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ITJ

ISSN 1812-5638

INFORMATION TECHNOLOGY JOURNAL

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Information Technology Journal 7 (2): 374-377, 2008
ISSN 1812-5638

Communication of Mobile Rover Based on FPGA, DSP and Wireless Communication

Amel Zerigui, Xiang Wu and Zong Quan Deng
School of Mechanical Engineering, Harbin Institute of Technology, Harbin, Heilongjiang 150001, China

Abstract: The control system of wheels mobile rovers is very important for recent and future research. The wheel type mobile rovers are one of the most practical and widespread robots. Wheels mobile rovers have a simple driving mechanism and high energy efficiency. This study describes the configuration of the communication of ($2n+2/0\leq n\leq 3$) wheels mobile rover (robot) presented by 2, 4, 6, 8 wheels mobile rovers by using digital signal processor TMS320LF2407 DSP from Texas Instruments and wireless communication presented by Bluetooth technology. Also the communication hardware design is based on Field Programming Gate Array (FPGA) chip. The design of the common control system of ($2n+2/0\leq n\leq 3$) wheels mobile rover gives a combined system with low cost and high performance. The Experimental results suggest that the data in the FPGA change before and after communication between DSP and FPGA for each rover subsystem.

Key words: Wheels mobile rover, wireless communication, FPGA, DSP, common hardware, common software

INTRODUCTION

Mobile robots are being developed for applications in many fields such as space exploration (Schilling and Jungius, 1996; Stooke, 2005), mining (Banta and Rawson, 1994), agriculture (Belforte *et al*., 2002) deep oceans discoveries (Cutts *et al*., 1995) and transportation (Maalouf *et al*., 2006). These applications desired to use high performance robot with good communication. In this work we will show the wireless communication system of ($2n+2/0\leq n\leq 3$) wheels mobile rover by using Bluetooth, (DSP) and (FPGA). This project is included under lunar car research in planetary exploration. Communication between the rover and the programmer is important such us wireless communication using antenna or radio waves.

In recent years the wireless communication systems have developed very fast where the transmission power can have significant system costs given the life of the robots. Wireless Ethernet is far more energy consuming and is 34 times expensive than radio waves but its natural medium for communication between mobile robots. Minimizing the transmission time can save power for other useful work. Robots typically act in strict real time constraints of fast navigation and rapidly changing environments that require the control input to be acquired on a regular basis to the agent. Communication therefore has the implications of the controllers, robustness, efficiency and capability. The communication should be as efficient as possible, to save power and reduce the latency (Agah *et al*., 2002).

In related work several methods of communication have been developed within this new medium. The wheels mobile rovers have different communication methods such us the two wheels rover Super Mario (De Luca *et al*., 2001) communication based on PC communicates through a radio modem with serial communication boards on the robot. The maximum speed of the radio link is 4800 bit sec^{-1} and wheel angular velocity commands ωL and ωR are sent to the robot and encoder measures $\Delta\varphi L$ and $\Delta\varphi R$ are received for odometric computations.

The four wheels rover Pioneer AT-3 (Maalouf *et al*., 2006) can be controlled either by an onboard computer or by a computer through a wireless serial or TCP/IP connection. All the information from the onboard sensors such as the encoders, sonar and gyroscope can be obtained through this connection and the reference linear and rotational speeds are sent through ARIA. By using computer system consisting of four microcontrollers can communicate with Zaurus (Sato and Ishii, 2005) to control it. The 8 wheels and rover Lunokhod had two speeds, ~1 km h^{-1} and ~2 km h^{-1}. Lunokhod was equipped with four TV cameras, three of them panoramic cameras. The fourth was mounted high on the rover for navigation and could return high resolution images at different rates (3.2, 5.7, 10.9 or 21.1 sec per frame). These images were used by a five-man team of controllers on Earth who sent driving commands to the rover in real time. Communications were through a cone-shaped omni-

Corresponding Author: Amel Zerigui, School of Mechanical Engineering, Harbin Institute of Technology, Harbin, Heilongjiang 150001, China Tel: + 86 13242018854

antenna and a highly directional helical antenna (Schilling and Jungius, 1996; Zerigui *et al*., 2007).

In this research, we will use the wireless communication by using Bluetooth in the common system which is the control system of 2, 4, 6, 8 wheels mobile rovers, where the same hardware and software is used in all the subsystems. The main component playing the critical role of communication in the hardware is digital signal processor TMS320LF2407 DSP from Texas Instruments which is the responsible link between (FPGA) and Bluetooth.

In this study, we will explain the communication of (2 n+2/0≤n≤3) wheels mobile rover which is 2, 4, 6, 8 wheels mobile rover, where each rover considered as a subsystem in the common system. We try to design a communication circuit that can be used in all the subsystems. We want to show the difference between the rovers after and before communication, where the value of the data in FPGA will change from situation to other. The principal of all the subsystems is same but the difference will be in the FPGA where we are interested.

COMMON HARDWARE DESIGN FOR (2 n+2/0≤n≤3) WHEELS MOBILE ROVER

The main components need to be controlled in (2 n+2/0≤n≤3) wheels mobile rover is DC motors where the number of DC motors are changed from rover to other which are 2 in two wheels rover, 4 in four wheels rover, 6 in 6 wheels rover and finally 8 in 8 wheels rover. This means each wheel will be independently driven by one electrical motor. These motors are controlled by FPGA which is connected with almost all the components in the hardware such as A/D converter, D/A converters. Also FPGA is connected with TMS320LF2407 DSP chip where it plays the communication role in the system by connecting with Bluetooth module which has wireless communication with Bluetooth adapter in computer. For that we can divide the electrical board into two main parts the first one is for control part which includes FPGA and its peripheral components, the second is for communication part which includes DSP and Bluetooth. In fact the hardware of (2 n+2/0≤n≤3) wheels mobile rover is common hardware for four wheel mobile robots hardware, which are the hardware for 2 wheels rover, 4 wheels rover, 6 wheels rover and 8 wheels rover. Our main aim is to combine all these subsystems in same control system and same hardware, where we reduce the number of components and obtain an electrical board or hardware with low cost and high performance. The main component in the hardware is a Field Programmable Gate Array FPGA which is a digital integrated circuit that can be programmed to do any type of digital function (Pooranil *et al*., 2005). FPGA has lot of advantages such as the design can be programmed into the FPGA and tested immediately, the same FPGA can be used in several different designs and there are excellent prototyping vehicles (Wolf, 2005). FPGA is programmed using support software and a download cable which is byte blaster connected to the computer. All the components in the board are connected to the FPGA. In our design we used FLEX EPF10K10 which is 144 TQFP package, has 10000 logic gates. FLEX EPF10K10 is an SRAM-based technology and therefore loses their configuration when power is shut down and must be reprogrammed when restarted that means once they are programmed, they can be disconnected from the computer and will retain their functionality until the power is removed from the chip. The FPGA can be programmed while they run, because they can be reprogrammable in the order of microseconds (Wolf, 2005).

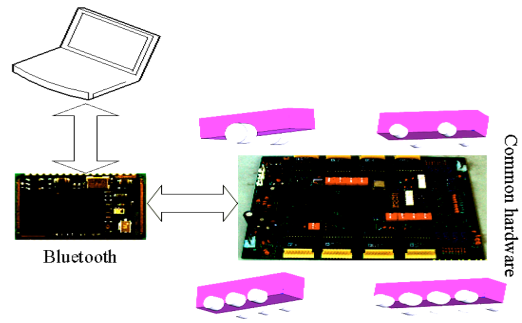

Fig. 1: The common hardware of the system

As we discussed earlier the components responsible for communication is DSP which is an analog device, TMS320LF2407 DSP chip is Texas instrument (Texas Instruments incorporated, 2005) witch run with 20 MHZ. The DSP has link ports that can be used to provide a direct path to other hardware but in our design TMS320LF2407 DSP is connected with the communication circuit and the FPGA. Figure 1 shows the common hardware of (2n+2/0≤n≤3) wheels mobile rover.

COMMON SOFTWARE DESIGN OF (2 n+2/0≤n≤3) WHEELS MOBILE ROVER

Common software overview: The control system of (2n+2/0≤n≤3) wheels mobile rover is based on FPGA and DSP chip. The software design is divided into three parts, the first one is by using VHDL language downloaded in FPGA where complete manual control by using this program is provided for the rover's four control signals:

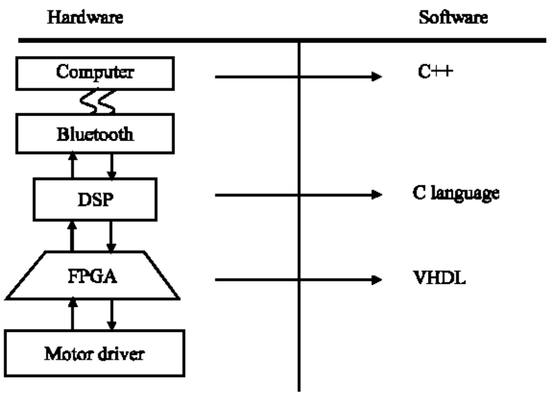

Fig. 2: Overall structure of the hardware and software

forward, backward, left and right (Fig. 2). C++language is used to build the software where we receive and send the data from and to computer. Finally C language is used to write the communication program between DSP and Bluetooth and the communication between DSP and FPGA. We will show and explain the last algorithm in this study.

The communication used in the common software: Using wireless communication is the most useful method of wheels mobile rover. A wireless communication system has a number of advantages, not just least the mobility of the devices within the environment. It is a simple matter to relocate a communicating device and no additional cost of rewiring and excessive downtime is associated with such a move. It is also a simple matter to add or remove a communication device from the system without any disruption to the remainder of the system. Other than the initial outlay on setting up the cell sites, the cost of running and maintaining a radio based communications solution is minimal. These and other factors, show the appeal that a radio communication system has for the office environment. In this design we use JBM-100SPP Bluetooth module with UART interface with programmable baud rate, the distance rate of this module is 10 m for experiment.

FSM of (2 n+2/0≤n≤3) wheels mobile rover communication: The main components responsible for communication are Bluetooth, DSP. We can also say FPGA is one of these components because it is the interconnection between the rover and the communication circuit other than these components also have computer. When the system will be in rest situation then there is no transmitting or receiving of data [SCIRXD = 0, SCITXD = 0] between the rover and computer as shown in Fig. 3 where we explain the finite state machine of the wireless communication circuit of (2n+2/0≤n≤3) wheels mobile rover. The DSP chip receives the desired direction

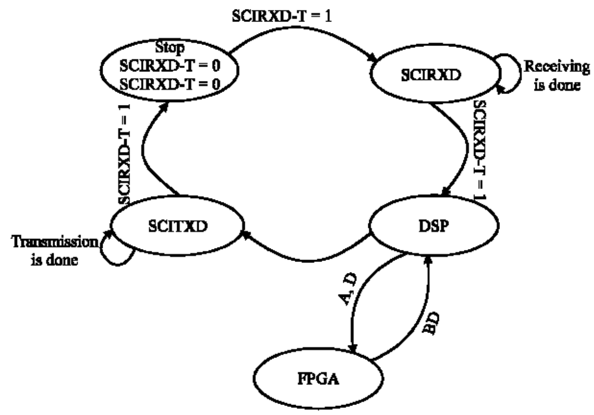

Fig. 3: Wireless communication finite state machine

information where it gives it to the FPGA through data bus and address bus, then when the rover moves to a new position and with a new speed will send this information via motor driver and D/A converter to FPGA. Then FPGA send this information to DSP through BD as shown in Fig. 3, the DSP will transmit this information to Bluetooth, then we will receive the new data in computer.

(2 n+2/0≤n≤3) wheels mobile rover communication flow chart: The communication algorithm chart based only on Bluetooth, DSP and FPGA which are the components responsible for communication. When we use the desired position from Pentium 4 computer through Bluetooth adaptor to the Bluetooth module in the board, here the distance of experiment should be less or equal to 10 m which is related to Bluetooth preferences. Then DSP will receive the desired data and send it to the FPGA. The field programming field get array (FPGA) send this data to the rover through AD converters, then the rover will move. The rover will be in new position will send new data via D/A converter to the FPGA and come back to computer through DSP and Bluetooth. This process is shown in Fig. 4 in the flow chart.

Communication between DSP and FPGA: In the Hardware design the communication between the DSP and FPGA is accomplished by using 74AC16245DL chip because their powers are different (5V and 3.3V). The communication of DSP and FPGA for (2 n+2/0≤n≤3) wheels mobile rover is same for all the rovers presented in 2, 4, 6, 8 wheels mobile rover but the control system in the FPGA is different, Table 1 presents the test results for the number of the I/O, total memory, Registers and LABs in the FPGA after and before the communication.

The number of I/O for all the rovers is not the same, where all the pins are equal in same situation after or before communication for each rover. For that the I/O before communication is same for all rovers and also same

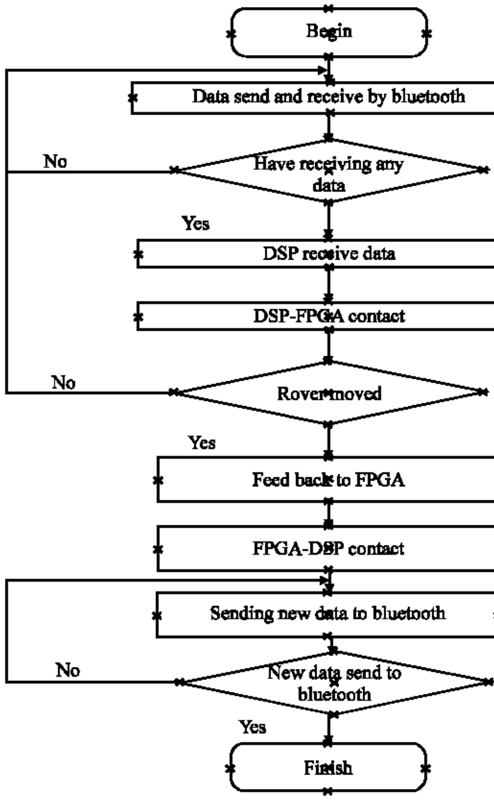

Fig. 4: Communication flow chart

Table 1: FPGA Test Results value after and before communication

FPGA test results	2 wheels rover (%)	4 wheels rover (%)	6 wheels rover (%)	8 wheels rover (%)
I/O before communication	43.26	43.26	43.26	43.26
I/O after communication	46.53	46.53	46.53	46.53
Total memory before communication	3.25	6.50	9.76	16.27
Total memory after communication	6.51	9.76	13.02	19.53
Registers before communication	3.47	6.94	8.68	13.88
Registers after communication	6.94	10.41	12.15	17.36
LABs before communication	8.33	16.66	27.77	41.66
LABs after communication	13.88	19.44	29.16	47.22

for all the rovers after communication, but the result are different for I/O after and before communication from rover to other. The total memory bits numbers after and before the communication for the entire wheels mobile rover are deferent. It increases with the wheels mobile rovers. And the number of registers for all the rovers after and before communication is unequal. Also we find the difference for LAB after and before communication between all the rovers.

CONCLUSION

In this study, the communication principal of (2 n+2/0≤n≤3) wheels mobile rovers has been presented. The hardware of the common control system has been described. Then the software of the communication system has been explained. The experimental results for the communication of (2n+2/0≤n≤3) wheels mobile rovers has been described, where we showed the differences between rovers hardware concern FPGA in I/O pins, Total memory bits used, Registers and LABs before and after the communication.

ACKNOWLEDGMENT

This work is partially supported by “The 111 Project” (B07018).

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