IITB-Monash Research Academy

Indian Institute of Technology Bombay | MONASH University

An Indian-Australian research partnership

Project Title:	**New models and algorithms for decentralized and adaptive coverage control in multi-robot systems**	
Project Number	**IMURA0411**	
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Research Academy Themes:

Highlight which of the Academy's Theme(s) this project will address?

(*Feel free to nominate more than one. For more information, see www.iitbmonash.org)*

1. Advanced computational engineering, simulation and manufacture
2. Infrastructure Engineering
3. Clean Energy
4. Water
5. Nanotechnology
6. Biotechnology and Stem Cell Research

The research problem

Define the problem

Consider the following applications,

1. Monitoring the temperature/current or oil spills in a part of the ocean.
2. Distributing agents to sense nuclear radiation in a region.

3. Network of UAV's in reconnaissance mission measuring enemy presence in a region.

In each of the above situations there is a need to distribute autonomous agents functioning as sensors to optimally cover an unknown environment.The problem of algorithm design for such a group of agents is usually in two parts. First is the notion of locational optimization to resolve how the agents should be ideally distributed in order to achieve optimum sensing capabilities. Second and perhaps the most important problem is what the requirements in communication (intervals between messages, communication topology, to name a few)are in order to achieve the desired optimum coverage configuration in a robust manner.

The scalable distributed coverage control algorithms must have several features. First, they must be decentralized. This implies that decisions should be madebased on purely local information since 1) communicating with agents far away is slow and hard to implementin dynamic environments 2) having a global leader would in general make the system fragile against any local failure around the leader. Second, the algorithms require the ability to adapt. This adaptation should be performed with respect to an unknown, possibly dynamic environment, which implies that the distribution of sensing tasks is rather time-varying and non-uniform and the communication graph canalso undergo dynamic changes.Finally and most importantly, the control algorithms should have theoretical guarantee that they can asymptotically drive given initial conditions to an optimal configuration.

There is considerable scope of improvement in terms of algorithms for decentralized coverage control, especially with respect to their adaptation capabilities in sensing distributions and dynamic communication topology. We would also like to extend results to decentralized coverage control design on nonlinear manifoldssuch as the space of rotations.

Project aims

Define the aims of the project

The project will aim to study advances in decentralized coverage control. This is an important coordinated control problem wherein a set of robots identify optimal techniques to cover an unknown environment for the purpose of sensing. Applications include, rescue and recovery, radiation and nuclear spill detection, underwater oil exploration etc. The aim would be to improve upon existing coverage control laws, which includes computing an optimal distribution and then reaching the same in a robust manner. All the control and computation tasks must bedecentralized.

Specifically,

1. Improvements in algorithms are sought in their ability to adapt to sensing uncertainties.
2. The existing algorithms will be analyzed for convergence characteristics under dynamic communication graphs,and modified if necessary.
3. Extensions of the existingalgorithms to coverage control on nonlinear manifolds will be investigated.

Expected outcomes

Highlight the expected outcomes of the project

1) A comprehensive literature survey of existing methodologies in decentralized coverage control design.
2) Identify decentralized techniques for optimal coverage.
3) Design nonlinear and adaptive feedback laws to ensure that the robots reach the desired optimum.
4) Implement decentralized coverage strategy on a laboratory setup with multiple autonomous robots.

How will the project address the Goals of the above Themes?

Describe how the project will address the goals of one or more of the 6 Themes listed above.

The project is expected to fall under the category of “Advanced computational engineering, simulation and manufacture”. The aim of the project would be to develop advanced algorithms operating in real-time to provide a high degree of autonomy to robotic agents used as distributed sensors. Advanced computational and analysis techniques for the purpose of feedback design and optimization will be employed. Real-time simulations with advanced distributed systems software and hardware proof of concept are also expected as an outcome of the undertaking.

Capabilities and Degrees Required

List the ideal set of capabilities that a student should have for this project. Feel free to be as specific or as general as you like. These capabilities will be input into the online application form and students who opt for this project will be required to show that they can demonstrate these capabilities.

The candidate should have a master’s degree in Mechanical, Aerospace, Electrical Engineering or associated fields with some exposure to Linear Systems Theory and Basic Control Theory.Computer programming experience especially with MATLAB/Simulink and C is expected.

Hardware and real-time programming experience with robots or other autonomous systems will be an added advantage. The ideal candidate is expected to have a Mathematical bent of mind.

Potential Collaborators

Please visit the IITB website www.iitb.ac.in OR Monash Website www.monash.edu to highlight some potential collaborators that would be best suited for the area of research you are intending to float.

Other potential collaborators include Dr Jan Carlo Barca