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Multi Robot Communication for Industrial Automation

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ABSTRACT: Industrial automation has an important role to play in the development process. Implementation of robotics in industries yields high accuracy and reliability in the products. This paper focuses on designing robots to communicate with each other through Zigbee technology and to complete the tasks in the industrial environment. An introduction to multi robot communication is briefed. An Industrial model is designed for this project and a message passing format is specially designed for communication between the robots. A brief explanation of various hardware and software used is provided.

KEYWORDS: Industrial automation, task distribution to robots, task selection by robots, wireless communication, data frame for multi robot communication, XBee implementation on robots, line follower robots.

I. Introduction

The Industrial Revolution has a major turning point in history influencing almost every aspect of our daily life in some way. Machineries with high-power capabilities were involved in carrying out the production in the industry, these were controlled manually. This led to slower process speed. With the recent trends in the technology, robots were introduced in the industries. Robotics has wide list of applications in Industrial automation. Growing interests in the study of multi robot systems have added to the increasing importance in area of robot communications and also encourages the development of various communication protocols.

The first stages of robots installed in the industries were controlled centrally. Communication between the robots and the central system was through a wired connection. This type of system limits the robot's motions and confines it to a fixed position. The second stage were allowed to move but were still controlled by the central system. Intelligent systems reduce the overhead on just one system as they divide the load. This can be achieved by letting the robots communicate with each other and decide upon the work to be done by them without central system instructing them.

There are many scenarios where we desire communication in the context of multi robot systems. Primary need is to co-ordinate actions between different robots so that the task can be accomplished without any conflicts. Second the robots could exchange knowledge about situations they are in, for example a map of a room.

II. Literature Survey

[1] Mr. Robert L. Avanzato published paper entitled "Multi-robot Communication for Education and Research". Author has designed a multi robot system with ROBOTC programming tool and XBee radio technology. Wireless communication is provided by XBee at low-cost and low-power with a range up to 300 feet.

[2] ShivalDubey& Abdul Wahid Ansari published paper entitled "Design and Development of Vehicle anti-collision System using Electromagnet and Ultrasonic Sensors". Authors have developed a model that can avoid vehicle collision. The system developed continuously keeps track of the distance between two vehicles using Ultrasonic range finder.

[3] ZhaiYuyi et al. presented a paper entitled "Control System Design for a Surface Cleaning Robot". The aim of this paper is to design a control a surface cleaning robot. Speed control of the propulsion control system is designed based on the principle of PWM speed control. The work is successfully designed and tested on a AVR microprocessor hardware. Robot is also controlled to move forward, backward and turn by the use of a stepper motor.

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III. WORKFLOW MODULE

A. *Industrial workstation model:*

Figure 1 shows the home position of the two robots, Assembly station and the component storage. The component storage facility has the components to be delivered. The assembly station provides the demands that are to be catered. Once the communication is established using XBee the work of the robots is to cater the demands of assembly station from components storage to respective demanding block.

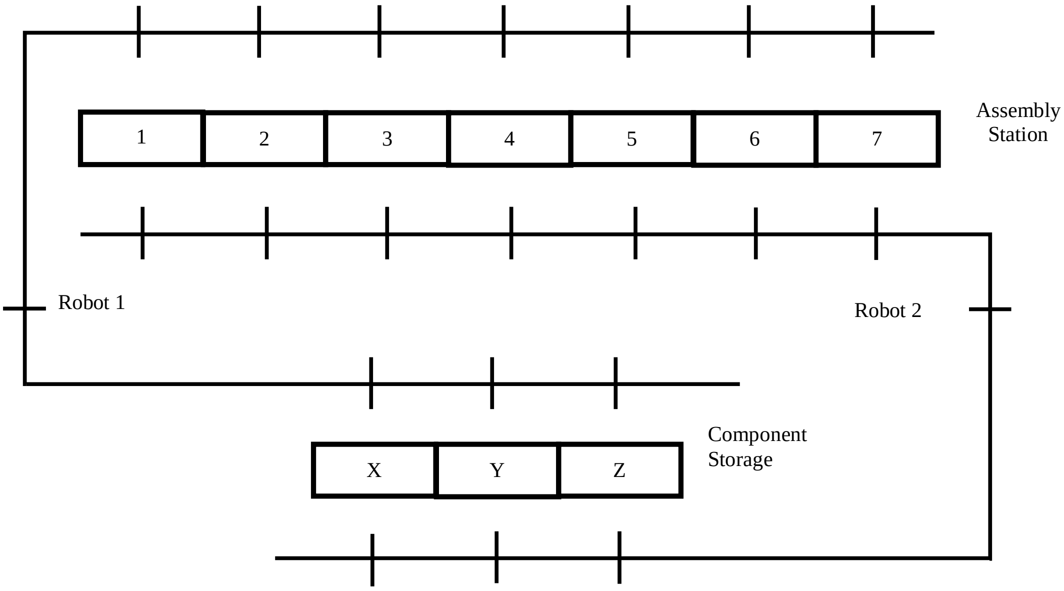

Figure 1. Workstation Map

B. *Task Maintenance table for Robot:*

To keep track of the robots and the work progress, a table is maintained in both the robots. The table is updated continuously by the robots while doing their work. The table 1 shows the task maintenance table.

Table 1. Task Maintenance table

INDEX	DATA	STATUS

The contents of the task maintenance table are as follows.

- Index is the destination value which can take values from 0 to 7.
- Data acts as the source location which can take values from 0 to 3.
- Status gives the work progress which takes value from 0 to 3.

The Data column is updated by the user and the values 0 to 3 define following

- 0 > nothing to be delivered.
- 1 > deliver from location 1.
- 2 > deliver from location 2.
- 3 > deliver from location 3.

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The Status column is updated by the robots and the values 0 to 3 define following

- 0 > Nothing yet delivered.
- 1 > Task taken by robot 1.
- 2 > Task taken by robot 2.
- 3 > Task completed.

XBee transmits one byte (8 bits) at a time. The byte of data to be transmitted is fragmented into group of one or more bits to represent some instruction and information. The designed data frame is shown in table 2.

Table 2. Data frame format

M7	M6	M5	M4	M3	M2	M1	M0

- M7, M6 are Control Bits. They take following values
  - 11 > Start (Start_Stop flag = 1)
  - 00 > Stop (Start_Stop flag = 0)
  - 10 > Update Table
  - 01 > Reserved for future use
- M5, M4 represent Data (Source Location) / Status of task
- M3 bit represents what to update, Data or Status table update mode
  - 0 > Data update mode
  - 1 > Status update mode
- M2, M1, M0 represent Index (Destination Location)

IV. FLOWCHART

Robots should be designed to select an unfinished task and then intimate this information to other robots as well. Robots which receive this information will then update their task maintenance table as work under progress. Once a robot selects a task, the next step involved is completing it. Robots have to be designed to follow the path to reach the component store (source), pick a component, reach assembly line (destination) and back to its home position. Then again select a new task. Till will continue until all the tasks are complete. Figure 2 shows the basic flowchart of the robots working.

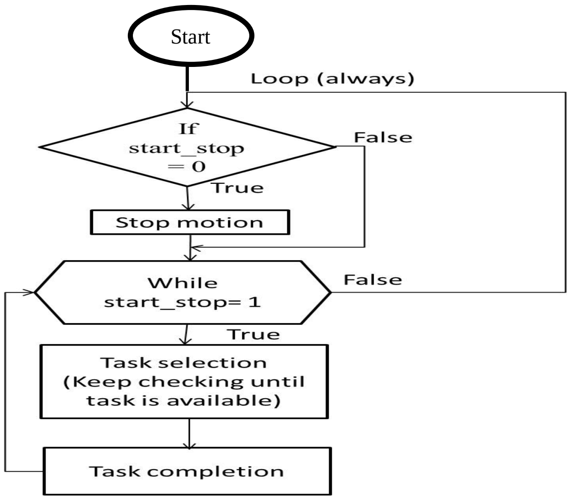

Figure 2. Basic flow diagram

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Task selection consists of checking the source column of the task maintenance table. If any valid source address exists then check the status of that task. If the status is incomplete then pick that task and convey this information to other robots. The flowchart for this module is shown in figure 3.

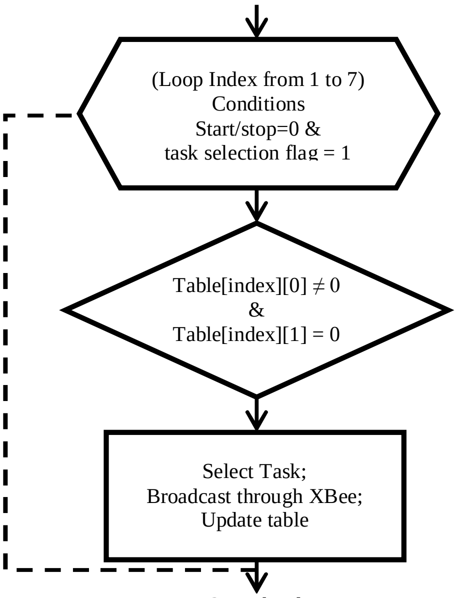

Figure 3. Task selection

Task accomplishment is done as shown in figure 4.

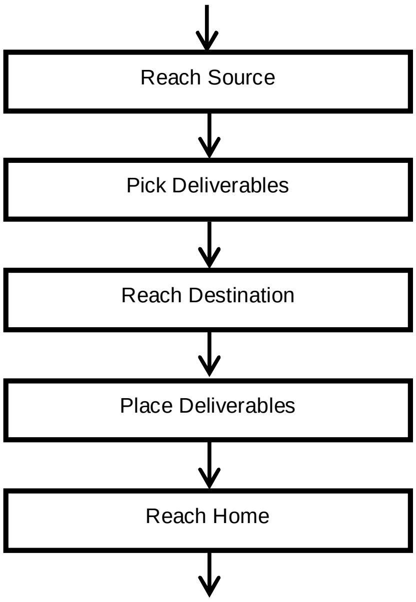

Figure 4. Task Completion

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V. METHODOLOGY

A. *Hardware*

Block diagram of the hardware is shown in fig 1. Two different modules are connected together. FireBird V Robot and XBee wireless communication module. On-board connected XBee module enables the robot to send and receive messages to and from other robots. XBee module connected to computer enables communication between robots and user.

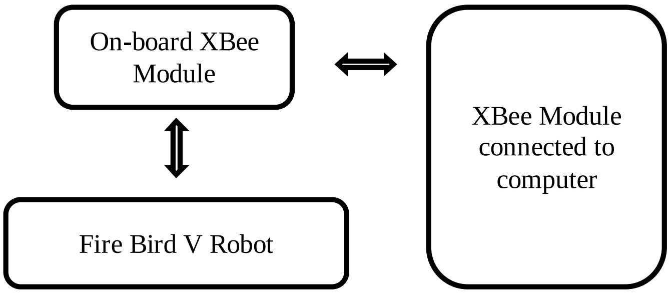

Figure 5.Block diagram

Fire Bird V ATMEGA 2560: The robot used in this project is Fire Bird V ATMEGA2560. It is a highly equipped robot with black/white line detection sensors and object detection sensors. It also provides connectivity to various modules like XBee, GSM and GPS modules. Technical specification of Fire Bird V is as follows.

- Microcontroller: Atmel ATMEGA2560 as Master microcontroller (AVR architecture based Microcontroller).
- Sensors: Three white line sensors (extendable to 7). Two position encoders (extendable to four). Battery voltage sensing.
- Indicators: 2 x 16 Characters LCD, Buzzer and Indicator LEDs.
- Control: Autonomously Controllable, PC as Master and Robot as Slave in wired or wireless mode.
- Communication: USB Communication, Wireless XBee(Externally installed) Communication.
- Dimensions: Diameter: 16cm, Height: 8.5cm, Weight: 1100gms
- Power: 9.6V Nickel Metal Hydride (NiMH) battery pack and external Auxiliary power from battery charger. On-board Battery monitoring system and intelligent battery chargering.
- Battery Life: 2 Hours, while motors are operational at 75% of time.
- Locomotion: Two DC geared motors in differential drive configuration and caster wheel at front as support. Top Speed of 24 cm / second. Wheel Diameter is 51mm. Position encoder has 30 pulses per revolution. Position encoder resolution is 5.44 mm.

XBee Module: The XBee RF Modules based on IEEE 802.15.4 protocol. It works at ISM 2.4 GHz frequency. Broadcast mode of communication is employed. CSMA/CA communication protocol eliminates collision of signals when two XBee modules tries to communicate simultaneously. On board XBee is supported by the Fire Bird V robot. XBee module is connected to the computer using XBee USB wireless adaptor board.

B. *Software*

This project is implemented using following software:

- AVR Studio: AVR studio is an Integrated Development Environment (IDE) for writing and debugging AVR applications. It is a code writing environment, with AVR Assembler support and any external AVR GCC compiler in a complete IDE environment. Embedded C code is written and hex file is generated using this tool.

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- AVR Bootloader: Hex file generated using AVR Studio is to be dumped on the ATMEGA 2560 microcontroller. AVR bootloader is a GUI that enables dumping of the hex file onto the hardware. Hex file is dumped onto the hardware using this tool.
- X-CTU: XBee module is configurable at different baud rates, at different frequencies and enables selection of PAN ID in order to allow many XBee wireless modules work at the same time without interfering with each other. XBee module has to be configured to broadcast mode. The X-CTU software utility has the most powerful option for reading, testing, updating the firmware, configuration setting of XBee modules. XBee is configured using this tool.

VI. Results

All tasks input by the user are updated by Robots in their own task maintenance table. The task data contains source address and destination address. Once instructed to proceed with the work each Robot picks a task from the table, checks its completion status and if found incomplete, sends a message to other Robot with regards to the task selected. Then it proceeds towards accomplishing that task. Figure 6 illustrates the robots working.

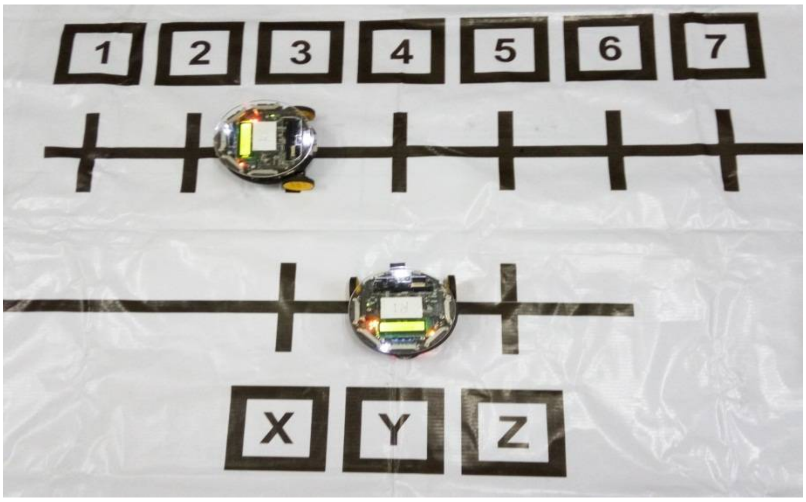

Figure 6. Robots at work

VII. Advantages and Disadvantages

A. *Advantages*

- Employment of robots makes the work flow easy.
- High accuracy in the task accomplishment is presented as compared to manual work.

B. *Disadvantages*

- Tasks entered by the user have a complex user interface. This might lead to errors and undesired working of robots.
- Robots are designed to follow a fixed path. This makes the robot partially automated. If any changes are to be made in the working environment, the robots have to be reprogrammed as per the new environment.
- Fixed path of the map adds to the extra distance travelled by the robot. A possible shortest path exists which reduces the time required in completing the tasks.

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VIII. FUTURE SCOPE

Various other features can be implemented. They are as follows.

- A GUI to send the tasks to the robots can be implemented using MATLAB.
- GPS technology can be used by the robots to position itself in the industrial environment and follow the shortest path to reach the desired destination.

IX. APPLICATIONS

Apart from the use in the industry, the robots can be used in various other applications. It forms a base to Machine to Machine communication and Vehicle to vehicle communication models. It can be employed in rescue operations and surveillance operations.

X. CONCLUSION

With the combined usage of motion control of Fire Bird V robot and wireless communication between the robots using XBee technology, we demonstrated that multi robot communication is possible without any conflict. XBee provides interference free communication between because of the implementation of CSMA/CA communication protocol. Hence a base for future level of industrial automation has been laid with the success of this project.

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