



Project Proposal for Ph.D.

Project Details (The research problem must clearly indicate the need for an interdisciplinary approach)

Project Title	Coordinated control of an octopoid multi-arm soft robot for underwater applications
Project Summary (Minimum 500 and maximum 2000 characters)	Traditional rigid marine robots, such as Remotely Operated Vehicles (ROVs) and Autonomous Underwater Vehicles (AUVs), excel in deep-sea transit but possess significant limitations in unstructured environments. The biological octopus provides an optimal evolutionary blueprint for aquatic robotics, utilising eight entirely soft arms to achieve unparalleled agility, strength, and tactile sensitivity. Translating this adaptability into an engineered system requires bridging two traditionally distinct fields. This highly interdisciplinary proposal brings together the fundamental strengths of soft mechanics—specifically non-linear material deformation, hyper-elasticity, and compliant structures—with advanced multi-arm robotics, including cooperative manipulation, distributed control, and kinodynamic motion planning. The primary barrier to engineering this bio-inspired platform is the infinite degrees of freedom (DoF) inherent in continuous soft appendages, which can bend, stretch, compress, or twist at literally any point. To solve this, the research must start at the level of material selection and actuation mechanisms that provide the necessary force and are compatible with marine environments. We will employ finite deformation nonlinear finite element simulations to optimise material and actuation behaviour. Once optimal baseline materials are established, we will mathematically discretise the continuous tentacle into a finite series of controllable points which can be tracked and controlled via a strain-informed feedback loop. Scaling from a single soft actuator to eight autonomous arms introduces challenges of coordination, entanglement, and interference. Beyond controlling individual arms, the system requires coordinated motion planning and control to ensure that the appendages can simultaneously perform complementary tasks while avoiding collisions and maintaining stability. We will develop coordinated control strategies and kinodynamic motion planning algorithms that explicitly account for the coupled dynamics and physical constraints of the soft appendages. While individual sensors inform the motion of a single arm, multi-axial strain sensors embedded in the central body between the arms will interface the multiple appendages to provide coordinated, multi-body control. Furthermore, moving one arm underwater displaces fluid, creating hydrodynamic forces that immediately impact the trajectory of the others. The robot must dynamically compensate for these fluidic couplings, buoyancy shifts, and current disturbances to maintain stability and execute precise grasping tasks in turbulent conditions. To mitigate technical risk, the project follows a rigorous, phased implementation strategy. The first phase focuses on fabricating a single tentacle system. Using the previously selected robust elastomers, we will prototype modular arms driven by identified actuation methods, validating the coupled kinematic model through high-fidelity physics-based simulations and developing reduced-order models suitable for motion planning and control. The second phase advances to a four-arm quadrupedal system integrated into a soft housing. We will develop coordinated motion planning and control strategies to enable crawling and walking gaits, validating the platform's ability to navigate a simulated seabed while maintaining stability and avoiding inter-arm interference. The final phase scales the hardware to the complete eight-arm configuration, integrating an inter-arm webbing structure to aid fluid displacement. This culminates in synchronised rapid-contraction algorithms for hydrodynamic swimming and complex multi-tasking, such as anchoring to a dynamic reef structure with four arms while manipulating a target object against a current with the remaining four.

Ph.D. Supervisors* (Supervisor 1 and Supervisor 2 cannot be from the same department of IITD)				
Role	Name of Faculty	Date of Superannuation\$ (DD/MM/YYYY)	Academic Unit in IITD/Institute/University	Email ID (Official) & Contact Number
Supervisor 1*	Mayank Sewlia	31/08/2060	Electrical Engineering	sewlia@ee.iitd.ac.in
Supervisor 2	Rahul G Ramachandran	31/10/2055	Applied Mechanics	gr_rahul@am.iitd.ac.in

*Supervisor 1 must be from IIT, Delhi.
 +All cells in this table are mandatory fields that need to be filled by faculty for consideration of proposal.
 \$The date of superannuation of supervisors should be at least three years from the date of registration of selected candidates.

Project requirements (Student qualifications, experience required, etc) *The candidate will be shortlisted based on common shortlisting criteria decided by ScRC (SIRe)
- Background in Mechanical, Electrical, Aerospace Engineering, Materials Science, or a closely related discipline. - Foundational knowledge in atleast three of the following areas: Theory of mechanics, fluid mechanics, strength of materials, control systems, finite element analysis, aerodynamics, and robotics. - Strong interest in interdisciplinary research, including theoretical modelling and hands-on experimental development and validation.

Source of fellowship/funding and project number (CSIR/UGC/DBT/ICMR/ICAR/NEET-PG/DST-INSPIRE/IRD/FITT Project details, if any)
Institute funded.

Role of Faculty Members involved:	
Supervisor-1	Stability (kinematic and dynamic) analysis, distributed control, multi-arm manipulation, motion planning, experimental space.
Supervisor-2	Material testing and development, actuation mechanism, finite element simulation, experimental space.

- Note :-**
- Approval from the respective DRC/CRC/ScRC of your Department/Centre/School will be required for using the "Full-time Institute Assistantship (Category-wise) (FIA)" for selecting the students in SIRe.
 - Declaration:- Faculty members, please ensure that you have at least 3 years of service left before superannuation along with adequate sitting space & lab facilities for the SIRe student.
 - PI/s are also encouraged to submit joint proposals with AIIMS, NII, JNU and institutes with which IITD has an existing MoU. If the Co-PI (Supervisor 2) is from outside IITD, kindly share his/her detailed CV.
 - If a research scholar is to be considered for selection under the project fellowship, then the project should have a minimum of two-year duration remaining.
 - A candidate applying with a valid JRF/INSPIRE/any national level fellowship should have at least two-year validity from the date of joining the Ph.D. program.
 - The third supervisor’s name (if required) can be added only after the formation of Student Research Committee (SRC) subject to a strong recommendation of SRC and subsequent approval from the competent authority.
 - If institute fellowship is being sought then the DRC approval of the parent departments of both supervisors is required at the time of selection.