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A Distributed Control System for Spatial Hyper Redundant Robot using CAN

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ABSTRACT

Spatial Hyper Redundant (SHR) robot has more controllable DOF than actual DOF due to hyper redundancy. The robot has increased dexterity and is well known for its use in unstructured environments. Due to higher controllable DOF, control system becomes extremely complex to implement. Hence, to develop the same, Controller Area Network (CAN) protocol which enables lesser number of bus signals and quite suitable in an environment where large number of microprocessor based systems are employed is used. In this case, stepper motors are used to actuate the links. This research involves in design of control system for an 8 link snake like robot using CAN protocol. A node consists of a microcontroller, CAN controller, CAN transceiver and a physical medium for transmission. A PIC 18F458 is chosen as the microcontroller which has inbuilt CAN module and it is programmed using CCS compiler for the application. The CAN communication was established by sending data from one node to other for physically actuating motions of links at its initial phase and then it was extended for multiple nodes with one node as master interfaced to GUI using RS232 on one side and to other nodes through CAN. Implementation of message filtering was done for each node. Performance of the system was also studied for multiple nodes of the system.

Key words: SHR robot, CAN protocol, distributed control system, filtering, CCS compiler, GUI

INTRODUCTION

Over the last several years, research in the area of hyper-redundant robots has become of great interest. Spatial hyper redundant robots are of many types: one such robot is snake robot. As the name suggests, they are long robotic devices developed by joining rigid links via robotic joints to perform similar to their biological counterparts (Shammas *et al.*, 2006). The actuators are the stepper motors in this robotic application which have to be controlled from remote places.

Their high degree of articulation makes hyper redundant robots superior for operation in highly constrained and hazardous environments, such as nuclear Industry, underground highly raffinated liquid toxic waste tanks. Excess oil leaks can be detected, where human cannot reach due to radiation. Snake like robots can be used mainly in cluttered environment.

There is a need for distributed control systems to make the tasks of SHR robot simpler. Distributed control systems are gaining increased popularity because they offer several advantages such as modular and flexible system design.

CAN protocol is used in industries for various applications such as in automobiles for connecting transmission and engine control unit, door locks connection, etc. Controller Area Network (CAN) offers an attractive alternative due to the availability and low cost of CAN based devices and technology of bit wise arbitration (Castro *et al.*, 2002). Distributed control system is implemented using CAN. Main feature of CAN is non destructive bit arbitration.

Zuberi and Shin (2000) presented the mixed traffic scheduler for Controller Area Network, that can provide increased schedulability compared to deadline-monotonic with less overhead than dynamic earliest-deadline scheduling. Liandong *et al.* (2004) presented a research work for the development of controller with PC-based open architecture which resulted in the benefits of low cost and increased sturdiness. Jingdong *et al.* (2007) developed evolutionary algorithm for optimal walking gait in a biped robot. Their study aimed at improving the stability during walking and improve the walking speed. Poplawski and Sultan (2007) gave a brief survey about position sensing methods of industrial robots with reference to accuracy, reliability and cost. Chiou *et al.* (2012), presented an interactive home robot with visual navigation system to provide collision-free control techniques.

CAN protocol broadcasts data to all nodes present on the bus, it is the choice of receiver node, whether to accept the data or not. Each node has the right to access the bus; faulty nodes will never hinder the bus communication. Not only that, they will self-switch off in such a case which is the main feature of distributed and redundant system. Though every node can hear the transmission, it is not mandatory that the data is accepted by receiver buffer. Local filtering is done at each receiver node (Farkande and Pawar, 2012). Broadcast communication reduces band requirements. The objective of the study was to check to the performance of the proposed system.

MATERIALS AND METHODS

In this research work, SHR robot consisting of 8 links has been developed. Each link is driven by 2 motors as shown in Fig. 1. End links of 8 link snake like robot have one motor only. Totally

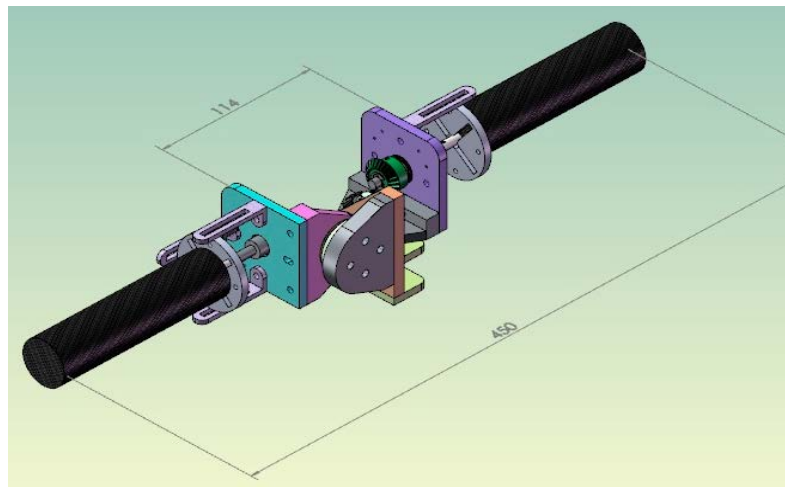


Fig. 1: SHR link

there are 14 stepper motors to physically actuate the joints. These motors have to be fixed to position the end effector. A distributed control system has been selected for hyper redundant robot. Master will be sending joint angles information to slaves through CAN bus.

Control system architecture

Hardware used:

- Master elements
- Microcontroller: PIC18F458
- CAN controller: In-built in PIC
- CAN transceiver: MCP2551
- Physical medium: Twisted pair
- RS232 serial bus
- Slave elements
- Stepper motor
- SHR joints and linkages, bevel gearing
- PIC18F458

Software tools used: For programming CCS compiler is used. It supports all the PIC series and the programmer is MACH_X programmer Visual Basic 6. In front end for GUI design, VB 6.0 is used to provide more user friendly features.

Data communication protocol is shown in Fig. 2. Master controller is connected to PC and accepts commands from PC through serial bus RS232, extracts data and makes a CAN frame which is suitable for CAN protocol. This CAN frame is broadcasted on CAN bus. Slave node which matches with message-id will accept the frame. On accepting command from master controller, slave will drive the motors for the specified direction and angle. MCP2551 is the line driver used between controller and CAN bus suitable for transmitting differential voltage suitable for 12 and 24 V systems.

For each link, there is one PIC controller to perform the task independently as shown in Fig. 3. There are 8 links, so 8 slave nodes for an 8 link snake like robot. Master controls all slave nodes. The transmission and receiver logic is shown in the flow charts in Fig. 4 and 5.

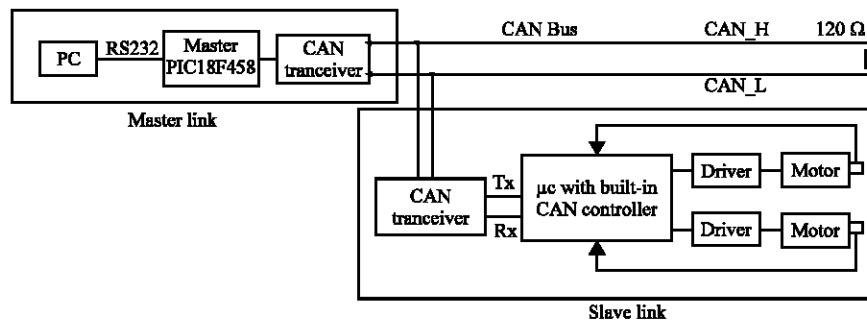


Fig. 2: Data communication protocol

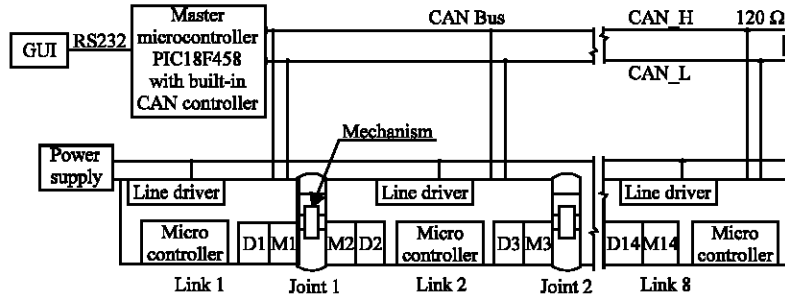


Fig. 3: Control system architecture

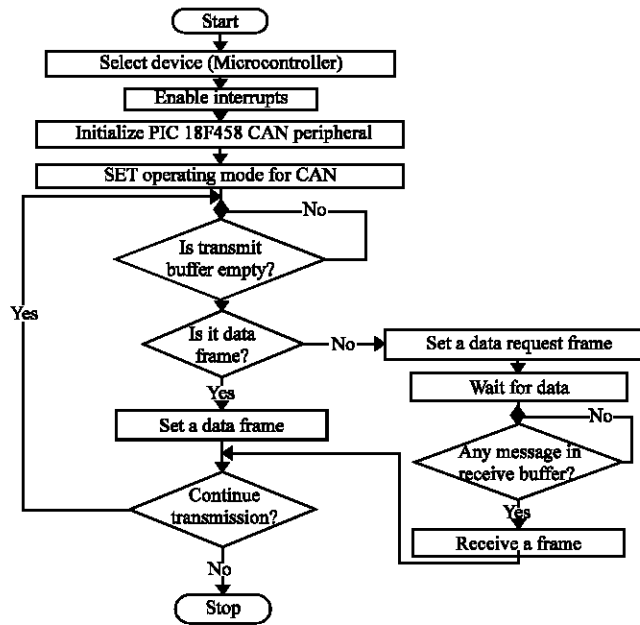


Fig. 4: Flowchart for data transmission logic

As shown in Fig. 6 transmitter is first sending a data with an id 24 having length of 8 bytes and data is 13 and in second cycle it is sending request by indicating through RTR bit and here data is irrelevant and soon it is receiving data from other node and the data received is 44.

As shown in Fig. 7 receiver buffer is receiving the data 13 and in the next cycle it is receiving a request from the transmitter side. Once, it receives a request data which is not important, it understands that the received message is a request and then it retransmits the data to the other node. The transmission begins with start of the frame which is an active low signal as shown in Fig. 8.

FILTERING

Message acceptance test is performed at each receiver node. Each message having unique message-id is compared with the filter value, if both are equal, the data is accepted into

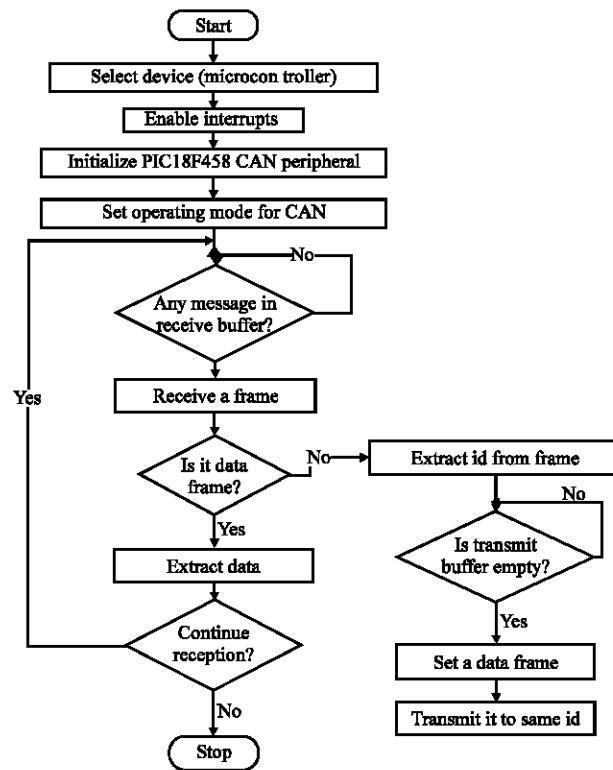


Fig. 5: Flow chart for data reception logic

```

X-CTU [COM1]
About
PC Settings | Range Test | Terminal | Modem Configuration
Line Status: CTS CD DSR
Assert: DTR [x] RTS [x] Break [ ]
Open Com Port Assemble Packet Clear Screen Show Hex

.
.transmitter buffer 0 has sent data. ID=24
LEN=8 PRI=3 EXT=1 RTR=0
. DATA = 13 13 13 13 13 13 13 13
.message has send
.
. m= 0

.transmitter buffer 0 has sent data . ID=24
LEN=8 PRI=3 EXT=1 RTR=1
. DATA = 14 14 14 14 14 14 14 14
.message has send
.
. m= 0
. receiver buffer 0 has received data
.....Printing Data Values.....
.GOT: BUFF=0 ID=24 LEN=8 OVF=0 FILT=0 RTR=0
EXT=1 INV=0
. DATA = 44 .
44 .
44 .
44 .
44 .
44 .
44 .
.

COM1 | 9600 8-N-1 FLOW:NONE | Rx: 26997 bytes
    
```

Fig. 6: Transmitter buffer sending data



Fig. 7: Receiver buffer receiving data

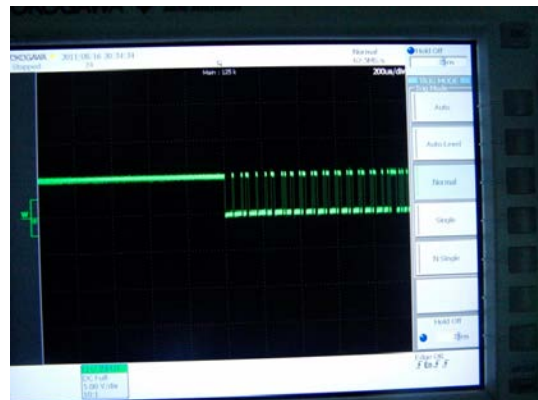


Fig. 8: CAN frame obtained in CRO

appropriate receive buffer. The examination of particular bits in the identifier with filter values is decided by filter masks. If a mask bit is zero it means that bit is accepted without the concern of filter bit.

VALIDATION

Different standard signals with different frequencies are sent to the robot slave modules. All the input standard signals are compared with the received data in the master controller computer, thus ensuring reliability and stability of the CAN bus between joint modules and the master controller. Figure 9 shows data transmission checking. The time taken to make one CAN frame has



Fig. 9: Data transmission checking

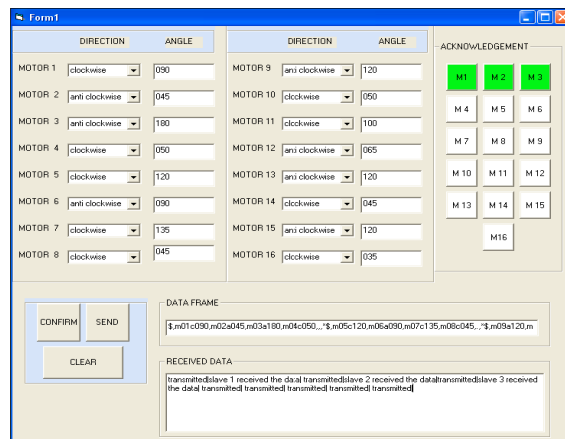


Fig. 10: Data communication result display in GUI

been measured in real time as 4.4 μsec for 20 MHz and 2.5 μsec for 40 MHz oscillator frequency. If the terminator resistance 120 Ω was absent in one of the ends of CAN bus, transmission still happened. But if the terminator resistance 120 Ω was absent in both the ends of CAN bus, transmission has not happened. Data communication result display in GUI is shown in Fig. 10. The developed snake robot is shown in Fig. 11.



Fig. 11: Snake robot

CONCLUSION

Spatial hyper redundant robotic control system requires control of many actuators with stepper motors. The research deals with a control system development using CAN. A PIC 18F458 microcontroller has been chosen which has an inbuilt CAN controller. A transceiver IC is used to connect to the common CAN bus. The CAN bus is terminated with $120\ \Omega$ resistor appropriately to avoid reflection. GUI is developed using VB6. A CCS compiler is used to compile the written embedded C code to transmit the data from one node to another. It was checked for the communication at both ends and it was ensured for the proper data. The same communication is extended further by adding new nodes to effectively implement the distributed control system for SHR robots. Implementation of the filter for selective addressing of the nodes and motion control is done. Different CAN transmission parameters are tested.

SCOPE FOR FURTHER WORK

Further, the research can be extended to cover overall gait simulation at PC and to formulate the link orientations.

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