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Implementation of Integrated Wireless Network and MATLAB System to Control Autonomous Mobile Robot[i]

Tamre M[*a]; Hudjakov R[b]; Shvarts D[c]; Polder A[d]; Hiiemaa M[e]; Juurma M[f]

Department of Electrical Power Engineering and Mechatronics,
TalTech (Tallinn University of Technology), Tallinn, Estonia

[*a]mart.tamre@ttu.ee, [b]robert.hudjakov@ttu.ee, [c]dmitry.shvarts@ttu.ee, [d]ahti.polder@ttu.ee
[e]maido.hiiemaa@ttu.ee, [f]mart.juurma@ttu.ee

ABSTRACT

In this article a wireless network using Xbee modules is designed and applied for autonomous mobile robot combined with GUI (Graphical User Interface) in MATLAB. The GUI panel and control structure in MATLAB allows to monitor and control all remote robots online by operator. Results and calculated solutions from MATLAB are directed back to autonomous mobile robot for Its performances and communications in the real time. This paper discovers a secure wireless network and low-cost with powerful data processes supportive to remote micro-controllers on autonomous mobile robot.

Keywords: microcontrollers, Wireless network, XBee module, MATLAB GUI, autonomous mobile robots.

1. INTRODUCTION

This paper introduces the design and implementation of a wireless communication network based on IEEE 802.15.4, and integrated with the graphical user interfaces (GUIs) in MATLAB to monitor and to control autonomous mobile robots. Robots are equipped with smart sensors, cameras and microcontrollers. In this research, the microcontrollers LPC2148 are used since in LPC2148, there are already inbuilt two serial ports (UART0 and UART1). One port can be used to connect to an XBee wireless module and the other port can be used to connect to an iPhone SIM card. The system can perform a mesh network and enable to monitor and control from a PC with MATLAB graphical panels and from other iPhones via their GPS system.

XBee modules can create a meshing network connection of more than 64000 units at a data speed of 500k bit per second. Each XBee module consumes a very low energy of few milliwatts (mW) and provides a communication range of some hundred meters. This wireless network can be used for inter-communicating with smart sensors and remote microcontrollers. However, the embedded microprocessors in those microcontrollers are not designed for fast data process and complicated computation because of the very limited memory and size by themselves. Therefore, the use of MATLAB can support the calculation for those remote microprocessors.

There are still few applications for such integrated system. A review of recent applications for mobile sensor wireless using WIFI, Zigbee, and XBee modules can be

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[i] *This paper is a revised and expanded version of a paper entitled 'CONTROL OF AUTONOMOUS MOBILE ROBOTS USING WIRELESS NETWORK AND MATLAB' presented at 11th International DAAAM Baltic Conference 'INDUSTRIAL ENGINEERING', Tallinn, Estonia, 20–22 April, 2016.*

read in reference [1]. An application of a wireless network for smart sensors to monitor and to control the temperature in a museum is presented in reference [2]. Another new application for smart housing with wireless Zigbee modules for intelligent furniture in a house can be read in reference [3]. A new home security system with XBee wireless applications is designed in reference [4]. The data communication via internet and wireless networks for industry with S7-1200 SIMATIC are introduced in reference [5].

Recent applications of MATLAB GUIs to control and support microcontrollers are relatively still few since only recent MATLAB versions of 2014 to 2016 have updated new GUIs for fully design of graphical human robot interfaces and interactions to remote microprocessors via wireless networks. A review of MATLAB online for data achieving and processing supported remote microcontrollers can be read in reference [6]. Another application with MATLAB for monitoring and controlling using graphical interfaces for remote microcontrollers is presented in reference [7].

Regarding recent references for the control of mobile robots, some papers have developed control algorithms using MATLAB to generate feasible paths of autonomous robots. A recent paper regarding this issue can be read in reference [8]. Conditions to assure stability for controllers are presented in reference [9]. And a new application for a wireless sensor network using MATLAB and embedded microcontrollers can be read in reference [10].

This paper attempts to design new applications of MATLAB graphical interfaces and interactions to monitor and to control remote autonomous robots via XBee wireless modules. The contents of the paper are as follows: part 2 presents the design of the hardware, part 3 introduces the design of the software, part 4 summaries some experimental results, and finally, part 5 concludes key outcomes and recommendations.

2. DESIGN OF HARDWARE

The design of hardware for this system is consisting of remote mobile robots and a PC as a control center. Robots are equipped with smart sensors, camera and microcontrollers LPC2148. XBee wireless modules are connected to the UART ports of those microcontrollers and connected to the USB ports in the PC. SIM cards of iPhone can be also connected to those microcontrollers to monitor the activities of robots at anywhere if possible.

Each robot can communicate to others and to the PC control center via the wireless network and also to the iPhone GMS system. Figure 1 illustrates the configuration of the tested autonomous mobile robots. In our experiment, these mobile robots are used the robot platform Rover5 with four driving wheels run by four DC motors connected to four encoder disks to control the movement of each wheel.

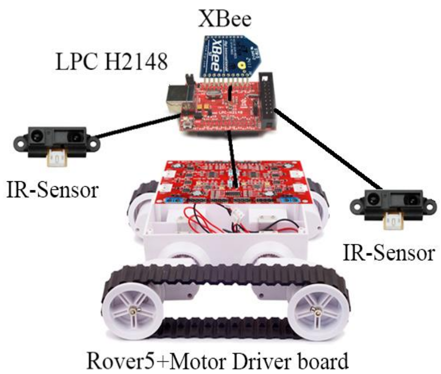

Fig. 1. Mobile robot’s configuration

A PC with MATLAB version 2016 plays as a control center. MATLAB GUIs interfaces and interactions are used to monitor and to control those remote mobile robots via their XBee wireless modules. All sensory data from remote robots are stored and displayed as the real time on the PC screen multiple panels with tough functions. Connection of the PC control center is illustrated in figure 2.

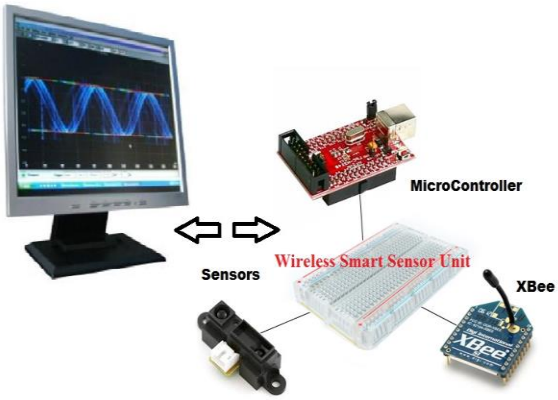

Fig. 2. Connection of the PC control center

This hardware allows the support of MATLAB powerful computation to the remote microcontrollers on mobile robots. The PC can also support the data achieving and storing data to the PC hard disks. The next part presents the design of software for this system.

3. DESIGN OF SOFTWARE

The design of software includes the design of multi graphical panels in MATLAB GUIs for human robot interfaces and interactions. Figure 3 shows an example for a MATLAB interfaced control panel. The operator can monitor the remote robots via camera and control the robots via touch screen panels as in the real time.

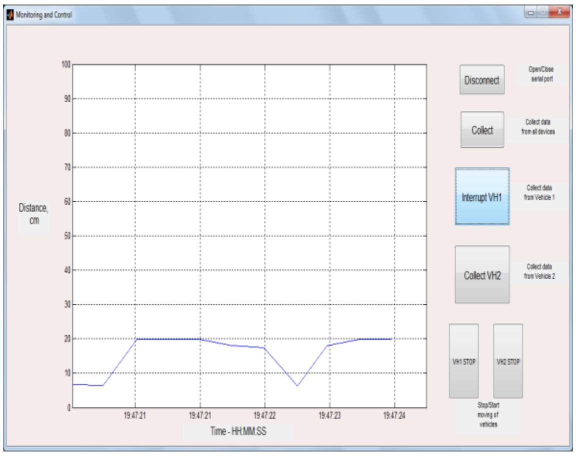

Fig. 3. MATLAB graphical panel

The next is the development of the software for each XBee modules. Each XBee module is designed to perform the following functions: receive data from sensors and transmit them to its microcontroller and to other modules and to the PC control center via a meshing wireless network and/or to the iPhones via the GMS system. Data exchanged from/to other autonomous mobile robots allows them to collaborate with each other based on the pre-programming software in their microprocessors. The PC control center can monitor and control all remote robots. The PC control center can also update new programming software for remote microprocessors. All sensory and video data from remote robots are achieved and processed with MATLAB in the control center PC.

The operators can view all control panels, stop or start as real time all remote microprocessor. The design of XBee communication software flowchart for this system is presented in figure 4.

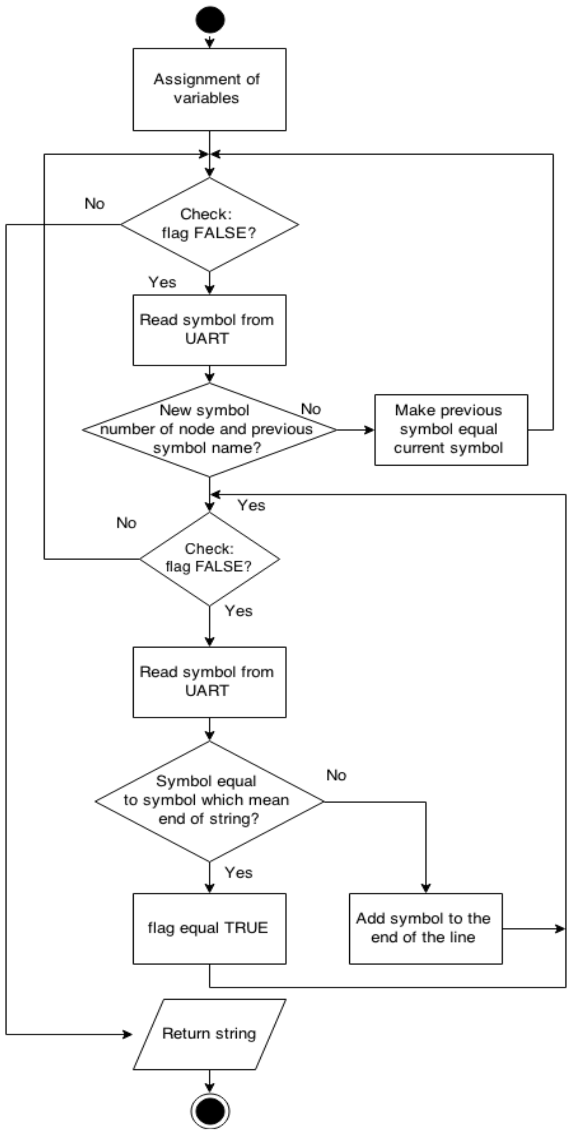

Fig. 4. Software design flowchart

From the above flowchart, all communication ports must be synchronized with pre-setting for transmission rate, parity, stop bit, data buffer, etc., and the inputs and outputs assigned for each node.

Then, the main control loop for every node starts by checking the command from the control center. Working status of each node will rely on the activated signal from the control center. When the control signal for each node is checked and accepted, the node begins its operations according to its pre-programming. This system allows each robot working independently, collaboratively, and autonomously to each other's. In this experiment, each XBee node receives data from other nodes and from the control center. The next part introduces some experimental results from this project.

4. EXPERIMENTAL RESULTS

Each robot has it owned pre-programming software to generate its feasible paths subject to the environmental obstacles and the robot itself physical constraints. Based on the real time data from camera and smart sensors, the microprocessors in each robot can calculate and map out the best solution from feasible paths to move from the current initial position with the initial body direction to the next destination position with the destination body direction. Figure 5 illustrates a solution path for a mobile robot from a starting point coordinate position of *x*, *y* [0,0] and with the body direction at 0 degree. The robot is planned to move to the next destination coordinate position of *x*, *y* [10,10] and the destination robot body direction of 180 degree (the robot moves to other position and reverses its body direction).

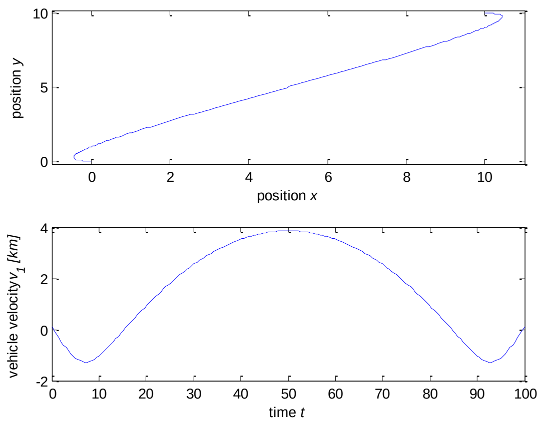

Fig. 5. Feasible path and velocity solution

In figure 6, the robots are tested to avoid obstacles and collisions. They can perform their feasible paths from any starting points to any other destination points. Further, the robots can collaborate to each other to avoid the collisions by exchanging their position, speed and direction data.

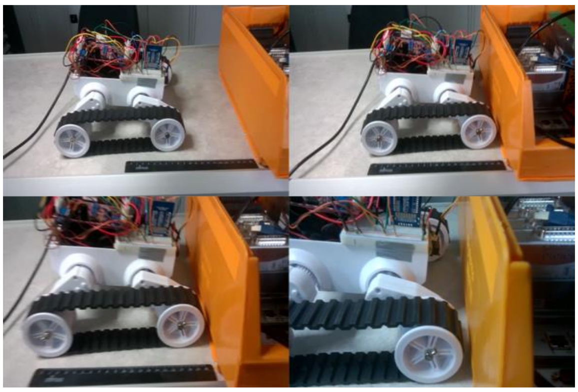

Fig. 6. Test of collision avoidance

Next tests are for the human robot interfaces and interactions with the PC control center. Figure 7 shows that from the control center, the operators can monitor and control any remote robots. The operators can also upload new pre-programming to remote microprocessors upon the new working situations and the changes of their environments.

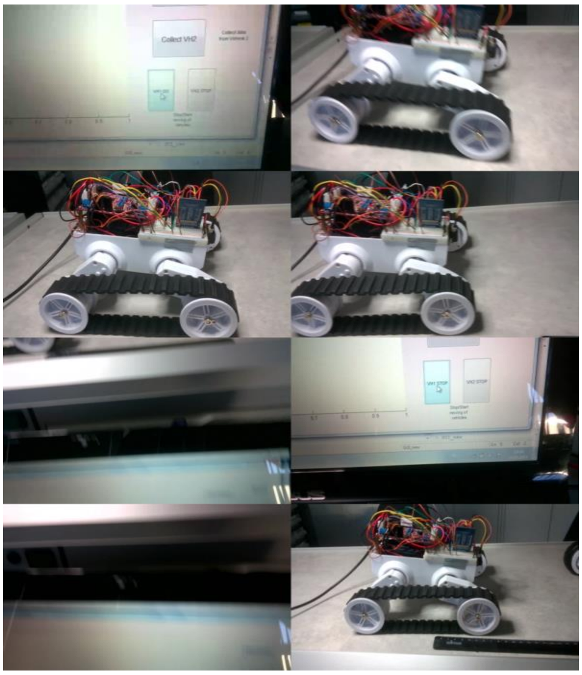

Fig. 7. Monitor and control of robots

Video and sensory data from remote robots can be stored and processed with MATLAB in the control center PC. Figure 8 shows the sensory data achieved from one remote robot online. These data will be calculated in MATLAB and will be sent back to the remote robots.

141	288	124.909614	19:01:39
142	289	123.690184	19:01:40
143	288	124.909614	19:01:40
144	288	124.909614	19:01:41
145	709	6.906000	19:01:41
146	728	6.107361	19:01:41
147	726	6.230501	19:01:42
148	713	6.803806	19:01:42
149	727	6.170150	19:01:43
150	706	6.961350	19:01:43
151	705	6.975867	19:01:43
152	710	6.883540	19:01:44
153	310	99.826740	19:01:44
154	289	123.690184	19:01:45
155	288	124.909614	19:01:45
156	288	124.909614	19:01:46

Fig. 8. Sensory achieving data

The MATLAB computation support to remote microprocessor vie XBee modules is the new application for MATLAB GUIs. This allows the robots performing very complicated and sophisticated activities via the connection of MATLAB at the control center. The calculated results will be sent back to remote microcontrollers as shown in figure 9.

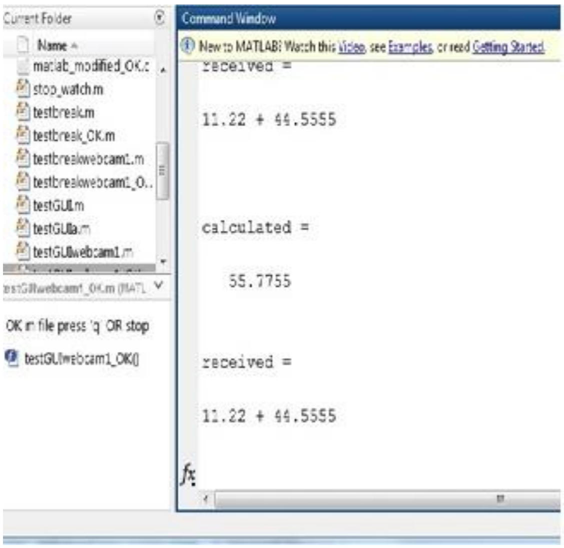

Fig. 9. MATLAB computation support

Communication among autonomous robots via XBee wireless modules is illustrated in figure 10. Each XBee module can send and receive data from others. The programming software for each XBee module must contain the transmitted addresses, the start, the end, and the confirmation mark for each sending and receiving message.

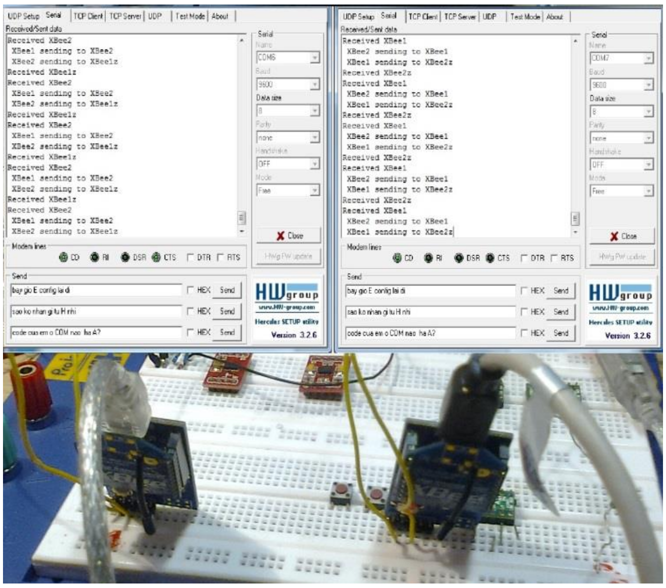

Fig. 10. Communication among XBees

In summary, the integration of wireless network for remote autonomous mobile robots and MATLAB GUIs in a PC control center can enhance the computation ability for remote mobile robots. The designed communication network is low energy consumption, low cost and fast data achieving and processing using the latest applications of MATLAB version 2016.

5. CONCLUSION

In this paper, a new wireless communication network for remote autonomous mobile robots integrated with MATLAB GUIs to support data achieving and processing are designed and tested. This project promotes new applications of XBee wireless communication and MATLAB graphical control panels supported to remote microprocessors. The network can be also opened for iPhones GPS system. Recent MATLAB versions can support new graphical panels for human robot interfaces and interactions.

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CONFLICT OF INTERESTS

The authors declare that there is no conflict of interest regarding the publication of this research article.

REFERENCES

[1]. Chakkor S., Baghouri M., Ahmadi C., & Hajraoui A., Comparative Performance Analysis of Wireless Communication Protocols for Intelligent Sensors and Their Applications, International Journal of Advanced Computer Science and Application, 2014, 5(3), 76-85.

[2]. Jinhui H., ZiYu X., Xu X., & Siyang T., Zigbee-based Intelligent Home Furnishing, International Journal of Smart Home. 2015, 9(1), 61-68.

[3]. Jeba Samuel C. P., Prakash S., Ananda Kumar M., & Manivannan D., ZigBee Based Home Security Alert System: Integrated Approach, Journal of Artificial Intelligence. 2013, 6(1), 89-94.

[4]. Ustad V. K., Mali A. S., & Kibile S. S., Zigbee Based Wireless Air Pollution Monitoring System Using Low Cost and Energy Efficient Sensors, International Journal of Engineering Trends and Technology. 2014, 10(9), 456-460.

[5]. Singh B. & S Harender., Intelligent monitoring & controlling of agricultural field parameters using ZigBee, IJITE, 2015, 3(1), 23-27.

[6]. Malika Sardana & Charu Rana, International Journal of Computer Applications.2014, 3(4), 374-380.(2013).

[7]. Mohini R. & Vidya S., Development of an Embedded System and MATLAB based GUI for Online Acquisition and Analysis of ECG Signal Measurement,.2014, 43(9), 1119–1126.

[8]. Vu Trieu Minh, Afzulpurkar Nitin, & Muhamad, W. M. Wan, Fault Detection Model Based Controller For Process Systems, Asian Journal of Control, 2011, 13(3), 382-397.

[9]. Minh, V. T. & Rashid, A. A., Modeling and Model Predictive Control for Hybrid Electric Vehicles, International Journal of Automotive Technology, 2012, 13(3), 477-485.

[10]. Minh, Vu Trieu, Tamre Mart, Musalimov Victor & Valeri Altunin, Development of a Wireless Sensor Network Combining MATLAB and Embedded Microcontrollers, Sensor Letters, 2015, 13(12), 1091-1096.