**Decentralized Swarming by Robot Collectives**

**Research Goal:**
Develop a framework for decentralized swarming by robot collectives using artificial potential fields.

**Our Approach:**
- Takes advantage of the **Artificial Potential Field Approach** for obstacle avoidance and with **Augmented Lagrangian Constraint Satisfaction** to ensure formation maintenance.

**Challenges:**
- **Decentralization** with minimal centralized coordination is critical from the viewpoint of scalability.
- **Formation maintenance** at every stage of the motion is crucial for payload transport.

**Motivation:**
- Task may be inherently too complex for a single robot to accomplish.
- Improved performance can be achieved using a group of robots.
- Developing simple small-sized robots can be cheaper, more flexible and fault tolerant.

**Application Arenas:**
- Military Swarm Robots
- Oceanographic Sampling
- Space Exploration
- Medical Nanobots
- Search & Recovery
- Cooperative Robots
- Buildings Surveillance
- Entertainment Industry

**Methods:**
**VisualNastran Simulation:**
- Test and evaluate swarming strategies using Visual Nastran simulation environment.
- Nonlinear, non-smooth effects, including slip and friction can be modeled and simulated.

**Hardware-in-the-loop Testing:**
- Advances in networking and miniaturization of electro-mechanical devices allow the deployment of such systems.
- iRobot’s Create mobile robots and MICA Motes allow creation of an ad-hoc networked multi-robot testbed for experimental validation.

**Results:**
- Study: 10 Robots and an Obstacle
- Study: 3 Robots and an Obstacle
- Study: Changing Formation
- Study: Expanding Formation

**IDEA:**
By modeling workspace and obstacles as a potential field, the motion planning problem reduces to letting the robot follow the gradient of the potential field to reach the destination.

**Dynamics Formulation:**
\[ \mathbf{q} = \mathbf{v}, \quad \mathbf{M}(\mathbf{q})\dot{\mathbf{v}} = \mathbf{f}(\mathbf{q}, \mathbf{v}, \mathbf{u}) - \mathbf{J}(\mathbf{q})^\top \lambda, \quad \mathbf{C}(\mathbf{q}, \mathbf{r}) = 0 \]

**Solved using 3 methods:**
I: Direct Lagrange Multiplier Elimination Approach
II: Penalty Formulation Approach
III: Constraints Manifold Projection Based Approach