Protocole distribué d'anti-collision pour un groupe de robots mobiles autonomes

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Résumé :

Les problèmes de l'informatique répartie deviennent encore plus complexes dans les environnements de robots mobiles.
Dans cet article, nous considérons un système distribué composé de robots mobiles autonomes qui coopèrent afin d'exécuter les taches requises par une application utilisateur. Les robots mobiles communiquent par échange de messages via un réseau ad hoc sans fils. Dans ce contexte, on met l'accent sur le problème de fond qui consiste à prévenir les collisions entre robots mobiles. On a besoin d'un protocole distribué déterministe qui garantit que les robots se déplacent dans un espace donné sans qu'aucune collision ne soit possible.

Abstract :

The problems of distributed computing become more complicated in the environments of mobile robotics.
We consider a distributed system composed of cooperative autonomous mobile robots executing tasks provided by a user application.
The robots are communicating by exchanging messages through a wireless ad-hoc network. In this context we focus on the essential problem, which is the collision avoidance between mobile robots. This necessitates the presence of a deterministic distributed protocol, which guarantees that no collision can occur between robots while moving towards their goals.

Introduction:

Distributed computing extends its scope to address problems relevant to mobile environments (mobile computing). In these environments hosts are physically mobile. This property creates new challenges to traditional distributed computing, by considering problems related to the physical position of the nodes. [Def01].

We consider a distributed system composed of autonomous mobile robots communicating by exchanging messages through a wireless ad hoc network. We address the problem of collision avoidance such that no collision between robots can occur while robots are moving towards their destinations.

A system has two main classes of properties, the first ensures that bad or undesirable behavior never happens during the run of the system, because once undesirable behavior takes place the system is violated, this class of properties is called "*safety*" property, while the second class guarantees that a system is always in progress towards its final goal, this class of properties is called "*liveness*" property.

It is essential to establish a middleware that handles a group of mobile robots as one entity, for that we need group membership [YDK05], [CKV01] and failure detectors techniques [HDY04]. This middleware guarantees the collision freedom property, so this property will never be violated while the system is running, consequently no collision between robots can occur. This provides a solid and a reliable lower level layer that deals with a group of robots. Other properties like reaching the final goal (termination) of the system and the dead lock free property are handled in the application layer.

There exists some centralized techniques that address the collision freedom problem but they do not address the fault tolerance aspects and they are difficult to be applied in large-scale systems.

We identify the importance of a collision avoidance component as a basic building block of a middleware for mobile robotics.

1. System model

We model a distributed system as a set of autonomous mobile robots communicating by exchanging messages through a wireless ad-hoc network. The communications is asynchronous, in the sense that no timing assumptions are made on the communication delay between robots. [YCD05]

Every robot has an identifier, and provided by an access to a global coordinate system with a bounded error margin, so there is a range of incertitude concerning the information provided by the positioning system. The robots in this model do not have any vision possibility…

In this model we do not take the failures of robots in consideration, so we assume that all robots are correct during the execution time.

Concerning communication channels we assume that they are fair lossy but they are non-FIFO channels. This assumption corresponds in fact to the real world situations.

A path is defined as a curve-shaped route along which a robot moves from an initial point until the destination point.

2. Basic idea of the collision freedom problem

The intuition behind the collision freedom is the following:

We have an asynchronous system, so there are no timing assumptions on the communications delays. Consequently it is impossible to keep track of positions of other robots, because of the mobility and the asynchrony of the communications.

We use a reservation system, such that a robot reserves a path and releases it after reaching the end of this path. All robots agree on the reservation each time a path is reserved.

The reservations are consistent, in order to achieve the consistency we adapt some protocols used in traditional distributed systems.

Adapting the traditional protocols creates many challenges due to the mobility issues of robots, the asynchrony of communications, and the ad-hoc wireless communications characteristics. These communications are characterized by limited communication range and link breakage between nodes. [YCD05]

3. Conclusion

The collision avoidance between mobile robots constitutes a basing building block in the environments of mobile robotics.

We model a distributed system as a set of mobile robots communicating by exchanging messages through a wireless ad-hoc network. The communications is asynchronous, in the sense that no timing assumptions are made on the communication delay between robots.

The collision freedom property is achieved by a consistent path reservation system, such that all robots agree on the reservations.

The collision avoidance protocol guarantees that no collision can occur between robots while moving towards their goals.

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