Project Acronym: SOUNDPET

(INTEGRATED/0918/0008)

MRI-guided Focused ultraSOUND system for cancer in PETs
(dogs and cats)

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Ευρωπαϊκή Ένωση
Ευρωπαϊκά Διαρθρωτικά και Επενδυτικά Ταμεία

Κυπριακή Δημοκρατία

Διαρθρωτικά Ταμεία της Ευρωπαϊκής Ένωσης στην Κύπρο

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Executive summary

This deliverable presents the conference paper that was delivered during the first year of the SOUNDPET project at the *20th Annual International Symposium for Therapeutic Ultrasound* (ISTU) 2021, 6th -9th June 2021, HICO, Gyeongju, Korea. The deliverable includes the submitted abstract and the relevant PowerPoint of the oral presentation.

Submitted Abstract

MRI-guided Focused Ultrasound Robotic System for Preclinical Use of Small and Large Animals

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Objectives: Magnetic Resonance-guided Focused Ultrasound (MRgFUS) is increasingly gaining ground in the community of non-invasive surgery. A robotic system featuring four degrees of freedom was developed for preclinical use of MRgFUS on animals of all sizes.

Methods: The device comprises a single element spherically focused ultrasonic transducer and operates with a frequency of 1.1 MHz. A dual optical encoder setup was arranged on each motion stage to provide efficient position estimates. Extensive MR compatibility tests were performed. Ex vivo experiments in tissue-mimicking phantoms and excised porcine tissue, as well as in vivo experiments in rabbit models, evaluated the accuracy and repeatability of positioning and the overall performance of the system in both laboratory and MRI environments.

Results*:* The MRI trials proved the system as MR compatible and suitable for operation in MRI systems up to 7 T. The positioning mechanism provides motion in a highly accurate manner, with a mean positioning error smaller than 0.1 mm. Real-time *in situ* MR thermometry data confirmed sufficient heating. Reproducible and controllable thermal lesions were inflicted in vivo, in both discrete and overlapping patterns, without evidence of damage in healthy intervening tissue or other adverse events. Thereby, the procedure with the necessary anesthesia monitoring possesses no threat to animal welfare.

Conclusions: The device provides high standards of safety and accuracy. It will offer non-invasive, innovative therapy to pets with naturally occurring cancer, providing simultaneously the opportunity to advance human medicine. The device could be scaled up for future application in the treatment of abdominal cancer.

Acknowledgements

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PowerPoint of the Oral Presentation

MRI-GUIDED FOCUSED ULTRASOUND ROBOTIC SYSTEM FOR PRECLINICAL USE OF SMALL AND LARGE ANIMALS

TOPIC: ABLATION - THERMAL FUS

ORAL PRESENTATION

PRESENTER: Anastasia Antoniou

PhD candidate, Cyprus University of Technology

AUTHORS: Marinos Giannakou[1], Theocharis Drakos[1], Nikolas Evripidou[2], George Evripidou[2], Anastasia Antoniou[2], Christakis Damianou[2]*

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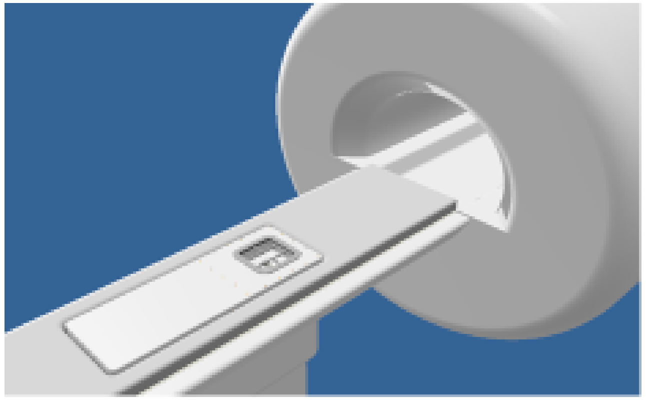
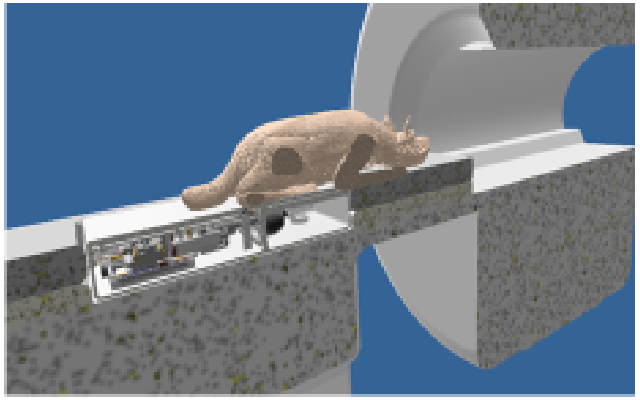
INTRODUCTION





Magnetic Resonance guided Focused ultrasound (MRgFUS) robotic device

- Preclinical use on animals of all sizes.
- Motion in 4 PC-controlled axes.
- Safe operation in conventional MRI scanners up to 7 T.

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ROBOTIC DEVICE

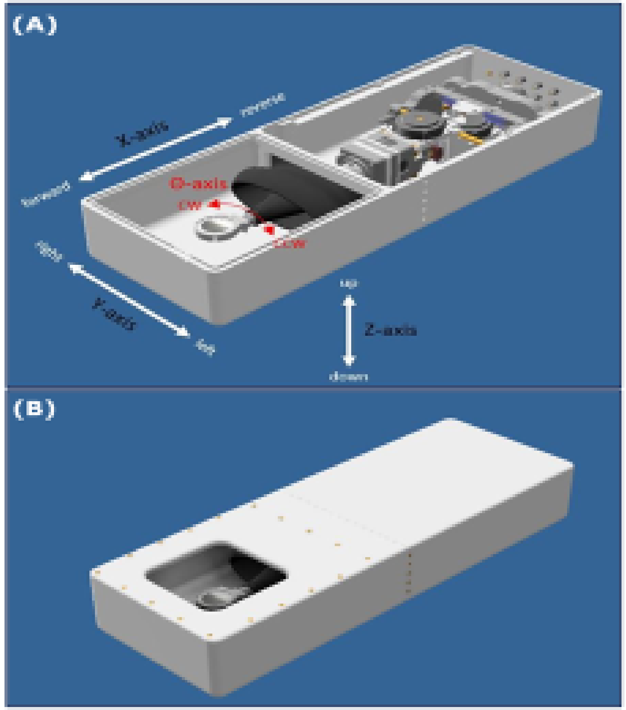

Figure 1: Robotic device A) interior view B) exterior view

- 3D printed (F270, Stratasys, Minnesota, USA) with Acrylonitrile Butadiene Styrene (ABS).
- Motion in 3 linear (X, Y, Z) and 1 angular (Θ) axes.
- Motion actuated by piezoelectric motors (USR60-S3, Shinsei, Tokyo, Japan).
- Motion control achieved with dual optical encoders (US Digital Corporation, Vancouver, WA, USA).
- Dimensions: 71 cm (L) x 25 cm (W) x 11.5 cm (H).

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FUS TRANSDUCER

- Optimal transducer characteristics based on simulations of power field and heating effects of beam.
- Single element spherically focused transducer with frequency of **1.1 MHz** to target **deep tissue** (70 mm radius of curvature, 50 mm diameter).
- Manufactured with **non-magnetic materials** for safe operation inside MRI.

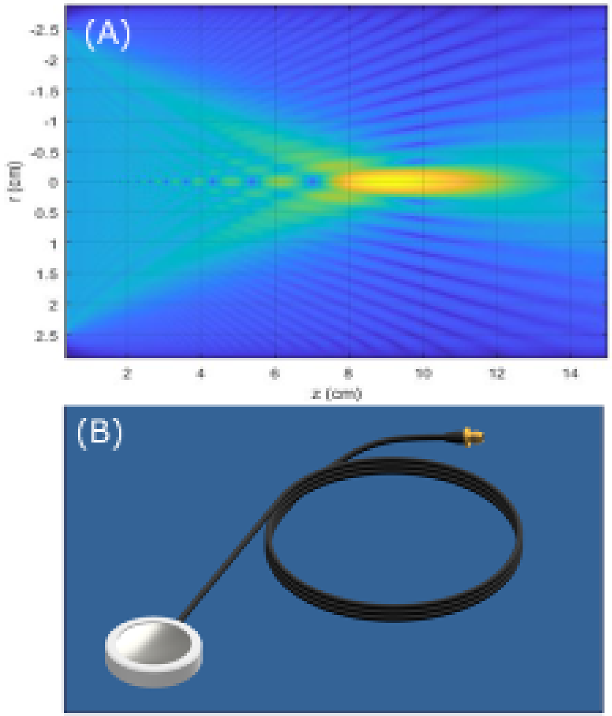

Figure 2: (A) Power field simulation (B) Ultrasonic transducer

MRI COMPATIBILITY

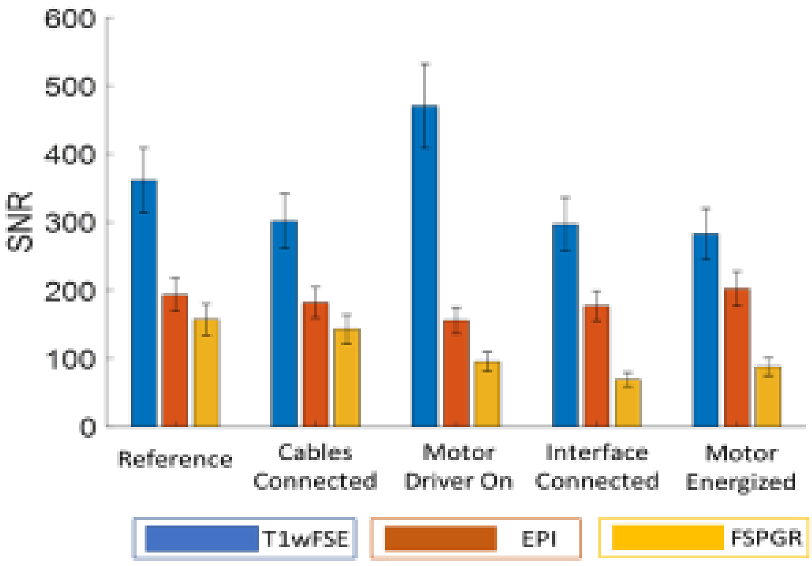

Figure 3: Bar chart of SNR for the various robot activation conditions and different pulse sequences.

- **Assessed in a 1.5 T MRI system** (Signa HDxt, General Electric, Fairfield, CT, USA) using a GPFLEX coil (General Electric, Milwaukee, Wisconsin, USA).
- Use of Fast Spin Echo (FSE), Fast Spoiled Gradient (FSPGR) and Echo Planar Imaging (EPI) sequences.
- SNR measured in a homogeneous GE phantom under different activation conditions of robot.
- Activation of motors does not affect the overall quality of FSE and EPI images.
- Noticeable decrease in SNR when the FSPGR sequence is used.

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MOTION ACCURACY

- Use of **special structures** for mounting the **digital calipers** on the motion stages.
- Motion commands through specially designed software.
- Motion steps of 1 mm, 5 mm, and 10 mm in X, Y, and Z forward and reverse directions.
- Rotation of 1º, 5º, and 10º in clockwise (CW) and counterclockwise (CCW) directions.
- Distance measured with caliper compared with the commanded distance.
- Linear positioning accuracy better than 0.1 mm.

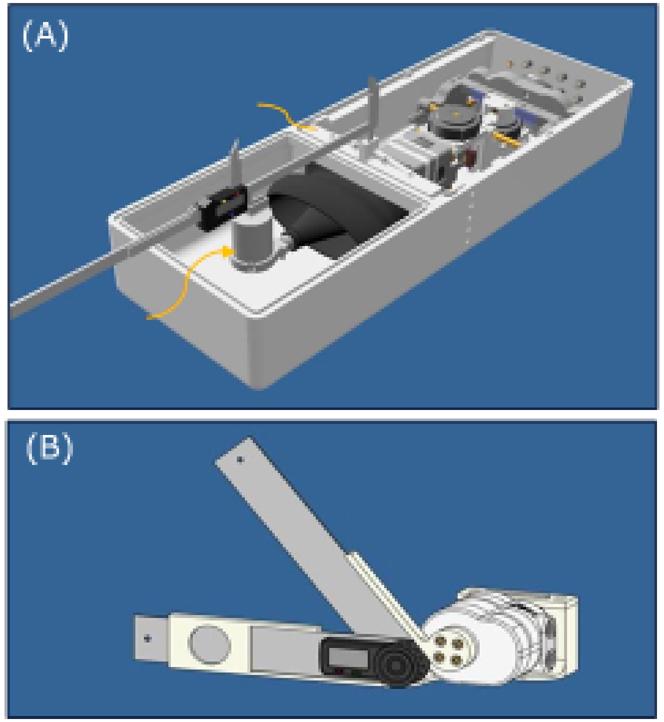

Figure 4: Experimental setup for evaluating accuracy of (A) linear and (B) angular motion.

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MOTION ACCURACY

- **Assessed in a 1.5 T MRI scanner** (GE Signa HD16, General Electric Healthcare, Chicago, Illinois, USA) using a GPFLEX surface coil (General Electric, Milwaukee, Wisconsin, USA).
- FUS transducer replaced by plastic marker.
- Bidirectional movements of 3 and 5 mm in X and Y axes.
- FSE images acquired after each step movement to detect the marker tip location.
- Images were superimposed onto one image for visualizing the motion patterns.
- Excellent repeatability evidenced by equally spaced spots.

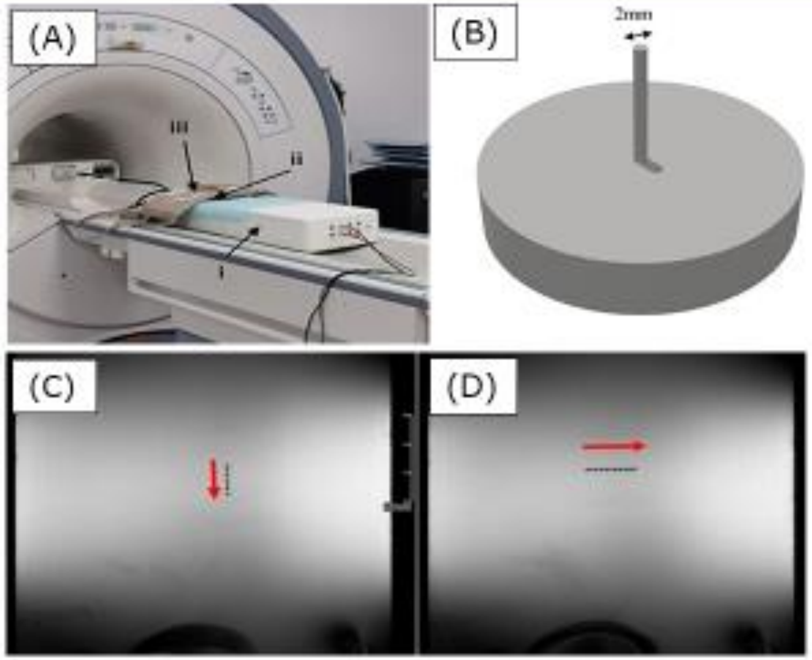

Figure 5: (A) Experimental setup, (B) plastic marker, and combination of FSE images showing (C) steps of 3 mm in X axis (D) steps of 3 mm in Y axis.

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THERMAL HEATING OF TRANSDUCER

Lesion creation in tissue mimicking phantom

- Development of a phantom containing 2 % w/v agar and 4 % w/v wood powder.
- Measurement of temperature increase using thermocouple.
- Recorded temperature change of 58.6˚C at acoustical power of 66.6 W for 30 s.

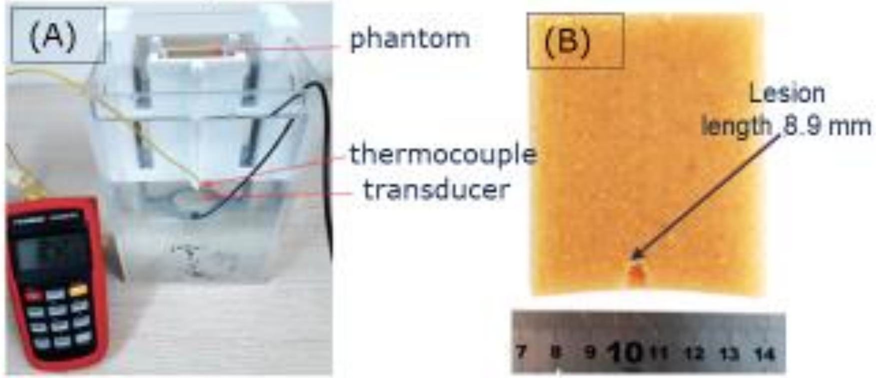

Figure 6: (A) Experimental setup (B) Phantom with lesion.

Lesion creation in excised pork loin tissue

- Robotic movement in grid.
- Overlapping lesions created using 55 W for 30 s in a 3x3 grid with 10 mm step.

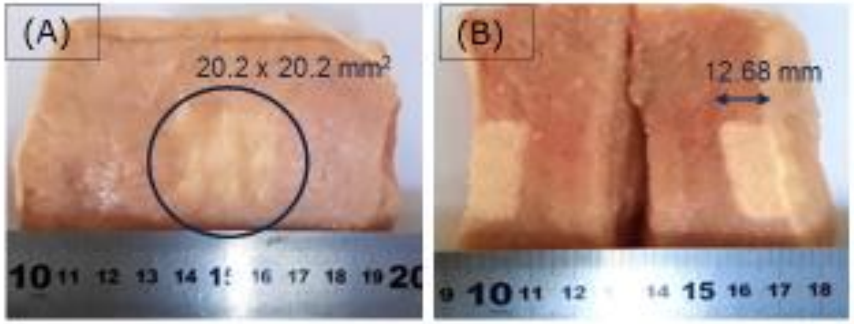

Figure 7: Lesion formed on plane (A) perpendicular and (B) parallel to the beam.

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IN VIVO EFFICIENCY OF THE SYSTEM

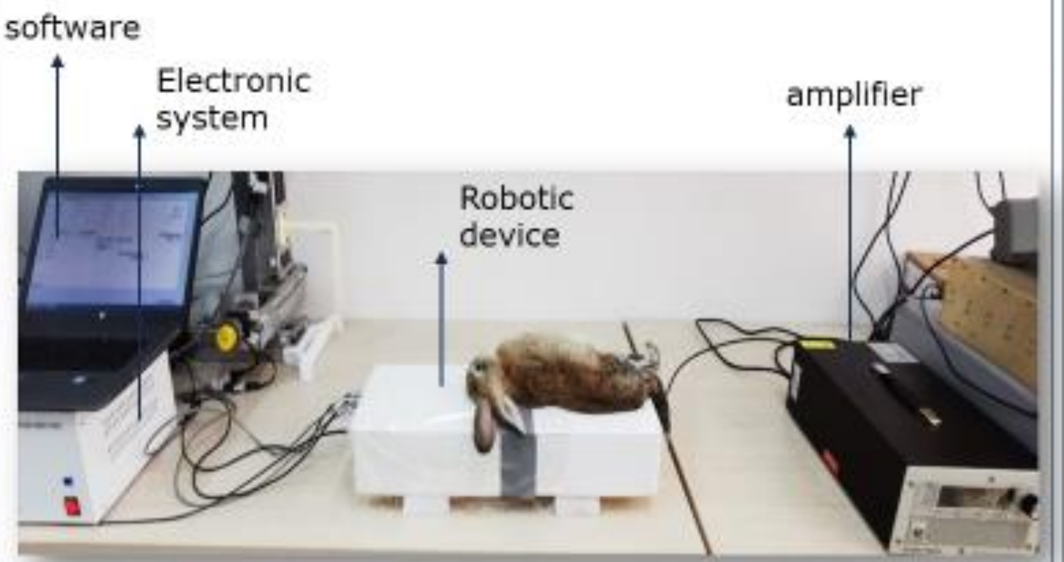

Figure 8: Animal positioning for thigh ablation.

- Ablation in a rabbit thigh model (n=20).
- Robotic movement of transducer in grid.
- Lesion formation in discrete and overlapping patterns.
- All experiments were approved by the authorities of the Veterinary Services, Ministry of Agriculture (CY/EXP/PR.L01/2020).

IN VIVO EFFICIENCY OF THE SYSTEM

Discrete lesions

- Acoustic power: 75 W
- Sonication time: 5 s

- *1 x 3 grid*
- *10 mm step*

- *4 x 4 grid*
- *10 mm step*

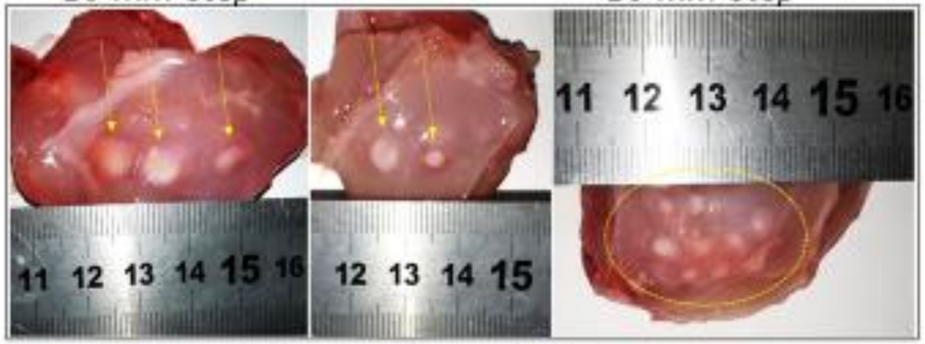

Figure 9: Sample images of discrete lesions.

Overlapping lesions

- Acoustic power: 75 W
- Sonication time: 5 s

- *4 x 4 grid*
- *4 mm step*

- *5 x 5 grid*
- *5 mm step*

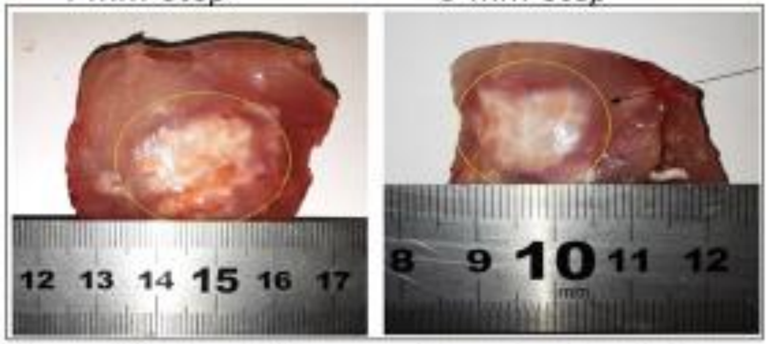

Figure 10: Sample images of overlapping lesions.

CONCLUSIONS

- Development of an **MRgFUS robotic system** for **veterinary use**.
- Compact, Portable, Cost-effective, and ergonomic.
- Safe integration with any MRI up to 7 T.
- Maintains high accuracy of motion.
- Efficient *ex vivo* and *in vivo* performance.
- Maintains high standards of animal welfare.
- Size modification for future clinical use in abdominal cancer.

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Κυπριακή Δημοκρατία

Ευρωπαϊκή Ένωση
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Διαρθρωτικά Ταμεία της Ευρωπαϊκής Ένωσης στην Κύπρο

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PROJECT: **SOUNDPET** (INTEGRATED/0918/0008)