Progress Report

1. Aim of our research:

The goal of our research is to design and implement a middleware system for distributed cooperating autonomous mobile robots.
The design issues, we aim that our middleware system achieves are:

- Enabling a developer to program a team of cooperative mobile robots as if it were a single entity.
- Separation between the target application and the internal structure of the system.

The principal problem that we focus on is: to design adequate mechanisms based on an abstract and modular view of the system. This requires identifying a minimal set of relevant abstractions that can handle both communication and motion control. These abstractions are the basic blocks in the design of our middleware.

This middleware should decouple the application, from the details of the system, such that, a developer can focus only on the required task, by writing a script containing a list of instructions to be executed by teams of robots, regardless of the infrastructure of the system.

To enable this middleware to be used to solve real-world problems, it is desirable to address aspects such as fault-tolerance behaviors, which can serve as a basic building block to implement self-stabilized teams of autonomous cooperative mobile robots.

2. Approach:

We need to identify relevant abstractions, corresponding to fundamental problems and applications in cooperative mobile robots world. These abstractions constitute the basic blocks in the design of our middleware. We aim also at prototyping and implementing basing building blocks of the middleware such as distributed motion planning and group communications, which are convenient for cooperative mobile robots. Then we consider fault-tolerance aspects when a certain number of robots can possibly crash.

3. Progress of this year:

- Exploiting failure detection techniques for traditional distributed systems, in order to be adapted to mobile ad-hoc distributed systems. We investigated accrual failure detectors in conventional distributed systems connected via LAN and WAN networks. Accrual failure detectors emphasizes flexibility and expressiveness and can serve as a basing building block to implementing failure detectors in distributed systems. Our φ accrual failure detector dynamically adjusts to current network conditions.

- Providing fault-tolerant group membership and view synchrony protocols among robot teams where the communication model between teams of mobile robots is

relying on physical robot messengers. We look at the problem in the face of failures, in particular when a certain number of messenger robots can possibly crash. We considered two failure models, in the first we handle messengers failures while the second failure model considers both teams and messengers failures. We discussed the correctness of our algorithms and evaluated their behavior in terms of energy and time. Our group membership and view synchrony protocols constitute essential building components of our target middleware for distributed systems composed of mobile robots. This communication component is motivated by a mining application in which teams of worker robots cooperate to excavate minerals, and more generally it can be applied in environments where there are no established communication infrastructures.

4. Future directions:

Our future work targets the following points:

- Design distributed motion-planning building blocks of our middleware, which guarantee a safe navigation of robots without being in collisions.
- Implementing and testing these components.
- Refactoring these middleware components.
- Design navigation components tolerating the crash of a certain number of robots.
- Implementing and testing the previous fault-tolerant navigation components.
- Decomposition into microprotocols.

5. List of publications:

Fault-tolerant group membership protocols using physical robot messengers.
R. Yared, X. Défago, and T. Katayama. To appear in Proc. 19th *IEEE Intl. Conf. on Advanced Information Networking and Applications (AINA'05),* Taipei, Taiwan, March 2005.

The φ accrual failure detector.
N. Hayashibara, X. Défago, R. Yared, and T. Katayama.
In Proc. 23nd *IEEE Intl. Symp. on Reliable Distributed Systems* (SRDS'04), Florianopolis, Brazil, October 2004.

Fault-tolerant group membership protocols using physical robot messengers.
R. Yared, X. Défago, and T. Katayama. Research Report IS-RR-2004-019, Japan Advanced Institute of Science and Technology, (JAIST), Hokuriku, Japan, December 2004.

6. System Implementation:

We are actually implementing an application that enables a user to control mobile robots via a graphical interface from a remote machine.