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POSITION SENSING OF MOBILE ROBOTS FOR TEAM OPERATIONS

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Abstract - **In this paper, a position sensing system based on infrared techniques for multiple robots operating within a structured environment is introduced. Unlike many existing multiple robot systems, the proposed sensing mechanism enables each robot to determine its position and path of movement without the need of a central coordinator. The robots communicate with each other with a radio link passing information about their intentions, positions and the performed tasks. The system is simple and it does not require complicated vision and communication capabilities, thus, a minimum computing power is needed for the operation. Clearly defined objectives, robust position sensing capabilities and efficient inter-robot communications enable each robot with self-autonomy to determine its own task to be executed. The main objective of the position sensing system is to enable a number of robots to operate in a cooperative manner as members of a team.**

INTRODUCTION

Recently, multiple robot system applications has received much research attention. However, there are still many fundamental research and implementation issues need to be addressed. Some of these issues are: effective position sensing, collision free motion planning, communications between robots and the central coordinator, organisation in handling a common task, and distribution of load between robots. To this end, a challenging research project is currently undertaken by the authors with an objective to develop a team of mobile robots which are capable of operating in a co-operative manner as team members and also in a competitive manner against an opposing team. Thus, the project provides opportunities to investigate the issues involved in the operation of multiple mobile robots and to develop solutions for some of these problems.

With recent advances in technologies such as robot sensors, vision systems, superscalar processors, microcontrollers etc. it is now possible to create systems with "multiple robots" operating in the same workspace for the improvement of potential applications [1], [2], [3], [4]. When discussing multiple robots, many research topics cover either systems with multiple robots in the same workspace or multiple-arm robots performing a common task [5], [6], [7], [8]. In most implementations, the operation structure is based on a central coordinator controlling all the activities of the robots and making all the decisions [9], [10]. In this paper, the coordination of mobile robots is achieved without the need for a central controller by using a simple configuration of an efficient position sensing mechanism and an effective inter-robot communication system. The position sensing system is based on optics and the communication is based on UHF radio link. For position sensing, the use of laser optics or infrared techniques are found to be appropriate. However, in this paper the infrared sensing system has been selected for its cost effectiveness. Development of the position sensing capabilities and the inter-robot communications serve as the first phase of the research in solving some of the problems encountered in the team operation of mobile robots.

OUTLINE OF THE PROBLEM

If two mobile robots and an additional object to be manipulated are placed as shown in Figure 1, then the objective for each robot can be described as :

(a) co-operatively move the object to the predefined destination, or,
(b) competitively move the object in opposite direction to the goal while preventing other robot to achieve similar objective.

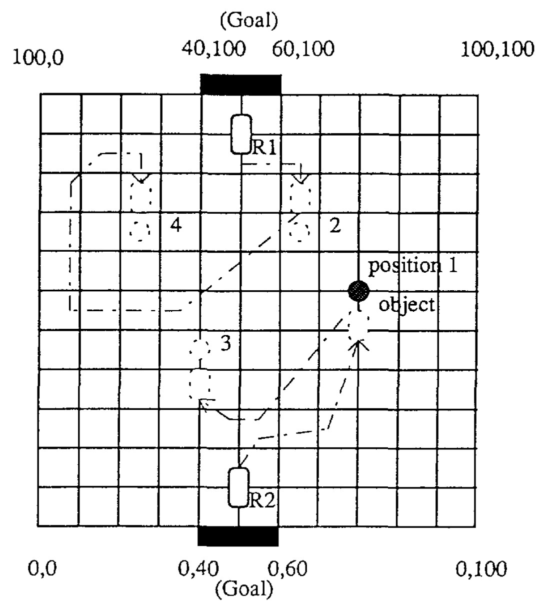

Figure 1: Positioning of robots on cartesian coordinates.

In order to achieve either of these objectives the following technical issues have to be addressed:

(a) Determination and interpretation of the positions of the robots and the position of the object.
(b) Inter-robot communications.
(c) Task and traffic planning.
(d) Development of control algorithm for the robots.
(e) Synchronisation of the tasks to be performed.
(f) Detection and description of obstacles using sensors based on proximity, pressure, ultrasonic techniques.
(g) Collision free path planning and collision avoidance scheme.
(h) The recovery and synchronisation of activities once collision occurs.

In this project, the development and implementation of the system is divided into sub-modules for position sensing, communications and navigation, motion control, map representation, planning strategies etc. The sub-modules are later to be integrated together into a complete stand-alone system.

THE PRINCIPLES OF POSITION SENSING

The position sensing system is based on the principle that a receiver is capable of determining the direction of a transmitting source by the interpretation of the information coming from the transmitter. If there are more than one known transmitting sources, the receiver will be able to deduce its own position with respect to the transmitters. Once the receiver knows its relative coordinates within a given area and together with the knowledge of the surrounding environment, a path of movement from point A to point B can then be planned. This principle has long been used in many situations such as marine navigation. Radio-waves of different frequencies or light signals from various sources are used to obtain the position of the vessel. The knowledge of the surrounding environment is represented in the form of a navigational chart or a radar display. The human navigators thence plot the route of movement. Communication with port authority and other vessels is established by radio to inform the present position of the vessel.. Hence, cooperation between vessels can be ensured and a collision-free passage is secured. A similar approach is adopted in the present work and the description of the overall system is detailed in the following sections.

THE ROBOTS

The robots are capable of moving forward, backwards and turn right or left. The motors are controlled by an onboard microprocessor system. Each robot is capable of carrying a payload of approximately 2.5 kg. The robots move on a smooth surface within a boundary of 7 by 7 meters.

THE INFRARED COMMUNICATIONS

An infrared system has been developed which is capable of transferring data in serial mode from 300 baud to 19200 baud. The half-power point or the beam angle of the transmitters is selected to be 10 degrees. The operational block diagram of the transmitter is given in Figure 2 while Figure 3 illustrates the block diagram of the receiver which is situated at a distance from the transmitter. File transfers at a data transmission rate of 19200 baud between two computers over a distance of 13 meters with zero error has been achieved. This communication method has been modified for the multiple mobile robot system as discussed in this paper. A total of 32 transmitters are arranged in a directional manner transmitting information in a multiplexed format. The receivers are installed on the robots placed in the area of manipulation.

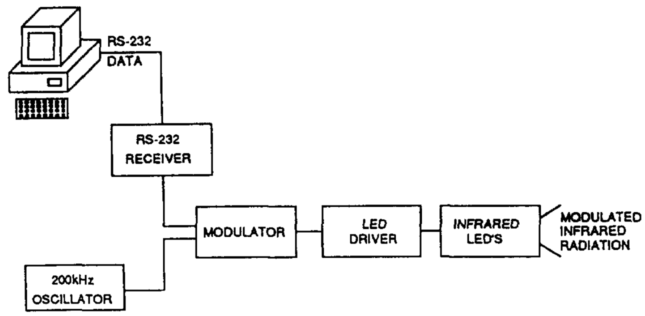

Figure 2: Block diagram of infrared transmitter.

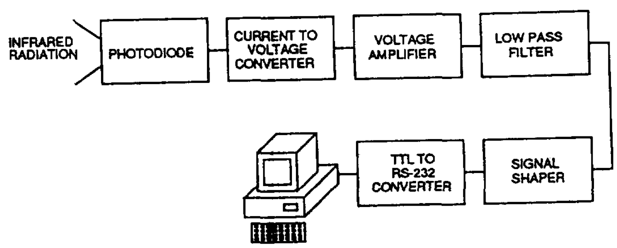

Figure 3: Block diagram of infrared receiver.

THE POSITION SENSING

The multiplexed infrared transmitters are arranged to operate in a master-and-slave form. Each transmitter has a unique identification code to be transmitted. The master controller is primarily responsible for the generation of all the data and the control signals for the slave controllers. The slave controllers on the other hand determines if the data is targeted to itself. If yes, it directs the data to the correct infrared transmitters. The basic block diagram of the master control unit is given in Figure 4. Figure 5 shows the block diagram of the slave controller. The transmitters are arranged in either one of the following configurations.

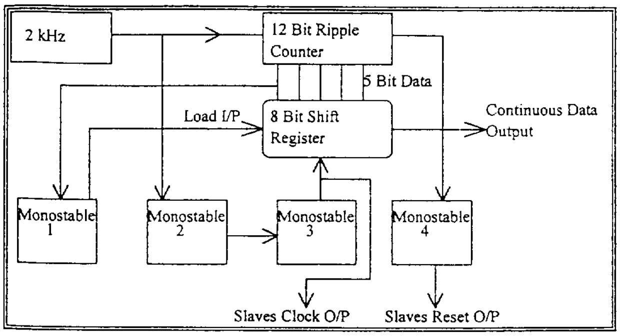

Figure 4: Block diagram of master control unit.

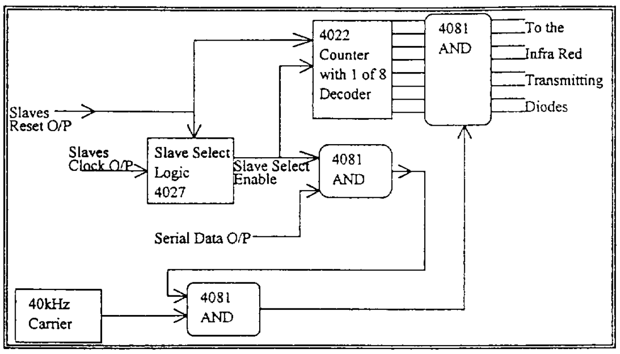

Figure 5: Block diagram of slave control unit

Polar Configuration

The arrangement of the transmitters in the polar position sensing system is given in Figure 6. The infrared transmitters are located at the four corners of the boundary and eight transmitters are placed in each corner. The beams of the transmitters are arranged at 10 degrees apart.

Cartesian Coordinates Configuration

In this case, the transmitters are arranged as illustrated in Figure 1. Instead of locating the transmitters at the four corners, they are evenly spaced on the perimeter of the operating area. Each slave controller is controlling eight transmitters on each side as in the previous case.

THE RECEIVER

The receivers located on the robots accept the serial data from the transmitters as inputs for the microprocessor. Reception is possible only if the receiver is located within the signal path of a particular transmitter. Depending on the position of the robots, signals from more than one transmitter may be received. Then, the exact position can be identified by comparing the received signals with the map already known by the onboard computer system.

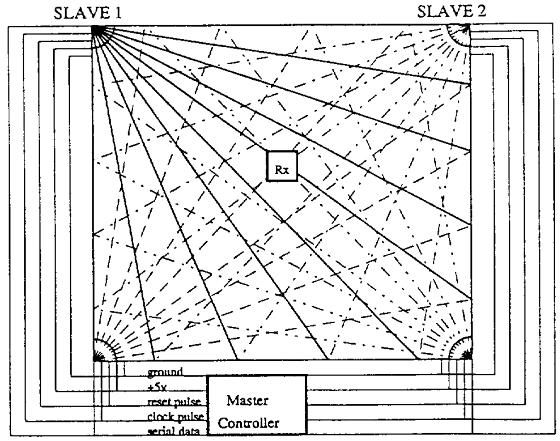

Figure 6: The polar position sensing system.

THE COMMUNICATION

Communication between the robots have been achieved via a two-way radio link. As in the case of the infrared transmitters, each robot sends out an identification code to be followed by the position information and any other relevant data. Data received by each robot is then decoded and processed by the onboard microprocessor system for further decision making. A description of the radio link is as follows.

The UHF transmitter

Each robot has a 12-channel UHF transmitter using a SAW resonator for frequency locking. The transmitter circuit is based on a trinary encoder IC, AX526. This device has four data inputs and eight address lines that are connected to either logic 1, logic 0 or open circuit The input encoder are connected to the microprocessor system. The data output operates a transistor on and off modulating the series of pulses at the carrier frequency.

The UHF receiver

The receiver receives signals from the transmitter. The received data from the transmitter is applied into the input of a trinary encoder IC, AX527. Once the addresses of this IC matches those of the encoded signal from the transmitter, a valid control signal from the receiver causes the data to appear as an output for the microprocessor system.

Conclusions

Operation of multiple robots in a structured environment has been discussed. A new position sensing technique has been introduced. Infrared communication system has been configured to transmit data at a rate of upto 19200 baud. The system has been arranged in various geometrical configurations for effective position sensing. The positions of robots and other relevant information are relayed by UHF radio link. Robots are programmed to operate in a coordinated manner.

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