-based model

3. Reception of echoes:

arrays

Received signal synthesis using Auld reciprocity principle



Continuous validation, optimization and enrichments of this general approach in order to address new (complex) cases



method taking into account the geometry and the material properties Time of flight • Amplitude ٠ Wave polarization • • Synthesis of the impulse response • Convolution by any wave form $u(M,t) = h(M,t) \otimes v(t)$ Harmonic computation at any frequency **h(t)**

Computation of the contribution of each source point using the pencil



EXTENDE

CIN

DYNAMIC RAY TRACING MODEL (DRT)

Μ

list

Ceatech



DYNAMIC RAY TRACING MODEL (DRT)

Ray-paths and travel time

Rays travel in straight line inside each homogeneous domain

Ray amplitude

Computation of the ray amplitude through matrix products expressing the evolution of a paraxial ray describing a ray tube or « pencil ».



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APPLICATION TO TRANSCRANIAL PROPAGATION

Pressure field calculation through the skull bone

skull:

homogeneous and isotropic elastic media

 $= 1908 \text{ kg/m}^3$, ρ $c_1 = 3183 \text{ m/s},$ $c_{\tau} = 1600 \text{ m/s}$



Probe :

 Φ : 160 mm Curvature : 180 mm Annular and sectoral cutting 109 elements 3 MHz







Pressure field in water (no phase law)

Pressure field through the skull Pressure field through the skull (no phase law)

(adapted phase law)

Experimental validation in progress



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Uist PRINCIPLE OF FULL MATRIX CAPTURE (FMC) ACQUISITION

- · N successive shots (N: nb of elements)
- One shot: 1 transmitting element All elements receiving



Acquisition

N elements $\rightarrow N \times W$ elementary signals $S_{ij}(t)$





PRINCIPLE OF TOTAL FOCUSING METHOD (TFM) IMAGING

Post-processing

Acquisition





EXPERIMENTAL SET-UP



transcranial ultrasound imaging



Linear array probe (SL10-2, Supersonic Imagine)

Water tank



Acquisition

- FMC using an Ultrafast Ultrasound device, AixplorerTM,
- Fusion navigation module to locate the probe according to the skull



- TFM imaging
- Time of flight computed by CIVA
- 3D CAD file of the skull from CT
- Skull considered as homogeneous and isotropic
- optimization loop on speed











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• Aim : the improvement of transcranial ultrasonic brain imaging

• Mean

- FMC acquisition with fast ultrasonic device and fusion navigation module
- CIVA Model based TFM imaging with 3D CAD file for skull description (CT)
- Simplified description (homogeneous and isotropic) of skull properties

Results

- Significant improvements in terms of sensitivity, resolution and positioning
- Proof of concept: homogeneous description enables use of fast DRT model

• Perspectives

- Specialization and optimization of the DRT model for very fast imaging
- At long term, autonomous imaging system, free from morphological CT or MRI.
- Virtually, all brain diseases could benefit from this improvement. The societal impact could therefore be significant











Thank you for your attention

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