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科学研究費補助金研究成果報告書

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研究課題名（和文）　自己組織群ロボット分散制御のための高信頼グループ通信ミドルウェアの構築
研究課題名（英文）　Research on dependable group communication middleware for self-organizing groups of distributed mobile robots.

研究代表者
DÉFAGO, Xavier（デファゴ　クサビエ）
北陸先端科学技術大学院大学・情報科学研究科・准教授
研究者番号：７０３３３５５７

研究成果の概要：
The main results of the research project are as follows;
- We have designed and developed a mobility platform to avoid collisions between robots moving independently.
- We have identified several coordination problems for robot self-organization and proposed robust algorithms to solve them.
- We have found several impossibility results and proposed for the first time to use randomized algorithms for robot cooperation in the presence of faulty robots (crash and Byzantine).

交付額

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	直接経費	間接経費	合　計
２００６年度	8,600,000	2,580,000	11,180,000
２００７年度	6,500,000	1,950,000	8,450,000
２００８年度	6,500,000	1,950,000	8,450,000
年度			
年度			
総　計	21,600,000	6,480,000	28,080,000

研究分野：総合領域
科研費の分科・細目：情報学・計算機システム・ネットワーク
キーワード：分散システム、耐故障性、グループ通信、群ロボット、アドホック通信、分散アルゴリズム、自己安定

１．研究開始当初の背景

More and more projected applications involve autonomous mobile robots that cooperate toward a common goal. For instance, search and rescue, intelligent transport, or unmanned space exploitation all require several autonomous nodes to act as a coherent group.

Bringing and keeping the cohesion of a group is however not an easy task, especially when this must be done reliably, even in the face of unexpected events such as node failures. Consequently, this leads to two important design goals: (1) the

control of the group should be fully decentralized, since a central control unit would represent a single point of failure for the entire system, and (2) the system should rely on provably correct algorithms, because it must guarantee proper operation even in the face of unexpected events.

２．研究の目的

The objective of the research is to provide a sound basis for cooperation by establishing a link between research on fault-tolerant distributed algorithms and the development of multiple robot systems. The research forms the basis for building a fault-tolerant middleware framework for cooperative mobile robots.

３．研究の方法

We have addressed the problem from two different angles.

(1)
On the theoretical side, we have studied the fundamental principles of self-organization in distributed robot systems. One of the main concerns is to ensure self-organization using provably correct algorithms, while relying on a minimal set of assumptions. For instance, robots may not initially have a common positioning system.

(2)
On a more practical side, we have developed network protocols to handle the movement of multiple robots while preventing collisions. The approach was to rely on ad hoc networking combined with adaptation of various techniques such as mutual exclusion, state-machine replication, failure detection, and deadlock avoidance techniques.

４．研究成果

During this research project, we have had very positive results and made several important contributions.

(1)
We have made several contributions to self-organizing and self-stabilizing distributed algorithms for mobile robots. This includes an extensive study of the basic coordination problem known as gathering. We have shown how to solve the problem even in the face of unreliable sensors (both with fluctuating and fixed but inconsistent compasses). We have also provided solutions to the problem in the face of faulty robots or even malicious robots.

(2)
We have addressed the problem of dynamic coordination by looking at the flocking problem. We have studied the problem in the presence of faulty robots. One of the proposed solutions solves the problem even if some of the robots face arbitrary corruptions of their memory.

(3)
From a more practical viewpoint, we have developed algorithms and a platform to prevent collisions between robots. We have proposed mainly two algorithms. One is for indoor operations and provides a high degree of fault-tolerance. The second, less robots, is however very scalable and adapted for outdoor operations and ad hoc networking. We have also developed a prototype using real robots.

(4)
We have also made several secondary but useful contributions on other important protocols, such as leader election, consensus, and scheduling. All of these are fundamental parts of a middleware for robots. We have also extended a network simulator with the ability to simulate communicating mobile robots.

５．主な発表論文等
（研究代表者、研究分担者及び連携研究者には下線）

〔雑誌論文〕（計１４件）

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６．研究組織

(1)研究代表者

DEFAGO, Xavier（デファゴ　クサビエ）

北陸先端科学技術大学院大学・情報科学研究科・准教授

研究者番号：70333557

(2)研究分担者

(3)連携研究者