Controller Area Network based Distribution of Coconut Harvester Process

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ABSTRACT
To make a tree climber / harvester more powerful and efficient there is a need for networked control between the various subsystems. The board to board communication becomes a need in any complex distributed system and it is proposed to be achieved by creating a CAN communication between them. In the proposed system the various nodes namely, motor ECU, sensing subsystem, image processing subsystem and router MCU are all connected over a Controller Area Network. Every node is controlled by an individual microcontroller that will perform its programmed functionality. In the proposed work the climbing motor is controlled by the sensing subsystem whose sensed parameters will reach the climbing unit over the CAN bus. Later when the climbing process is terminated the image processing subsystem is triggered to start by a CAN message and with the result of image processing the hand motor is controlled. The whole process is monitored and controlled by a base station. All these proposed nodes have their communication capabilities extended through a CAN controller (MCP 2515) and Transceiver (MCP 2551) interfaces at the SPI of each node. Further it is possible to introduce additional nodes as required for the sophistication of the application.

General Terms
Embedded Networking, Distributed Embedded System

Keywords
Controller Area Network (CAN), MicroController Unit (MCU), Nodes, Electronic Control Unit (ECU), Microcontroller.

1. INTRODUCTION
The Controller Area Network (CAN) is a serial and differential bus communication protocol developed by Bosch in early 1980s. It is a standard for efficient and reliable communication between sensors, actuators, controllers, and other nodes in real-time applications. CAN is a de facto standard in a large variety of networked/distributed embedded control systems. The early CAN development was mainly used in vehicle industry: CAN is found in a variety of passenger cars, boats, spacecraft, and several other types of vehicles. This protocol is also widely used these days in industrial process automation with applications in diverse products such as production machineries, medical equipments, building automation, weaving machines, etc.

In the automotive industry, embedded control has grown from stand-alone systems to highly sophisticated and Networked Control Systems (NCS). The concepts of NCS are dealt in detail by Rachana[1]. By networking electro-mechanical subsystems, it becomes possible for modularizing functionalities and also the hardware, which facilitates reuse and allows adding capabilities. Introducing networks in vehicles also makes it possible to more efficiently carry out diagnostics and to coordinate the operation of the separate subsystems.

A current trend in the agricultural area is the development of mobile robots and autonomous vehicles that helps automating the agricultural process. One of the major challenges in the design of these robots is the development of the electronic architecture for the integration and control of the devices. Recent applications of mobile robots have used distributed architectures based on communication networks. A technology that has been widely used as an embedded network is the CAN protocol. The implementation of the ISO11783 standard represents the standardization of the CAN for application in agricultural machinery. This work describes the design and implementation of an electronic architecture for a mobile agricultural robot. The proposed project deals with the electronic architecture of a coconut tree climber/harvester that uses a Controller Area Network. The proposed project is just the implementation of an electronic architecture that visualise the data flow and control flow between various counterparts of the coconut harvester system.

2. A NERWORKED CONTROL SYSTEM
A networked or distributed control system is the one in which the system tasks are split among more than one processing element. This art of distribution of the work between several processing elements has several advantages. Some examples of these kind of distributed systems are described by, Sunil Kumar [2] and Darren [3]. The advantages of distributed design over a regular system are,

1. The distributed processing reduces the load of the main controller thus increase the system performance.
2. Modularizes the functionalities and hardware, which allows reuse.
3. It has the potential to operate even under the presence of some faults through the use of redundant units configured as special fault tolerant units (FTU).

There are many standard and defined networking protocols for obtaining distribution in the proposed design networking protocol CAN V2.0B is used as it suffices the design requirements of an agricultural mobile.

An example of agricultural mobile using CAN based design is described in Jiantao[3], M. J. Darr [4], Eduardo[5] . Moreover use of CAN is preferred for the following advantages of the protocol, it is Weight saving, CAN has the ability to cope up with the complication of vehicles and most importantly it facilitates fast information processing with good price performance ratio. The table.1, itself justifies the selection of CAN over other protocols for the proposed system of coconut harvester process automation.

Table 1: Features of various networking Protocols

Bus	Transfer Type	Rate (b/s)	Max. Length (m)	No. of Nodes
RS232	Point to point	20k	15	1
RS485	Network	35k	1200	32
I^2C	Master-Slave	100k	1	128
SPI	Master-Slave	110k	1	any
CAN	Network	1M	40	120
USB	Master-Slave	480M	5	126

3. APPLICATION CLASSES OF CAN

Controller Area Network since 1980 is a widely used standard in distributed embedded systems. It is one of the Serial Bus Communication protocol used in variety of automobiles and Industrial machinery. In spite of its existence since 1980s it is successful because of its continual up gradation and improvements in terms of data rate needs for present day applications and reduced complexity. The three main accomplishable design requirements by using this kind of a wired network were identified as Distributed Control, Process Monitoring, and Internetworking.

3.1 Distributed Control

It is possible to implement a distributed control through the networking of several microcontroller boards with CAN bus. Such a system that uses distributed type of control was described by Liang Chen[6]. D.V.S.Reddy[7] shows the implementation of an industrial parameter control through CAN protocol by using 8051 microcontrollers as ECUs (Electronic Control Units). In the work of Mazran Esro[8] it is seen that the overall security system is based on the integration several subsystems communicating through CAN Protocol. One important advantage in distribution of a process among multiple processors is that the distributed processing from different subsystems performed by different nodes reduces the load of the main controller thus increasing the system performance.

3.2 Process / Parameter Monitoring

Other than Control applications process monitoring through sensed parameter identification and propagation through a network is also possible. CAN Bus is used in some process monitoring systems for transferring the sensed parameter from a remote node to a base station.

Du Chen[9], constructed a CAN bus based monitor system was constructed in which multiple tasks including data acquisition, information exchange and data storage was performed at a frequency of 1 MHz. The quoted work consisted of a series of microcontroller driven nodes to collect on board information. In each node, an embedded controller was utilized to perform the data acquisition (e.g. engine speed, threshing drum speed and grain loss, etc.) and communication task.

3.3 Internetworking

Sometimes passing data from other communication protocol into the CAN bus for some application requirement becomes the need. In that case the concept of internetworking is used. A special node with internetworking capabilities is needed to perform protocol conversion of upstream or downstream data. In case of protocol conversion from CAN to WLAN and vice versa a protocol converter is named "Wireless Internetworking Unit (WIU)" is needed. The implementation of internetworking enables remote monitoring of the associated process or remote control of the associated process.

One such WIU was described by *Cuneyt Bayilmis[10]*,The interworking device described here has a wireless support to extend CAN segments, utilizing an IEEE 802.11b WLAN is a practical solution for such an industrial environment.

Usage of this internetworking for remote monitoring and control of the CAN bus and its constituent nodes was well implemented by *CuneytBayilmis[11], i*n their work, has a WIU that establish communication between the base station and the distributed system. The speech signal received at the base station is converted into control commands for the CAN nodes and are passed to the routing node for passing to any node connected to the CAN Bus.

Again, *K.Pavani[12]*, use a couple of sensors located at the industries acquire the information, process the data and transmitting through the CAN bus to the ARM7 processor. This processor receives the data from the sensor nodes and transmitted to central receiver via ZigBee Communication. The central receiver systems which can collect the data from the node receiver unit and transmitted this data to data logging sever, and if there is any over threshold sensor readings according to that it loads the data with corresponding control signal information along their ids and send it through Zigbee.

4. HARDWARE ARCHITECTURE

The proposed system architecture is shown in the fig.1. The figure simply illustrates the various hardware blocks that are used in the system. The process flow is controlled by the application programs which are not visible on the block diagram. The main elements of the block diagram include the CAN Bus and the various nodes connected to it. Every node has 2 main components,

a. MCU – MicroController Unit

b. CCT – CAN Controller and Transceiver/ CAN Module

In addition to the two components further essential modules are contained at each node.

The node wise numbers are provided like N1,N2,… in order to provide a name for each node that will ease the discussion to some extent. The first node N1 is found to have 2 motors connected via suitable driver circuits. The node N2 has a distance sensor interfaced to it to the ADC input pin and an RFID reader at the UART. N3 is found to have a zigbee module installed on its SPI. N4 has a camera connected to it. The role of every module installed is better understood while analysing the work flow of the system.

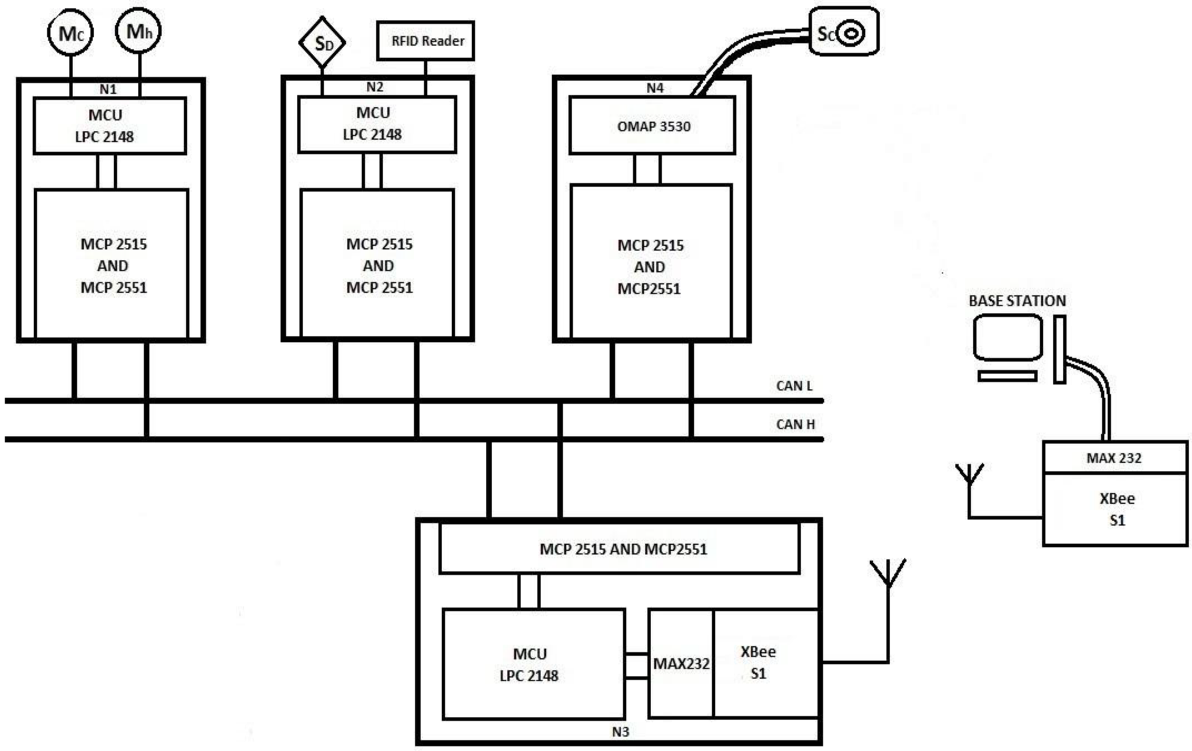

Fig 1: Proposed System Block Diagram

A very much used controller transceiver pair for CAN interface is used. A custom made PCB that has the Stand Alone CAN Controller (MCP2515) and High Speed CAN Transceiver (MCP 2551) with SPI interface to the MCU was used. Depending upon the requirement of the system the MCUs of different configuration are used. LPC2148 is the simplest choice as the proposed work does not involve complex power scaling and power reduction schemes.

The various description on the Fig 1 are listed below,

a. N1- node1/ ECU of the motor control subsystem
b. N2- node2/ ECU of the sensing subsystem
c. N3- node3/ Internetworking ECU
d. N4- node4/ ECU of the image/video processing subsystem
e. Mc- Motor representing the climber
f. Mh- Motor representing the robotic hand
g. Sd- Distance Sensor
h. Sc- Camera

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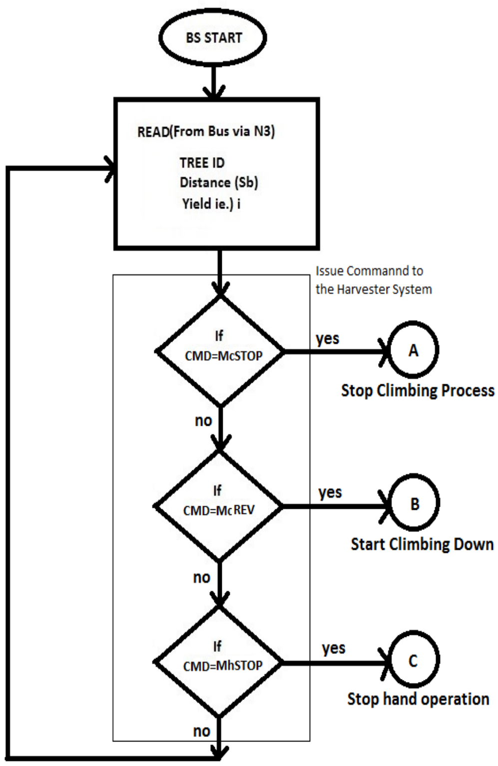

Fig 2: Process Flow in Base Station

5. THE PROCESS FLOW

The Process Flow Model has various steps involved in the working model proposed. The sequence of operations and the flow of control between the nodes are illustrated for the full process. In Fig 2 there is the process flow of the base station alone, the possible conditions created at the base station affect the entire system. It is seen that commands issued from the base station control the climber unit.

The commands are generated at instances A, B, C. Hence A, B, C in Fig 2 and Fig 3 are not connectors but points where the commands issued at the base station affect the remote climber/harvester's process.

The Fig 3 shows the process flow of the entire system. The representation of events is realised by variables and their change of values. To describe the process completely it needs complete understanding of the hardware block diagram in Fig.1. The operating conditions created with user interference at the base station affect the system's automatic mode of operation.

The Base station and the nodes in the network are booted simultaneously. The node 2 finds the tree ID with the RFID module and checks if the tree is not climbed and a tree ID is a valid tree number. If true it puts the ID value on the bus and then the distance sensor at N2 reads the distance and the value is put on the bus. N1 takes this distance value and compares to a threshold, when greater than the threshold it starts the climber motor Mc in forward direction.

A timer at N2 tracks the amount of time Mc is running forward, let that be't'. The motor Mc continues running forward and it is stopped if the distance value drops below or equals threshold value. Simultaneously N4 takes the distance value from the bus and if threshold value is reached it activates the camera Sc to take still images and process the image to get the position of a single mature coconut. If no mature coconut found rotate Mh in reverse direction. If a mature coconut is identified rotate Mh in forward direction.

The condition check for the number of reverse rotations less than 8 (Number of hand positions for image acquisition) is made if satisfied then further process of rotation and imaging is continued. If number of reverse rotations is equal or greater than 8 then the climbing motor Mc is run in reverse signifying reverse climbing for the climb interval recorded i.e.) t. Also the forward rotations of Mh are counted and this will in turn be the yield (Number of coconuts per tree).

The significance of each motor direction is as follows,

Mc FWD: Up Climbing

Mc REV: Down Climbing

Mh FWD: Making a harvest

Mh REV: Changing the hand position.

The hand unit is expected to have 8 positions for imaging, each at an angle of 45degrees from the previous position. This can be achieved by a special hand structure with joints and the angle of rotation controlled by the applied torque to the motor. However the mechanical structure is purely independent of the data flow between the various controlling MCUs hence they are considered out of scope to the proposed electronic architecture

Further the base station simultaneously obtains the Tree ID, Distance value, and Yield. It is also featured to issue higher priority commands to stop the climber and climb down namely STOP Mc and REV Mc which is found to affect the main remote unit's process at points A, B, C.

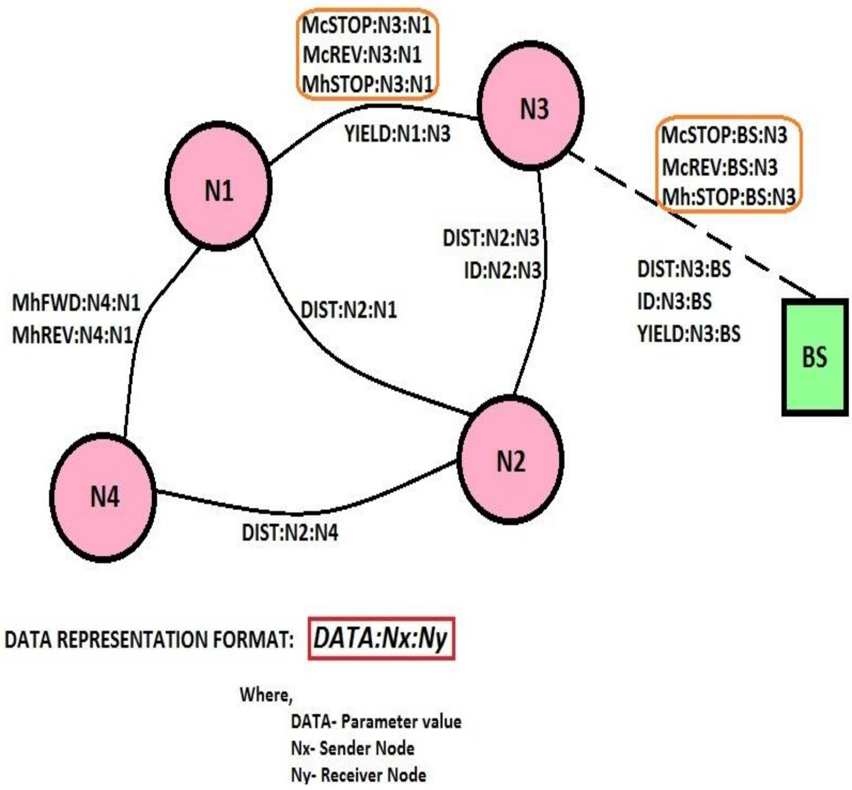

Fig 4: Data Flow between the Nodes

6. THE DATA FLOW

The next step is to analyse the flow of data between the various nodes available in the system. This shows the flow of data on the bus which is termed as bus activity (or channel activity in the case of wireless medium). The data representation format has three entities namely, Parameter value (data), Sender node and the Receiver node.

In the Fig.4 the data flow model for the proposed system is shown. Every node in the block diagram is denoted by circles and the continuous lines in the diagram show the wired connection between the nodes and the dashed lines describe the wireless link. The Data Activity diagram thus shows which data flows between which two nodes. However the time of data transfer is not shown in this diagram because some data transfers are not time triggered but event triggered.

The node N2 puts the id value and distance value in to the bus. The ID is received by node N3 and the distance value has multiple receivers namely nodes N1, N3, N4. The node N3 sends the ID and distance value to the base station. The commands McSTOP nad McREV are issued on the base station and are routed to N1 through N3. The node N3 serves the purpose of a router in the network architecture.

The boxed control commands are the higher priority user issued commands generated from the base station. These commands are used to control the system manually under some needy circumstances. The hand motor control commands namely MhFWD and MhREV are issued by N4 and are received at N1. Further the YIELD value is sent to the base station from N1 via router N3. This data activity diagram helps configuring message Ids and buffers for every message in their associated nodes. Later when calculating the load on the network this data activity is converted into a timer based mapping so that bus load during the process can be estimated in order to validate the system.

7. CONCLUSION AND FUTURE WORK

This process of Coconut Harvester is realized in hardware. However for a complete system design it is needed to sophisticate the process of climbing and identification of mature coconut by adding additional nodes to the constructed Controller Area Network. Some expansion ideas are as follows.

The testing for mature coconut is only camera imaging and image processing in the proposed work. But to increase accuracy in the process and reduce the error in estimation, a secondary test can also be adapted. As a secondary test, an ultra sound probe can be interfaced to any MCU and can be included in the process. This work is only an electronic architecture and it needs complete revision and sophistication to make it adaptable in real time. Some possible enhancements in the proposed system are given below.

- The distance sensor used in this model is not capable of sensing a long distance (in terms of 10-15 feet) which needs to be revised for real time operation.
- The base station in this project keeps track of only the parameter values; it is also possible to perform video streaming (with a Wifi module as in Kanitpong[10]).
- Since node N3 uses an XBee S1 it needs to be replaced with second generation Zigbee module like CC2520 which has better selectivity in the 2.5Ghz band.

Adding features means adding new nodes to the existing system and it is always possible in the design proposed.

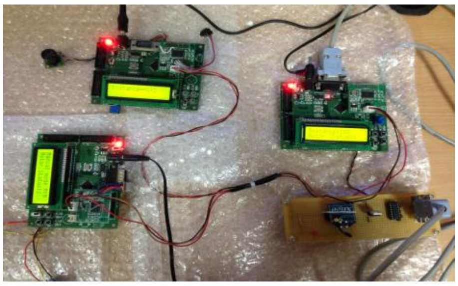

Fig 5: Nodes N1, N2, N3 and suppotred processes have been developed

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