Multi-robot formation control for collaborative SLAM

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Context

This Post-doc subject is proposed in the context of the ROAD-AI Challenge involving the Cerema and the Inria Team ACENTAURI.

ACENTAURI is a robotic team located in Sophia Antipolis that studies and develop intelligent, autonomous and mobile robots that collaborate between them to achieve challenging tasks in dynamic environments. The team tackle perception, decision and control problems for multi-robot collaboration by proposing an original hybrid model-driven/data driven approach to artificial intelligence and by studying efficient algorithms. The team focus on robotic applications like environment monitoring and transportation of people and goods. In these applications, several robots will share multi-sensor information eventually coming from infrastructure. The effectiveness of the proposed approaches are demonstrated on real robotic systems like cars AGVs and UAVs together with industrial partners.

Non Destructive Evaluation of Structures and Materials (ENDSUM), directed by Cyrille FAUCHARD, has for main objective to contribute to the development of tools and methods of characterization and diagnosis with great efficiency, less invasive than the current tools and not altering the environments auscultated to meet the challenges of Asset Management of Infrastructures (IPM). The research carried out is aimed first of all at the physical and geometric characterization of environments using a multi-parameter, multi-scale and multi-physical approach linking the quantities measured to indicators useful for the diagnosis and monitoring over time of the environments observed. ENDSUM also aims at the development of analytical and numerical modeling, inversion and data processing and analysis methods (signals, images) allowing access to the desired physical and geometric properties. Finally, ENDSUM aims to develop innovative prototype software and hardware as well as tools for training, research and expertise.

Post-doc subject

The infrastructures (road network, bridges, buildings, …) are among the most important elements of the public heritage. Operators are responsible for maintaining, operating, developing, replacing and preserving this heritage while ensuring careful management of budgetary and human resources. Today, these infrastructures are put to the test by climate change (increase in the frequency of extreme phenomena which in particular favor floods and land movements). Users are also extremely attentive to questions of safety and comfort related to the use of infrastructure but also to environmental issues relating to their construction and maintenance.

The ROAD-AI Challenge objective is to design a multi-robot system comprising ground vehicles and aerial drones collaborating in the collection of data on structures with on-board sensors. Aerial drones seem to be a very promising solution for data acquisition because they can have points of view not obscured by obstacles and access structures more easily. On the other side, the ground vehicle seems better appropriated to supervise the mission of data acquisition for environment exploration and mapping.

In this Postdoc, we want to study active strategies of data acquisition involving a master robot (the ground vehicle) and two slave robots (aerial robots) in order to optimize in terms of accuracy and stability the mapping of the environment. Each robot will be equipped with its own large field vision with a time stamping. We assume also that synchronized velocity control inputs can be sent to the ground and aerial robots. The master robot centralizes the information and manages the multi-robots formation. One robot of the formation, so-called the leader (not necessary the master) is manually driven by a human operator who ensures the completness of the exploration of the scene.

The first scientific problem we want to deal with in this Postdoc will be to guarantee a stable structure of the robot formation in the reference frame of the master robot. The choice of an optimal structure of the formation will be directed by the task objectives (i.e., exploration context, optimization of the map acquisition…). Recent works on Cooperative Multi-Robots Systems [1],[2],[3],[4],[5],[6] will be used to organize and to manage the formation taking into account the navigability constraints. Considering that each robot can be observed by at least one of the other, we intend to realize and to control the formation by means of sensor-based control and visual servoing techniques [7], [8].

The second scientific concern will be to investigate how we can use the constraints induced by the formation to stabilize the ill-posed problem of SLAM (Simultaneous Localization and Mapping). SLAM is a key problem in mobile robotic which consists of exploiting the observation of the environment for conjointly estimating the robot's trajectory and building a map of the environment [9],[10], [11]. Basically, the robot's trajectory is built thanks to an odometry method integrating an estimate of the displacement. As result, we observe a drift

in the trajectory leading to a distorted map. A classical solution to minimize this drift and to correct the distortion is the use of closed loop methods based on the re-observation of landmarks and a backpropagation of the drift along the trajectory [12],[13]. To be efficient a sufficient large number of landmarks dispatched all along the trajectory have to be re-observed. Considering the constraints introduced by the structure of formation described above, it seems possible to formulate a SLAM problem for collaborative robots as a global optimization problem involving the trajectories of the different robots AND the constraints due to the structure of the formation. In such a case, we expect to largely simplify or, maybe to eliminate, the problem of drift and the need of closed loop methods.

The system will be evaluated on Inria robots on a structure known to the Cerema Mediterranean services, for which the civil engineering service will be requested. For the experimental evaluation, the candidate will work in close collaboration with a PhD student and an R&D engineer who will be in charge of the implementation of the multi-robot system.

Work-plan

The work will be broken down into stages as follows:

- Bibliography on Visual Servoing, mission planning for collaborative robots, SLAM techniques, nonlinear optimization
- Implementation of the most efficient state-of-the-art techniques
- Study and implementation of a robot's formation specification and control using visual servoing
- Study and implementation of a collaborative SLAM scheme
- Comparison with state-of-the-art localization techniques
- Validation with remotely operated robots (not autonomous)
- Writing articles for international conferences

Skills

The candidate should preferably have a PhD in Robotics, solid foundations in software development (C / C ++, Python, LINUX, ROS, Git, OpenCV). He / she should also be endowed with a strong passion for multidisciplinary studies and all aspects of research ranging from fundamental work to experimental work. Finally, a good level in read / written / spoken English is also important.

How to apply

Interested candidates must send a detailed CV and one or more letters of recommendation to ezio.malis@inria.fr

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