Overview & Objectives: MRI-guided and robot-assisted interventions will have a far-reaching impact by enabling a leap in minimally invasive procedures (a) from “keyhole” visualization (i.e., laparoscopy) to in-situ real-time imaging guidance, and (b) toward using the emerging steerable or shape-conformable tools. The objective of this project is to develop and investigate the operation of an integrated system for performing MRI-guided and robot-assisted interventions on the beating heart. Our primary directive and hypothesis is the reliance on true sensing of the physical world with multi-contrast imaging to control the surgical robot while offering a comprehensive perception to the operator.

Proposed Team: It will be composed of five members, N.V. Tsekos (UH: MRI, MR compatible robotics, visuohaptic interface) Z. Deng (UH: real-time data pipeline, visuohaptic interface and system integration), Grigoriadis (UH: control and visuohaptic interface), D Shah (TMH: Cardiovascular MRI and visuohaptic interface) and M. Davies (TMH: specifications in robot design, cardiovascular surgery and visuohaptic interface). All five members have well established collaborators as attested by publications [1-27] in referred journals and conferences, as well as common NSF CPS grants and pending NIH applications. In addition, the team will be supported by two postdoctoral fellows (one at each site), an RT and animal Technician (TMH), a CAD/mechanic specialist (UH) and three graduate students (UH).

Industrial relevance and appropriateness for the center: The proposed project includes the development and investigation of a wide range of enabling technologies and methodologies pertinent to the operating room of the future. Thus, there is direct relevance to industry, as well as to the proposed center:

- The sought outcomes of such academy-industry collaborations will be: First, this project either as parts of MR guidance or adopted for other tissue-level modalities (e.g. ultrasound), will offer enabling methodologies that will be of high value in advancing the field of image-guided robotics and it can also serve as a versatile platform for developing and applying other current or emerging high-resolution sensing methods of limited penetration and field-of-view.
- Further advancement of this research and its eventual clinical application requires closed collaborations with corporations specialized on the development, production and distribution of similar technologies, including original equipment manufacturers (OEM) of MR scanners, surgical robots and catheters.
- The center will provide the framework and offer the needed networking, legal and IP arrangement and advising to foster such complex industry-academia projects like the one proposed herein

Experimental plan: The proposed team has already established collaborators in this area and we embark on a systematic research that will focus on and deliver enabling methodology in three areas:

- Introduction of MRI data collection (i.e. ultrafast volumetric pulse sequences) and image processing strategies that mature raw imaging data to decision-making quality information that can be used for image-based manual and automated control.
- Development of an MR compatible robotic device that actively compensates for the motion of the heart and offers the dexterity needed to reach an epicardial (by circumventing the heart) or endocardial (via a transapical access).
- Development of control strategies that capitalize on the multi-modal MR image-extracted information to maneuver a conformable robotic manipulator to the targeted area under conditions of dynamically changing tissue geometry.
- Development of a visuohaptic human-information/machine-interface that maximizes the conveyed informational content (i.e., offering dynamic safe access corridors) for minimal work-load but comprehensive perception in setting up, configuring and minimal distraction at its in-the-field operation.

**Deliverables and Annual/Total cost:** It is estimated the project will require a total of three years to complete, at an estimated cost of $1,250,000. At the end of the first year, which will require an estimated cost of $450,000, the project will deliver the first prototypes of (1) an MR compatible 7-DoF robotic manipulator for procedures on the beating heart and (2) a visuohaptic human-machine interface with an image-based force-feedback haptic-like interface. Over the remaining two years, at an estimated cost of $400,000/year, the two prototypes will be (1) tested on dynamic cardiac phantoms and animal models in the MR scanner (i.e. real-time MR-guidance), (2) optimize their operation and implement any needed changes, and (3) seamlessly combined into an integrated system. Studies will both assess the engineering aspects of the system and investigate its clinical functionality and integration into the operation room. At the conclusion of the project the system will be at a stage suitable for pre-clinical assessment.

**References:**
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24. Erol Yeniaras, Nikhil Navkar, Mushabbar A. Syed and Nikolaos V. Tsekos “ A computational system for performing robot-assisted cardiac surgeries with MRI guidance” in the Intelligent Medical Systems & Bioinformatics of the 15th Society for Design & Process Science (SDPS 2010), Dallas, TX June

