Integration of Heterogeneous Unmanned Ground Vehicles with Synchronized Communication

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Abstract

This study investigates the communication scheme to integrate a group of heterogeneous unmanned ground vehicles in a lead-follower network. The unmanned ground vehicle network has two communication protocols: wireless communication between host computer and the leader via WiBoxes, and wireless communication between the host computer and the followers via fast wireless communication modules. Integration of these heterogeneous components requires synchronized and high efficient communication within the unmanned ground vehicle network. Two different communication schemes have been compared and applied to a real platform with one leader and four followers. The real-time sharing was achieved by exchanging the collected information from the leader and the followers through the host computer.
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Introduction

Synchronized communication is highly desired for cooperation among a group of unmanned ground vehicles (UGVs). In most cases, UGVs are heterogeneous with different operational systems, communication protocols, communication frequencies and hardware interfaces, which impedes the cooperation among the UGV team. In this application, we carried out research on the synchronization scheme for multiple heterogeneous UGVs in a network and compared the efficiency of different communication schemes. The research results lay a foundation for integration of heterogeneous systems and provide guidance for performance improvements of the UGV group.

Problem Statement and Methods

The UGV group in this project includes one P3-AT robot as the leader and four X4-Rovers as followers. Cooperation of the leader and the followers is supported by wireless communication among the host computer, the leader and the followers. Specifically, communication between the host computer and the leader is achieved by Lantronix WiBoxes. One WiBox is linked to the onboard computer of the leader through a DB9 DTE serial port. The second WiBox is connected to the host computer through its USB port.

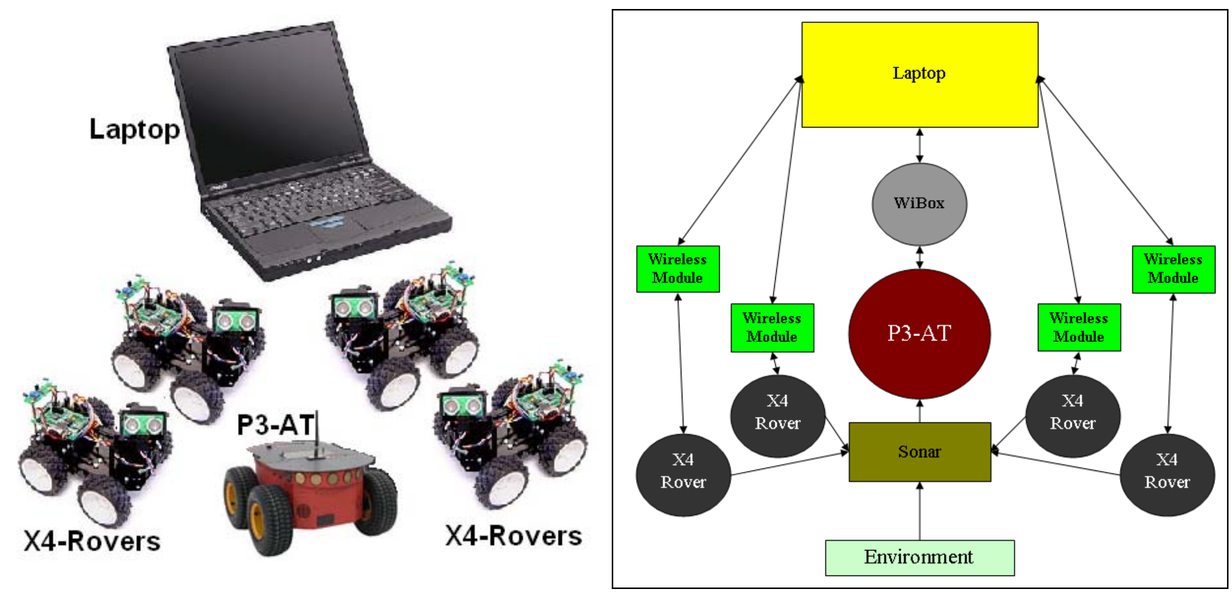

Figure 1. System configuration of the unmanned ground vehicle group (left) and the wireless/sensor network

The communication between the host computer and the followers is achieved by fast wireless communication modules (FWCMs). Each follower has one FWCM connected through an I^2C port and the host computer is connected to a FWCM through its serial port.

Difficulties of the group integration are caused by heterogeneous communication protocols, potential inconsistent communication (caused by obstacles or limited sensor ranges), and inaccuracy of the local sensors. To address these problems, we establish a database in the host computer to manage the transmitted data in the network with specific UGV identification number and time. In addition, we added a geometry constraint for the UGVs so that the leader would detect the followers within the working range of its position sensors. The inaccuracy of the sensors will be addressed in our future research.

Communication Network

Communication between host computer and the leader P3-AT robot

Data transmission rates of the WiBox ranges from 300 to 921,600 bps. The baud rate is set as 9600 bps, remote IP address is set as 129.115.1.100 for the leader and 129.115.1.000 for the host computer. The communication drivers are provided by the manufacturer.

Communication between the host computer and the followers (X4-Rovers)

The FWCM is a 433 MHz RF communication module. Each module can support bi-directional wireless communication with 100% data accuracy over a distance of up to 300 meters. The module is designed to work with both the followers through I^2C connection and the host computer through RS232 serial communication. When configured for normal mode, a FWCM network can have at most 255 modules with each one assigned a unique address (figure 2). In our UGV network, the host computer and each follower is equipped with FWCM.

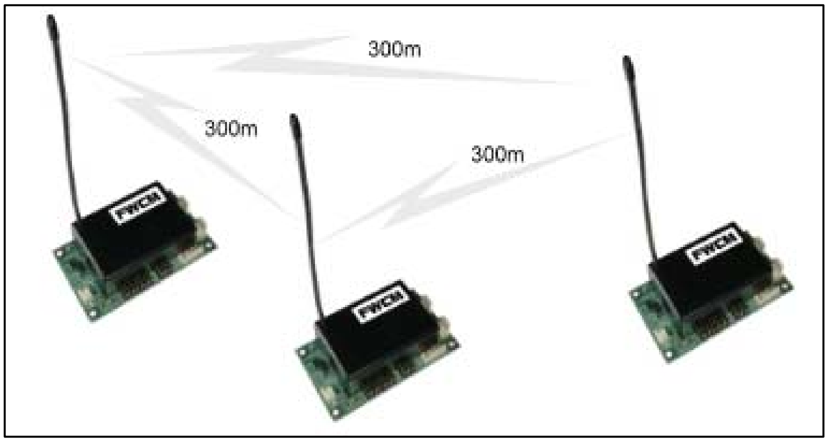

Figure 2. Communication range can be enlarged with serial FWCM chain in a team.

With such hardware configuration, position and velocity information of the leader and the followers can be exchanged through the host computer.

Communication schemes of the wireless UGV network

Since each FWCM can behave as both transmitter and receiver, there are three communication schemes between the host computer and the followers: parallel, serial, and broadcast scheme. In parallel communication scheme (figure 3, left), the host computer (node 9) can communicate with two followers (node 1 and 2) and the signal paths are in parallel. The serial scheme is shown in figure 3 (right) where the host computer communicate with one follower (node 2) through a relay (node 1), and the signal path is a serial chain. If more followers (nodes) are needed, a broadcast scheme can be used by which the host computer broadcasts the information and all the followers behave as listeners. This scheme is not used in our real application due to the lack of feedback information to the host computer. The serial communication scheme is able to maintain a larger communication range than a parallel communication scheme but has a tradeoff on communication efficiency due to the delay caused by multi-relay. The intent for future research is to switch back and forth between the two communications schemes depending on whether or not the rovers are within the threshold range of the parallel scheme.

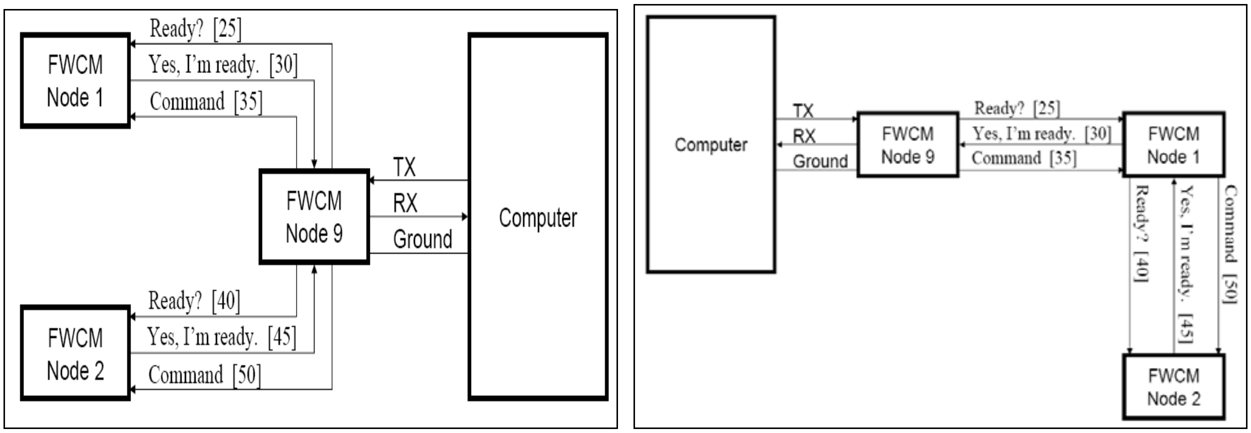

Figure 3. Parallel (left) and serial (right) communication schemes for the host computer and the followers.

Implementation of the FWCM with the host computer and the followers

The serial port for the host computer (Baud rate is 19200) and its communication protocols are configured with Matlab scripts[2] using "fread' and "fwrite" commands. The data stream was represented as a row vector.

The communication protocols for the followers are written in C and executed on the onboard controller (OOPic) of the followers[8,9]. Protocol flow is described as:

1) Read sensor data (compass, sonar) and transmit to the host computer.

2) Wait for computer to respond with calculation-finished flag and data.

3) Match heading in command data.

4) Move forward for received amount of time.

5) Send "done" to computer.

6) Repeat steps 1 to 5 [3].

The interaction among the host computer and the followers were tested and verified.

System Integration

Integration of the UGV team includes two steps: information exchange among the leader and followers, and geometrical constraint for the leader and the followers to keep continuous communication.

The database includes the specific identification number of the leader (P3-AT) and the followers (X4 rovers), P3-AT's position (x, y), orientation (θ), velocity (v), X4's position (x_r, y_r), and the specific sensing time. The database is administrated by a synchronization algorithm in the host computer. This synchronization algorithm will interpolate data entries at specific time points and share the information with the leader and the follower via communication network described.

In order to guarantee a continuous communication among the leader and the followers, a geometrical constraint was proposed to guarantee the followers to stay in the detection range of the leader (figure 4, left). This rover detection area is located directly behind the P3-AT and only sonar readings within this area are considered for determining the followers' position. Any sonar readings outside of this area are disregarded as possible X4-rovers but are still used for navigation and obstacle avoidance purposes. If there is no sonar reading within the detection area, an alarm of "OoR" (Out of Range) will be generated instead of a numerical value of the follower's position. A series of MATLAB simulations were carried out to verify and improve the rover (follower) detection prior to actual implementation on the P3-AT (Figure 4, below).

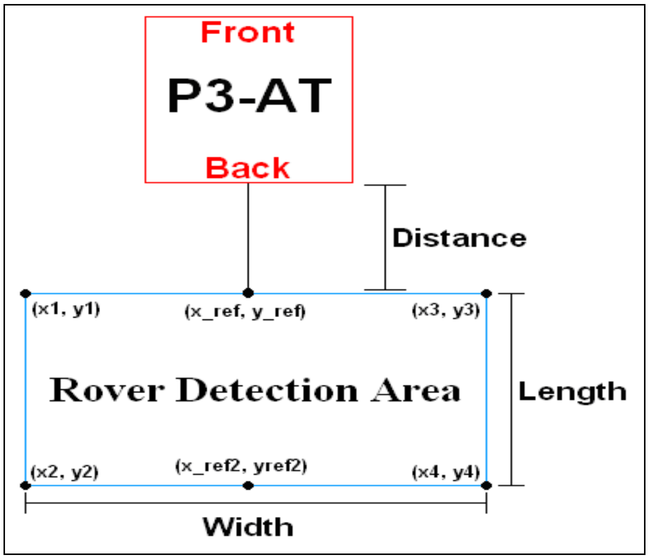

Figure 4. Rover detection design for continuous communication

Results

Integration of the control algorithm running in the host computer and the onboard controller on the rovers led to successful cooperation among the UGV group (figure 5). The leader and followers sent their positions, orientations, velocities to the host computer. The host computer synchronized the collected data and generated trajectory commands for both leader and followers in the following calculating period. These commands were sent back to the team and executed independently. The synchronization scheme between the host computers and the followers are demonstrated in Figure 5. We ignore the details of the algorithms[4,5,6] executed in the central host computer since focus of this paper is to present the application of synchronized communication scheme among the heterogeneous UGV network.

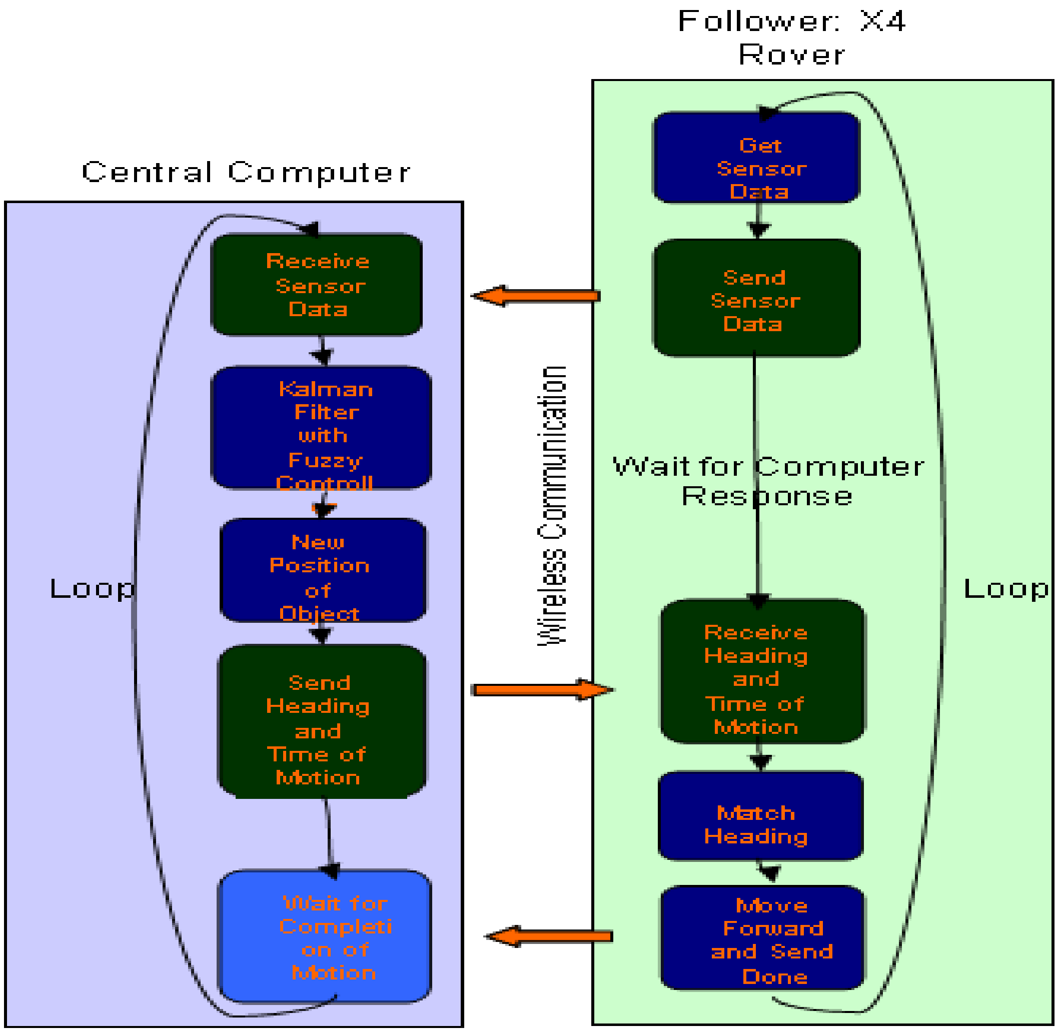

Figure 5. Interaction among the host computer and the followers.

Conclusion

A heterogeneous UGV group has been successfully integrated in this project. Synchronized communication was guaranteed by database administration and rover detection algorithm. Parallel and serial communication schemes have been individually tested and applied. Integration has been validated with applications on a real platform. Our future research includes robust control design for the leader in case of discontinues communication with the followers, which will save energy consumption and improve security of the system.

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