Thesis subject:

Robust Multi-robots Visual SLAM using Heterogeneous Mobile Cameras Network

PhD Advisors:

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Context of the thesis:

The thesis is part of the project activities of the Laboratory of Excellence (LABEX) at the Université de Technologie de Compiègne (UTC) in France on the Control of Technological Systems of Systems (MS2T) (http://www.labexms2t.fr). Specifically, the thesis belongs to the research activities planned in the context of the Defis Team DIVINA. It is also part of the project of equipment of excellence ROBOTEX in the topic of mobile robotics with an application on perception/navigation for multi-UAV.

PhD thesis description:

In order for the robots of a multi-robot system to coordinate for accomplishing some task, while navigating autonomously within a given area, they must be able to determine their positions. In an environment where absolute position information, like that coming from GPS, is not available, the robots can improve their localization accuracy by recording robot-to-robot relative position measurements, and processing them in order to update their position estimates. However, performing cooperative localization solely based on relative position measurements has the limitation that the uncertainty of the robots' position estimates would continuously increase, and the attained accuracy may not be sufficient for certain applications [1].

An alternative approach is for the robots to localize themselves while concurrently building a map of the environment and in this case the uncertainty in their position estimates would be bounded. The latter approach introduces the problem of Cooperative Simultaneous Localization And Mapping (C-SLAM) that has recently attracted the interest of many researchers [2]. In statistical terms, SLAM is a high-dimensional estimation problem characterized by two major sources of uncertainty, pertaining to the noise in sensing and in motion. Whereas SLAM has mostly been addressed for single robot systems, the problem is particularly challenging for multiple robots that seek to cooperate when acquiring a map. Recent research has led to a flurry of more capable algorithms, introducing concepts such as hierarchical maps, particle filters, information filters, and junction trees into the SLAM literature.

From a sensing point of view, traditional SLAM approaches rely on bulky sensors having a high range and accuracy (e.g., laser range finders) which cannot be used on robots working as a fleet, such as small flying vehicles (UAVs) or small ground rovers. As a result, several researchers focused on using vision sensors instead of laser range finders in a multi-robot framework modelled as a sensor network [3][4]. Since cameras are an attractive alternative due to their limited weight and low power

consumption, visual sensor networks [5] have emerged as an important class of sensor-based distributed intelligent systems, with unique performance, complexity, and quality of service challenges [6][12]. Consisting of a large number of low-power camera nodes, visual sensor networks support a great number of novel vision-based applications like Visual SLAM [3] and Structure-From-Motion [7]. The camera nodes provide information from a monitored site, performing distributed and collaborative processing of their collected data. Using multiple cameras in the network provides different views of the scene [8], which enhances the reliability of the captured events. However, the large amount of image data produced by the cameras combined with the network's resource constraints require exploring new means for data processing, communication, and sensor management based on Swarm Intelligence and self-organizing QoS routing protocol [9][10]. Meeting these challenges of visual sensor networks requires interdisciplinary approaches, utilizing vision processing, communications and networking, and embedded processing.

To summarize, in this thesis project, we will focus on distributed Visual SLAM algorithms with multiple heterogeneous cameras [11], where the robots can cooperate with and learn from each other. Specifically, we will address two kinds of cooperation among robots: the explicit and pre-planned cooperation based on the design of intelligent mobility-aware networking protocols, and the swarm cooperation emerging from some basic individual communication rules and behaviours. The former will guarantee a reliable multimedia transmission in normal conditions, whereas the latter should make the system work even during occlusions and non-visual overlap situations.

Scientific challenges will be on:

- Inter-camera pose estimation and mapping to deal with dynamic objects and heterogeneous cameras (in terms of field-of-view, resolution, etc.) in the localization and mapping process, and especially in the case of non-overlapping cameras using generalized camera models.
- Definition of distributed networking protocols for explicit cooperation and design of basic communication behaviours for swarm cooperation based on bio-inspired mechanisms.
- Quality of service guarantee in multimedia transmissions based on camera clustering according to their view overlap, estimated positions and maps, and through specific data compression algorithm [4].

The PhD work also includes an experimental aspect, which is to integrate the techniques developed on existing experimental platforms (quadricopters, Renault electrical vehicles and Wifibots) within the framework of project equipment of excellence ROBOTEX.

Keywords: Visual sensor wireless network, Distributed Algorithms, Visual SLAM, Swarm Intelligence, QoS routing protocol.

Candidate's profile:

Advanced Knowledge required in Computer Vision, Bayesian Filtering, Distributed Algorithms, Swarm Robotics, Networking and an advanced level in programming in Matlab and C/C++.

Documents required to apply:

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- Curriculum vitae
- Motivation letter
- At least two references and/or recommendation letters
- A statement of research experience and interests

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