Progress Report in 2007

---- Research on Fault Tolerance of Mobile Robots

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1. Introduction of our research

Mobile robots cooperating in groups offer several advantages, e.g., redundancy and flexibility, and can sometimes perform tasks that would be impossible for one single robot. Recent advances in robotics have started making it feasible to deploy large numbers of inexpensive robots for tasks such as military scout vehicles, satellite exploration and surveillance missions [1]. However, coordination of multiple robots to accomplish such tasks remains a challenging problem [2].

One of the important applications of multiple robots is the flocking problem. In short, flocking is the ability of a group of robots to move in formation and to preserve it while moving. Concretely, simple robots are allowed to move, with basic rules governing their movement. The moving in formation has many applications, for instance, transporting large objects, exploring hazardous areas and surveillance. Even though the cheap, simple and relatively weak robots have many advantages in the applications, those characteristic of robots also may bring its proneness to crash. Specially in flocking application, all robots coordinately generate a certain formation. If some robots are crashed, the other robots can not distinguish the alive robots in waiting state from the crashed ones. Thus, the desired formation with the current robots can not maintain while moving. Therefore, it is necessary to find a method that can distinguish the correct robots in waiting state from the crashed ones.

Therefore, fault tolerance of robot systems becomes very important in the coordination of multiple mobile robots. While, the design of fault-tolerant distributed flocking algorithm for multiple robot systems is very necessary and still a largely unexplored direction. Specially in flocking application, all robots coordinately generate a certain formation. If some robots are crashed, the other robots can not distinguish alive robots (not faulty robots) in waiting state from the crashed ones (who will stop working and never recover). Thus, the desired formation with the current robots can not maintain while moving. Therefore, it is necessary to find a method that can distinguish the correct robots in waiting state from the crashed ones. As we know, it is not applicable in dynamic applications like flocking, because the probability of robot failure during execution is much high due to influence of various environments.

2. Progress of this year:

- Propose a fault tolerant flocking algorithm for mobile robots in CORDA model with K bounded scheduler. The proposed algorithm includes three modules: non-faulty robot selection module, preprocessing module and flocking module. In the first module, the non-faulty robots are selected based on K-bounded scheduler. In this part, we don't only consider initial crash of robots, but also we take into account crash of robots during execution. This is different from the existed schemes. In the preprocessing module, the robots that are initially located at random places can self-organically generate a desired formation (regular polygon).

Finally, in the third module, for a given desired regular polygon, we provide a method for robots to maintain such quasi-regular polygon while moving.

- Propose a novel and simple flocking algorithm, which can achieve and keep the desired distance with its neighbors when there is no obstacle, also can avoid collision between a robot and its neighbors and between robots and obstacles when there are obstacles in the environment. By simulation results, this algorithm can effectively achieve the above two goals simultaneously.
- Compares several parametric and adaptive failure detection schemes in terms of their respective QoS. We proposed an improvement over existing methods, called TAM FD, and evaluate their benefits. First, we propose an optimization to enhance the adaptation of Chen's FD, which significantly improves QoS, especially in the aggressive range and when the network is unstable. Second, we address the problem of most adaptive schemes, namely their need for a large window of samples. We study a scheme that is designed to use a fixed and very limited amount of memory for each monitored–monitoring link. Our experimental results over several kinds of networks (Cluster, WiFi, wired LAN, WAN) show that the properties of the existing adaptive FDs, and that the optimization is reasonable and acceptable. Furthermore, the extensive experimental results show what is the effect of memory size on the overall QoS of each adaptive FD.

3. Future direction:

The specific concept is as follows

- Extend the dependable methods in traditional distributed computing into mobile computing, for example, find consensus methods for sensor network, ad hoc network and robotic network;
- Evaluate the proposed failure detectors for mobile network mainly from two properties, that is, completeness and accuracy;
- Multiple goals would be considered simultaneously in designing a failure detector, for example, in sensor network, the energy saving, packet loss

4. Publications in 2007

[1] N. Xiong, **Y. Yang**, X. Defago, "Comparative analysis of QoS and memory usage of adaptive failure detectors", in Proceeding of the 13th IEEE Pacific Rim International Symposium on Dependable Computing (PRDC 2007), pp. 27-34, Melbourne, Victoria, Australia, December 17-19, 2007.

[2] X. Defago, N. Xiong, **Y. Yan**g and N. Hayashibara, "Pragmatic accrual failure detection with Kappa-FD", Technical report, JAIST, Japan, November 2007.

[3] **Y. Yang** et.al, "A Decentralized and Adaptive Flocking Algorithm for Autonomous Mobile Robots", accepted by the 2008 International Symposium on Advances in Grid and Pervasive Systems, in Kunming, China.

References

[1] M. J. Daigle, X. D. Koutsoukos, and Gautam Biswas, "Distributed diagnosis in formations of mobile robots," IEEE Transactions on Robotics, vol. 23, no. 2, pp. 353-369, April 2007.

[2] H. Ando, Y. Oasa, I. Suzuki, and M. Yamashita, "A distributed memoryless point convergence algorithm for mobile robots with limited visibility," IEEE Transactions on Robotics and Automation, vol.15, no.5, pp. 818-828, October 1999.