COLLISION PREVENTION METHOD FOR A DYNAMIC GROUP OF COOPERATIVE ROBOTS WHO COMMUNICATE WIRELESSLY

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Abstract. This paper presents the collision prevention method for the cooperative robots who communicate wirelessly. The basic idea is in essence a mutual exclusion on reserved zones in the work space. When a robot reserves a zone, her gripper can move safely inside the zone. When a robot' gripper wants to move along a given corridor it must reserve the zone that surrounds this corridor. Once the gripper reaches the end of the corridor, it releases the zone except for the area that the robot occupies.

Keywords: Collision prevention, cooperative robots, wireless ad hoc networks

1. Introduction

Many interesting applications are envisioned that rely on groups of cooperating robots.

While most efforts are still aimed at mobile ad hoc networks and sensor networks, there is also a gradual realization that cooperative robotics raises many interesting new challenges with respect to distributed systems, and particularly in relation to mobility. Indeed, unlike traditional distributed systems and even more so than ad hoc or sensor networks, mobility becomes an essential part of the problems to address.

On the other hand, an important challenge is to ensure that robots will not collide against each other, regardless of their respective activities.

2. Problem Statement

Robots are considered as endowed with the ability to communicate wirelessly and also that they can query their own gripper position according a common base referential, as given by a positioning system (e.g., GPS).

However, the robots' grippers do not have the ability to detect each other's position in the environment, and they are not synchronized. In addition, communication delays are unpredictable, and actual robot motion speed is unknown.

In that context, our goal is to ensure safe motion, in the sense that, regardless of the respective activities of the robots, no two robots ever collide.

The safety of the system must never be compromised, regardless of the uncertainty of the underlying system. However, the performance of the system may possibly degrade as the result of badly unstable network characteristics or variable robot speed.

There are several approaches to address the problem of avoiding collisions between robots. First, a general approach consists in using proximity sensors (e.g., infrared, sonar, laser) in the same way fixed obstacles are detected [1]. This approach is, however, sensitive to the robots respecting planned speeds, and normally requires an unbroken line-of-sight.

A second approach consists in relying on global motion planning, specifying the respective timing of robots as well as the path to follow [2]. This approach is even more sensitive to the speed of the robots, and normally requires much synchronization between the robots.

A third approach uses wireless communication as a means to synchronize the robots and their gripper motion [3]. To do so, communication is extended to satisfy strict real-time guarantees or at least probabilistic ones.

3. Wireless Communication as a Means to Synchronize the Robots

Designers and manufacturers of robotic systems incorporate radio communication – including wave propagation, antennas, transmitters, receivers, short-range radio systems – to assure save-operation of a group of robots two share the same work space. Frequently they add a wireless interface just for wires eliminate, on an existing wired system.

They may adapt a wireless subsystem, which is easy to integrate electrically into robotic systems. It is for these adapters of wireless subsystems are aimed at what are generally defined as short-range wireless applications. Some information about is given below with special reference to short-range applications.

A new direction in short-range applications is about to appear in the form of high-rate data communication devices for distances of several meters. Short-range devices are often used to replace hard wiring, so when similar performance is expected, the limitations of radio propagation compared to wires must be accounted for in each application. The radio channel for short-range applications is short, and for a large part the equipment is used indoors. Practically all short-range devices have built-in antennas, so their transmission lines are relatively short and simple.

The antenna is the interface between the transmitter and the receiver and therefore it is a deciding factor in the performance of a radio (wireless) communication system. The principal properties of antennas-directivity, gain, and radiation resistance-are the same whether referred to as transmitters or receivers.

Computer accessories send continuous digital data over the short range link. These data are organized according to protocols that include sophisticated error detection and correction techniques.

With this approach, protocols must rely on explicit time and the speed of the robots. This is fine as long as both robots and communication meet their timing assumptions. However, if a robot happens to move too slowly or too fast, or a few messages are delayed for too long, then there is a risk of collision. In contrast, our aim is to rely as little as possible on the respect of timing assumptions from the underlying system.

4. Computing/Communication Architecture

The computing architecture of the robots' grippers - as the robotic agents -, is illustrated in Figure 1. It is hierarchical two-level architecture. The higher level is built around a main processing unit that handles the external communication with other agents, the local vision system and the robot behaviour.

A distributed low-level sensing/actuating system handles robot attitude and power monitoring.

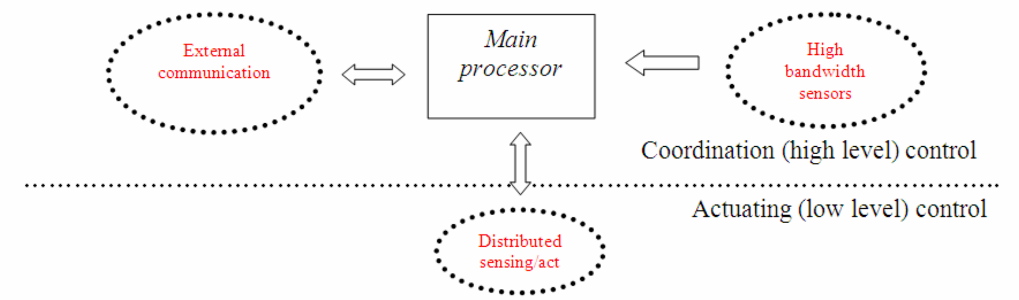

Fig. 1. Robots' grippers communication architecture

The main processing unit is currently implemented on a Personal Computer (PC) with a built-in wireless interface. The PC runs the operating system with the timeliness support necessary for time-stamping, periodic transmissions and task temporal synchronization provided by a specially developed user-level real-time scheduler, the Process Manager [6]. This approach provides sufficient timeliness support for soft real-time applications, such as multiple robot coordination, and allows profiting from the better development support provided by general purpose operating systems [3].

The team robot grippers communicate with each other by means of a wireless network as is illustrated in Figure 2. The communication is managed, i.e., using an Access Point (AP), and it is constrained to using a single channel shared by the grippers at each task.

In order to improve the aptness of the communications, our robots' grippers team use an auxiliary transmission control protocol that minimizes collisions of transmissions within the team. Each robot' gripper is equipped with own antenna and regularly transmits its own data while the remaining ones receive such data and update their local structures.

Beyond the robotic agents, there is also a monitoring station connected to the team that allows following the evolution of the robots status on-line and issuing high level team coordination commands.

5. Communication among Agents

As mentioned grippers agents communicate through the AP using an local area network (LAN). An LAN is a computer network that connects computers and devices in a limited geographical area such as home, computer laboratory or manufacturing hall.

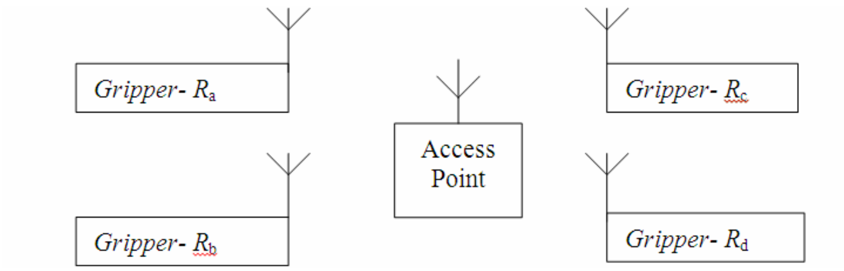

Fig. 2. Communication environment

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Agents communicate through the AP using an LAN network, sharing a single channel with the grippers of the cooperative team.

This raises several difficulties because the presence of uncontrolled traffic in the channel is unavoidable. Conversely, there are also some benefits in terms of consistency in the team, which is enforced by the AP. An agent is considered reachable by the team when it has an active link with the AP and unreachable otherwise. This is a realistic application in many application scenarios. For example, for team of surveillance robots within large indoor spaces, such as manufacturing halls, it is normally feasible to provide an AP that guarantees the radio coverage of all robots' grippers.

It is recommendable to place the AP on top of one of the robot's gripper deployed near the center of the operations area that will provide coverage for the other ones. In all these cases, it is also impossible to control the access to the channel and thus the technical solutions adopted must manage with such circumstance.

In this paper we present a reliable system on which cooperative robots' grippers rely for their motion, thus ensuring that no (physical) collision ever occurs between robots. Its core consists of a collision prevention protocol for a dynamic group of cooperative robots with asynchronous communications. As a simple illustration, consider the robots group who must accomplish assembly tasks [4].

A decentralized autonomous gripper's team cooperate to carry the components, on the work table. Two welding robots wait to assembly the elements on the work table as is presented in Figure 3.

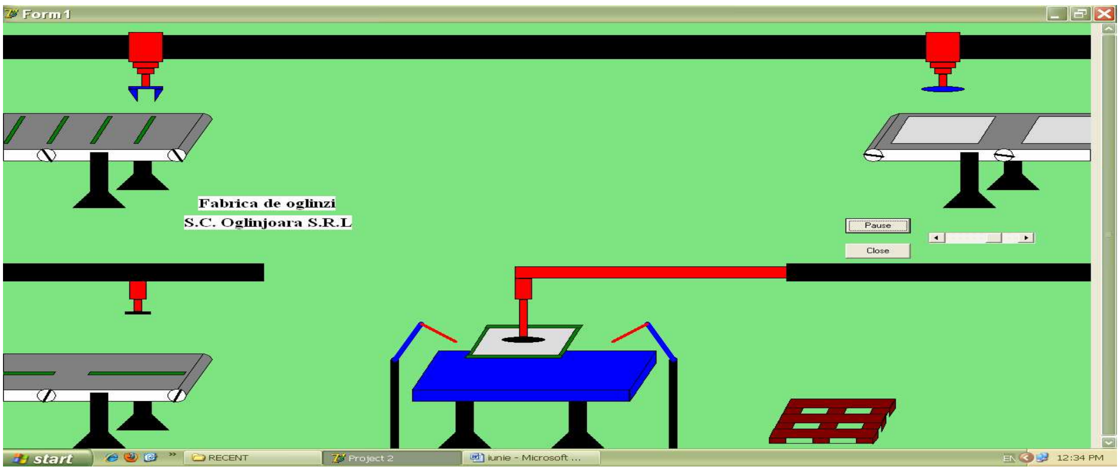

Fig. 3. Work-cell of the manufacturing process deserved by four manipulator robots

These tasks require the robots to almost constantly move the same limited space, namely the activities space, while moving along according to their respectively assigned tasks. Due to the nature of the system, the robots cannot share exact knowledge of each other's location, speed, or even current intention.

6. Model of the Cooperative Robots' Grippers

A dynamic distributed system of set of robots {R_a, R_b, R_c, R_d} is considered, in which each robot has a unique identifier. The total composition of the system, of which robots have only a partial knowledge, can change dynamically.

Robots have access to a global positioning device that, when queried by a robot returns him position with a bounded error.

The robots communicate using wireless communication with a limited range. If the distance between two robots is less than limited range, then the two robots can communicate each with other.

Communications assume retransmission strategy such that communication channels are reliable. The system is asynchronous in the sense that there is no bound on communication delays, processing speed and on robots' speed of movement. Each robot has access to a neighbourhood discovery by Discover Algorithm (DA).

Neighbourhood DA is an algorithm that enables a robot to detect its local neighbours. These neighbours are within one communication loop and satisfy a certain known predefined condition. DA can be implemented as the traditional neighbourhood discovery primitive of mobile ad hoc networks. An implementation of DA can be performed by Geocast technique.

Geocast technique is the transmission of a message to some or all agents within a geographical area, allows promising new services and applications. Currently, geocast solutions for ad hoc networks provide only a means to send a message once, instead of periodically or on-demand every time a mobile agent enters the geocast's message destination region. Of particular interest is geocast in the cooperative robots domain. Each robot' gripper of the cooperative group represents an agent in the geocast net.

A contact message in a geographical region is centred on one gripper robot, at the time of calling DA. All the robots that receive the message and satisfy the predefined condition, acknowledge the caller of DA.

In wireless environments, the delays in delivering messages are very difficult to anticipate. There are several reasons for the asynchrony of communications in wireless environments, such as the delays required to access the shared environment, due to competition with other agents.

The competition to access the wireless environment causes message loss due to interference, collisions between messages, and fading. Therefore, a retransmission strategy is needed to ensure message delivery in wireless environments.

Figure 3 illustrates the cooperative grippers group of four robots. When the robot R_a starts *NDiscover*, the set of robots {R_b, R_c, R_d} respond by Discover Protocol (DP). The neighbors of R_a are: {R_b, R_c, R_d}. D_{tr} is the transmission range between two robots range and D_r is the reservation range of work area on the assembly table.

During of the presence of robot R_a on the work area, the robots R_b , R_c and R_d request zones that do not intersect with the reservation work area.

7. Conclusions

A fail-safe method on which cooperative robots rely for their motion has been presented. This method consists of a collision prevention strategy for a dynamic grippers group of cooperative static robots with asynchronous wireless communication.

The method ensures that no (physical) collision ever occurs between robot grippers regardless of the respective activities of the robots.

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