Web Robot Learning Powered By Bluetooth Communication System

Seref SAGIROGLU[1] Nihat YILMAZ[2] M. Arif WANI[3]
[1] Department of Computer Engineering, Faculty of Engineering-Architecture,
Gazi University, Ankara, TURKIYE
ss@gazi.edu.tr
[2] Department of Electrical - Electronics Engineering, Faculty of Engineering-Architecture, Selcuk University,
Konya, TURKIYE
nyilmaz@selcuk.edu.tr
[3] California State University at Bakersfield, School of Natural Sciences and Mathematics, Department of Computer Science, Bakersfield, USA
awani@csub.edu

Abstract

This paper presents a web robot web-robot learning powered by Bluetooth communication system. The web-robot system is used as the virtual robot laboratory integrating a number of disciplines in engineering. This virtual laboratory is a valuable teaching tool for engineering education used at any time and from any location through Internet. The mobile robot was controlled with robot server named as control center. The server can be connected to mobile robot via Bluetooth adapter. The mobile robot system focuses on vision sensing. Real time image processing techniques are realized by the web robot system. This system can also realize monitoring, tele-controlling, parameter adjusting and reprogramming through Internet exclusively with a standard Web browser without the need of any additional software.

Keywords: Web-robot, Learning, Bluetooth, Tele-operation, Artificial neural network, Vision sensing.

1. Introduction

Recent web technologies change traditional approaches, strategies and challenges in education. In those, remote experiments have been mostly achieved [1-6]. Remote and web-based laboratories are literally exploding new techniques and approaches increasingly adopted for education. The first generation of web-based robot laboratories, named as tele-robot is mainly based on manipulators (robotic arms) or simple mobile robots that are directly controlled by human operators while second generation of web-based robot laboratories was dealt with uncertain environment and autonomic activities [3-6].

The key features of the second generation of web based robotic laboratories are their adjustable or programmable structures, which enable them to be used for educational and scientific purposes in the real-world environments [4]. The mobile robots used in second generation robot laboratories have been equipped with touch sensors, range meter sensors, proximity sensors, contrast sensors, cameras, and sound synthesizer for realizing activities automatically. Thus, the information provided from sensors can be used to monitor results or provides feed-back for control or other purposes. The cameras are used for monitoring robot behaviors. But, direct use of camera for robot motion control is seldom at web-based laboratories. The reasons are that vision based web-robot applications require real-time control and image processing, need high bandwidths to transfer raw or processed images to the user platform, might cause delay in operation and require human operator [4-10].

Using more equipment in robotic applications requires large bandwidth and faster wireless communication for short ranges, but available techniques could not meet the requirements [11-13]. Bluetooth technology has provided best wireless communication for short range. Importance of the autonomous mobile robots increase more and more and controlling via wireless technologies or to be in communication of developed robots gets big advantages for us [13-15].

Bluetooth technologies, IrDA and Wi-Fi (wireless fidelity), might be used in our design but they have some disadvantages. IrDA is an optical and directional method and it does not support robotic technology well because of inevitability of the exact sight infrared ports among each other and notwithstanding sensitive tune difficulty and shortness of the communication distance. Although Wi-Fi has a wider communication area and high date rate as 11Mb/sec, it has a greater power consumption and cost then Bluetooth. Bluetooth and Wi-Fi have been used for different Wi-Fi LAN components have been recently used in a mobile robot application [8-10].

In this study, a multi-purpose web-robot platform was designed and implemented for a number of real-time experiments were presented. The platform consists of a mobile robot system, control center and an online library to support real-time monitoring, tele-controlling, adjustments and reprogramming through a standard web browser without any need for additional software to provide a number of real-time experiments.

In the following sections, the structure of web-based mobile robot, the details of the microcontroller programming through internet, an experimental study related with microcontroller programming were introduced. Finally, the experimental results were presented and the work was concluded.

2. Bluetooth for Robot Communication

Ericsson Mobile Communications was developed, adopted in a short time and presented to the users for wireless applications. It has been designated as a system to employ in the short range communications. Bluetooth technology can be applied to many devices require short range usage and low power consumption [14]. Among the connected devices, there is line of sight obligation so it provides comfort usage [15].

The best advantage of Bluetooth is that could support every kind of data. Connection could be established from 10m to 100m. Class1, Class2, Class3 samples give range alternatives depending and the power consumptions. Class 3 has the lowest power consumption so it gives the shortest connection range. Bluetooth uses the unlicensed ISM (industrial, scientific, medical) band between 2.4GHz and 2.48GHz. Data communications as asymmetric and symmetric were 723.2kbit/s and 433.9 kbit/s for each channel, respectively. At the same time, 3 numbers of voice channel which has 64kbit/s data rate or one synchronous voice and one asynchronous data channel have been supported. The channels supporting processes have been divided in to 79 channels at 1MHz intervals. There is a pseudorandom hopping among 1MHz channels in 625 micro second slots. This time slots are numbered according to the master's clock hopping. At the end of the 625 micro seconds hopping, the device hops to a different 1MHz channel.

In an established Bluetooth connection, there are connection points as called master and slave. Master is the device that starts and manages the connection. In such example the other devices which are synchronized to the master connections are slaves. Bluetooth devices connect each other in three ways. First way is point to point connection named as SCO link. This occurs between two devices. Maximum 7 slave devices can be connected to master device at the same time. This is piconet as second one. Piconets can be connected to each other and this is third one as called Scarternet. A master in a piconet can be slave in another piconet. In piconet links, situation of the slaves as active/passive are changes in a sequence so 255 slave connections is implementing. Sequence is a little time. A device can be active in 2ms. In the passive, slaves are not limited.[16]

Data transfers of the slaves are realized in control of the master. Slaves have to be synchronized with the master during the transfer. When the piconet is set up, master address information and clock information have been sent to the all other slaves. Address and clock information of slaves synchronized with the masters.

3. Web Based Mobile Robot: SUNAR-2

SUNAR-2 was especially designed for web-based distance control for various applications and its extension of SUNAR-1 [8-10]. The robot system consists of control center and mobile robot. The control center handles the controlling and internet connection of the mobile robot through Bluetooth connection. There are a powerful PC, a Bluetooth module, a wireless camera receiver and video capture device on Control Center. The mobile robot consists of microcontrollers, a wireless camera system, a Bluetooth adapter, motors and motor drives for movements of vehicle and camera, and speed sensors for calculating the position of it. The robot is a three-wheeled robot. Rear wheels are free. Front wheel steers and drives the mobile robot. For the simplicity and the cost concern, all body of SUNAR-2 is constructed from PVC (Polyvinylchloride) and polyethylene materials.

Two microcontrollers (PIC16F877) were used in hardware implementation. The block diagram of SUNAR-2 was illustrated in Fig.1. The slave microcontroller controls camera system, motors and sensors. It provides communication with master microcontroller via I^2C serial bus. Master microcomputer manages vehicle motion control, communication with portable PC and slave microcontroller. The master microcontroller is connected to portable PC via RS232 port. In addition, four DC motors with gearbox, four optical tachometers coupled to the dc motors, four H-bridges for DC motor driving and two LCDs are used for this implementation. The control center manages all activities in the robot vehicle.

Detailed information about the vehicle motion system, the camera system and communication system and control center are given in following sections sequentially.

3.1. Hardware of SUNAR-2

Hardware of SUNAR-2 consists of vehicle motion control, camera motion control, and communication system and control center. Positioning of SUNAR-2 is calculated by the master microcontroller using the kinematics equations in [8].

Three types of communications have been achieved among the control center-Bluetooth module, Bluetooth module-master microcontroller, and master-slave microcontroller. The first communication between control center and master microcontroller is realized in wireless by using Bluetooth module. Communication range is 100 m by Class-1 Bluetooth device. The second communication between the Bluetooth module on robot and the master microcontroller is provided through RS232 port in the form of Modbus ASCII, 38400 Baud, 8 bit and odd parity. Finally, communication between master and slave microcontroller is enabled through I^2C serial port.

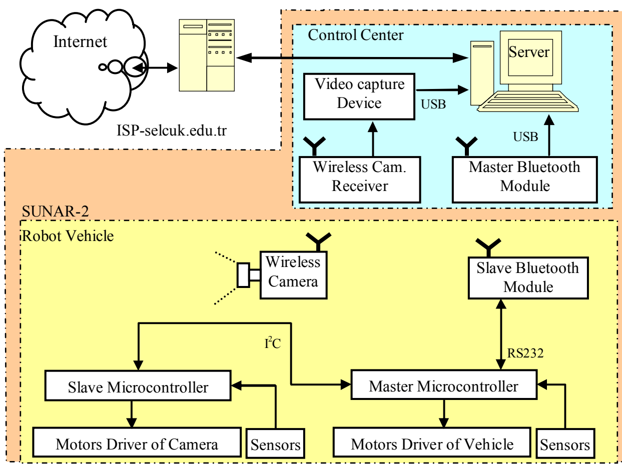


Figure 1. Block diagram of SUNAR-2 presented in this work

We used the F2M03C1 on the robot as the Bluetooth module produced by Free2Move. This module is a Class 1 Bluetooth device; surface mountable in an automatic mounting line or manually for prototyping. It provides a fully Bluetooth compliant device for data and voice communications. The interfaces to a host (UART and USB) support full Bluetooth data rate of 723.2kbps. A 13-bit PCM, 8K samples/sec, synchronous bidirectional audio interface is available. Digital and analog I/O and I^2C interfaces are supported by the module [16].

The module is available with a number of different firmware versions: The Wireless UART firmware implements the Serial Port Profile (SPP) with an easy to use command interface. All information sent to the serial interface is transmitted transparently via Bluetooth to the connected remote device. Other firmware versions are: Headset, HID, HCI, RFCOMM and the possibility to get customized standalone applications implemented as an on chip solution [14].

In the control center we used the Class1 Bluetooth dongle of the Toshiba Billionton.

The control center consists of a powerful PC compatible with IBM, a control program running on this computer and communication units. The specification of the computer is Intel Pentium IV 3.0 GHz microprocessor, 1 GB RAM, 120 GB HDD. The control center mainly realizes the following six functions: web server, program interpreter and video server, tele-control, communication and determining of vehicle position, vision based autonomous or semi-autonomous robot control, and application development.

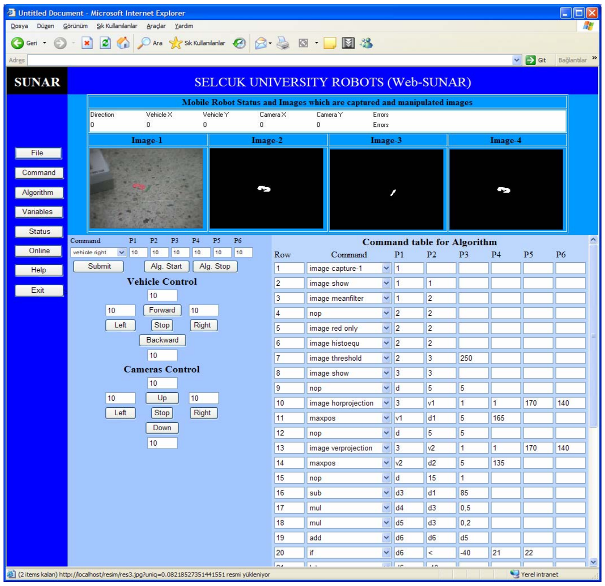
3.2. Software Developed

In this study, the developed software consists of three programming parts including microcontrollers, control center, and the web interface. The microcontrollers were programmed using MPLAB assembler programming. Programming the web application was based on PHP for database and JavaScript for timing and refreshing functions. Delphi was used for the control center. The image capturing and the serial communication were done via the third party component. The screenshots for the control center and web interface were given in Fig. 2.

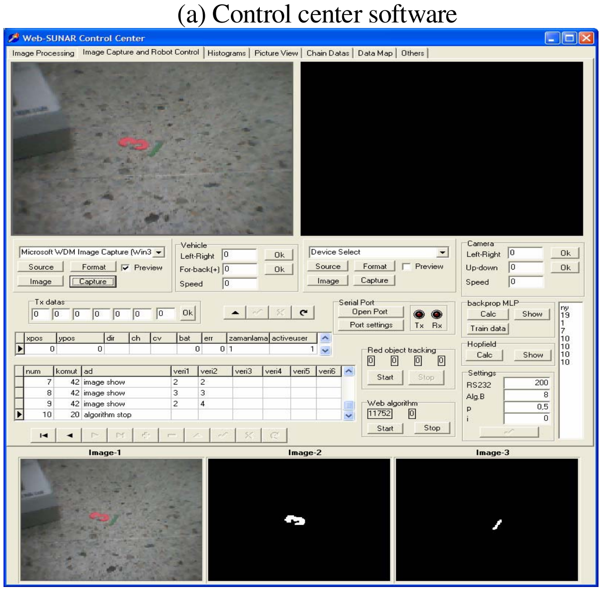
SUNAR-2 mainly consisted of two parts as shown in Fig. 1. Important controls were achieved in the control center. So there had been heavy communication between master microcontroller and control center. The control center helped to achieve simple and complex tasks. Simple tasks were to turn right or left, to move backward or forward, to adjust speed of camera and vehicle motions. All commands for the tasks were firstly stored to the system database and then executed. This reduces the process time and consequently simplified the simultaneous execution of several tasks. While one task continues the other starts so enough time is required to distinguish the tasks. Status of tasks is also stored to the database. It needs to be emphasized that all complex tasks are realized by the control center.

The program menu for the control center consisted of the database, the status of UDP port, the serial port controls, the image capturing, the speed control of camera and the vehicle for manual usage, the calculated positions for the camera and the vehicle. In addition, two menu buttons ("Option", "Image Processing") also develop and included on the control center program. "Image Processing" menu was used for the image processing covering the filtering, segmentation, moment functions and recognition for the vision system. "Option" menu provides a smooth control and communication utility covering the parameters

The web interface provides manual optional controls for the database, the captured images, the speed control of camera and the robot vehicle, the commands of semi-autonomous usage and the vehicle positions.



(a) Control center software



(b) Web interface

Figure 2. Screenshots from the software developed.

4. Web Robot Learning

Web robot learning for object recognition is based on artificial neural networks. Images were first captured by the camera on the mobile robot and processed for the required tasks. In this study, the task is to search landmarks. For doing that images were preprocessed and applied to ANNs. The preprocess was achieved after finding the landmarks roughly. Preprocessing consisted of median filter and histogram equalizations. Thus, the preprocessed image was ready for feature extraction process. There were a number of alternatives for feature extraction processes consisting of image raw data, histogram, projections and statistical properties of these. In this paper, invariant moment values of image raw data were used. These values were calculated using moments, central and normalized central moments values, as given in Eqns. (1)-(5) [17]. The moment values of an image can be calculated from

$$m_{i,j} = \sum_{x=0}^{m}\sum_{y=0}^{n} x^i y^j P(x,y) \tag{1}$$

where *P(x,y)* is the brightness values of image at x and y coordinates. Central moment values of an image can be computed as

$$\mu_{i,j} = \sum_{x=0}^{m}\sum_{y=0}^{n} (x-c_x)^i (y-c_y)^j P(x,y) \tag{2}$$

where c_x and c_y are coordinates of gravity center of image and they are computed as

$$c_x = \frac{m_{1,0}}{m_{0,0}} \qquad c_y = \frac{m_{0,1}}{m_{0,0}} \tag{3}$$

The normalized central moment values can be also obtained from

$$\eta_{i,j} = \frac{\mu_{i,j}}{\mu_{0,0}^{\gamma}} \tag{4}$$

where γ is $\gamma = (i+j)/2+1$. Other seven invariant moment values were derived from Eqns (1)-(4) as shown in Eqns (5)-(11).

$$\varphi_1 = \eta_{2,0} + \eta_{0,2} \tag{5}$$

$$\varphi_2 = (\eta_{2,0} - \eta_{0,2})^2 + 4\eta_{1,1}^2 \tag{6}$$

$$\varphi_3 = (\eta_{3,0} - 3\eta_{1,2})^2 + (3\eta_{2,1} - \eta_{0,3})^2 \tag{7}$$

$$\varphi_4 = (\eta_{3,0} - \eta_{1,2})^2 + (\eta_{2,1} - \eta_{0,3})^2 \tag{8}$$

$$\begin{aligned}\varphi_5 = {} & (\eta_{3,0} - 3\eta_{1,2})(\eta_{3,0} + \eta_{1,2})\left[(\eta_{3,0} + \eta_{1,2})^2 - 3(\eta_{2,1} + \eta_{0,3})^2\right] \\ & + (3\eta_{2,1} - \eta_{0,3})(\eta_{2,1} + \eta_{0,3})\left[3(\eta_{3,0} + \eta_{1,2})^2 - (\eta_{2,1} + \eta_{0,3})^2\right]\end{aligned} \tag{9}$$

$$\begin{aligned}\varphi_6 = {} & (\eta_{2,0} - \eta_{0,2})\left[(\eta_{3,0} + \eta_{1,2})^2 - (\eta_{2,1} + \eta_{0,3})^2\right] \\ & + 4\eta_{1,1}(\eta_{3,0} - \eta_{1,2})(\eta_{2,1} + \eta_{0,3})\end{aligned} \tag{10}$$

$$\begin{aligned}\varphi_7 = {} & (3\eta_{1,2} - \eta_{3,0})(\eta_{3,0} + \eta_{1,2})\left[(\eta_{3,0} + \eta_{1,2})^2 - 3(\eta_{2,1} + \eta_{0,3})^2\right] \\ & + (3\eta_{2,1} - \eta_{0,3})(\eta_{2,1} + \eta_{0,3})\left[3(\eta_{3,0} + \eta_{1,2})^2 - (\eta_{2,1} + \eta_{0,3})^2\right]\end{aligned} \tag{11}$$

Seven features extracted for red, green and blue colors using invariant moment equations were used as inputs to neural network for training to achieve the task.

The backpropagation with momentum [18] learning algorithm was used in this work because of being most commonly adopted ANN training algorithm. It is a gradient descent algorithm and gives the change $\Delta w_{ji}(k)$ in the weight of a connection between neurons *i* and *j* as follow:

$$\Delta w_{ji}(k) = \alpha \delta_j x_i + \mu \Delta w_{ji}(k-1) \tag{12}$$

where x_i is the input, α is the learning coefficient, μ is the momentum coefficient, and δ_j is a factor depending on whether neuron *j* is an output neuron or a hidden neuron [18].

Proceedings of the 5th International Conference on Machine Learning and Applications (ICMLA'06)
0-7695-2735-3/06 $20.00 © 2006 IEEE

Afore mentioned the platform presented in this work has a neural network library to be used for different applications such as identification, recognition, classification or analysis. ANN structures were supported within this library. The web users can use this neural library on their robotic, control, programming and image processing applications. Training and test processes in ANNs and their parameters can be set on the web menu provided. All ANN parameters can be selected or adjusted according to the user requirements. For a real time web robot application, the trained neural network parameters can be uploaded to the web server. It is then used for the application.

Generally, the input data sources to the ANN might be images or features extracted from the captured images. The images were pre-processed with the help of functions in image processing library, which were designed for SUNAR-2 and introduced in [8-10].

5. Experimental Results

In order to show functionality of SUNAR-2, three different tests (Test #1, Test #2 and Test #3) were introduced. Test #1 involves two different experiment sets. The first set deals with the recognition of the objects in different color and sizes. The other set was used to test the mobile robot if it passes the obstacle without any difficulty or crash. For this purpose, the position information of the boxes in Figure 7a was estimated from the images acquired from the web camera and the robot can move from one position to the target position smoothly.

The mobile robot could also achieve any movement without touching the objects to reach the target correctly even if the locations of the objects were moved during the operations. During test processes, color-based image pre-processing, moment-based feature extraction and multilayered perceptron ANN were used for this experiment. Furthermore, pattern analysis based terrain characterization (visual sensing) for the obstacle avoidance step and 20x20 sized array with the calculated object and robot positions for mapping were performed.

In Test #2, the image data for flowers were stored to the platform at given time intervals to be used for different applications. For this purpose, the flowers were initially identified and the positions of each flower (the positions of the flowerpots) were determined. This test was shown in Figure 3b while the mobile robot was in operation. The images of each plant (flower) were stored to the platform disk. The camera positions and time to take the pictures were determined by the operator. In the recognition algorithms used to estimate position and to make corrections, similar to Test #1, color-based image pre-processing, moment-based feature extraction and multilayered perceptron ANN for last processes were used.

In the last test (Test #3), the line tracking capability of the mobile robot was examined. In order to achieve an observation route or a path was considered and painted on the ground with red line. During this test, SUNAR-2 was expected to follow the line with minimum error as illustrated in Figure 3c. The real-time images of the line were captured by the camera and the position and orientation of the line was then estimated from processed images. According to this estimation, a control signal was achieved. It was then used as input to the position control algorithm to keep the robot in the route. From the experiments presented in this work, it was observed that the robot could follow the line or path accurately.

(a) Test #1 (b) Test #2 (c) Test #3

Figure 3. Test scenarios for SUNAR-2

6. Results and Conclusions

In this work, the mobile robot system SUNAR-2 for web robot learning applications was designed and successfully implemented as shown in Figs. 1 and 3 As explained earlier, SUNAR-2 platform was especially designed for multi-functional tasks. The results have shown that the web platform presented in this work can be used for various tasks successfully for web robot learning..

The results have also depicted that the real-time examples presented in this work were well-suited for distance education applications in engineering courses like image processing, robotics and programming. Implementing these real-time tasks to distance education and real-time experiments emphasizes the significance of this work.

Making use of the designed and developed control center, faster communication was attained by using TCP/IP protocol over web and UDP protocol over LAN. The autonomous structure of the robot reduces the intensity of communication between control center and operators and that makes it possible to realize low-cost real-time applications.

As a result, a multi-purpose web-based semi-autonomous mobile robot system has been successfully designed, developed and tested for four real-time experiments or scenarios. The obtained test results show that web-based mobile robot platform can be effectively used in multi-purpose applications.

The significance of this work is to present new concepts to remote (distance) education. This real-time distance learning support would help students and researchers to do their practices, applications and homework in using up-to-date technologies at their places. Another significance of this work was to support a number of real-time applications. These applications might be used for engineering education courses such as image processing, automatic control, algorithms, robotics, pattern recognition, programming, and artificial intelligence. The platform might be also used in other real-time remote laboratory exercises and R&D activities to develop new real-time applications.

The principal difficulties faced in this work in realization of this web platform were the integration of various hardware and software components into one design environment, transferring images to the platform and processing them in short time, and controlling many components and peripherals remotely.

7. References

1. H. Asoh, Y. Motomura, F. Asano, I. Hara, S. Hayamizu, K. Itou, T. Kurita, T. Matsui, N. Vlassis, T. Bunschoten, and B. Krose, "Jijo-2: An Office Robot that Communicates and Learns" Intelligent Systems, IEEE, Vol.16 (Sept./Oct. 2001) pp.46-55.
2. J. B. Park, B. H. Lee, and M.S. Kim "Remote Control of a Mobile Robot Using Distance-Based Force" Proceedings of the 2003 IEEE International Conference on Robotics & Automation, Vol.3, Taipei, Taiwan (14-19 Sept. 2003) pp.3415-3418.
3. K. J. Schilling, and M. P. Vernet "Remotely Controlled Experiments with Mobile Robots, System Theory" 2002. Proceedings of 24th Southeastern Symposium, (18-19 March 2002) pp.71-74.
4. K. Matsumaru, A. Fhjimori, T. Kotoku, and K. Komoriya "Action Strategy for Remote Operation of Mobile Robot in Human Coexistence Environment" Industrial Electronics Society, 2000. IECON 2000. 26th Annual Conference of the IEEE, Vol.1, Nagoya Japan, (22-28 Oct. 2000) pp.1-6.
5. S. Vitabile, G. Pilato, F. Pullara, and F. Sorbello "A Navigation System for Vision-Guided Mobile Robots" Image Analysis and Processing, 1999. Proceedings. International Conference, Venice Italy (27-29 Sept.1999) pp.566-571.
6. R.. C. Luo, and T. M. Chen "Development of a Multibehaviour-based Mobile Robot for Remote Supervisory Control through the Internet" IEEE/ASME Transaction on Mechatronics, Vol.5 (Dec. 2000) pp.376-385.
7. K. J. Yoon, and I. S. Kweon "Artificial Landmark Tracking Based on the Color Histogram" Proceedings on Int. Conf. on Intelligent Robot and Systems, Msui Hawaii USA (29 Oct.-03 Nov 2001) pp.1918-1923.
8. Yilmaz, N. *Design, Realization And Applications Of A Web-Based Mobile Robot System*, PhD Thesis, Selcuk University, Institute of Natural and Applied Sciences, Konya, Turkey, 2005 (in Turkish).
9. N. Yilmaz, S. Sagiroglu, and Bayrak, M. "A Web Based Semi-Autonomous Mobile Robot: SUNAR", TAINN'2005, Cesme, Izmir, Turkey (16-17 June 2005), pp.410-417.
10. S. Sagiroglu, N. Yilmaz, and Bayrak, M. "Design and Implementation of A Web Based Mobile Robot" Virtual International Conference on Intelligent Production Machines and Systems, Wales, UK, July 2005, pp. 4-15.
11. S. H. Choo, S. H. M. Amin, N. Fisal, and C. F. Yeong "Multiple Mobile Robots communication Using Bluetooth Transceiver" Second International Conference on Artificial Intelligence in Engineering and Technology, August 2004, Sabah, Malaysia, pp.610-616.
12. C. F. Yeong, S. H. M. Amin, N. Fisal, and J. A. Baka "Bluetooth Enabled Mobile Robot" Int. Conf. on Industrial Technology, Vol.2, Dec.2002, pp.903-908.
13. Bray, J. and Sturman, C. F. *Bluetooth Communication Without Cables* 2nd Ed., Prentice-Hall, Upper Saddle River, NJ, 2001.
14. http://www.palowireless.com/infotooth/tutorial.
15. http://www.bluetooth.com
16. http://www.freetomove.com/fm203
17. A. Kadyrov, and M. Petrou "Object Descriptors Invariant to Affine Distortions", BMVC 2001, University of Manchester, UK., 2001, pp.391-400.
18. Haykin, S.: *Neural Networks: A Comprehensive Foundation*, New York, Macmillan College Publishing Company, ISBN 0-02-352761-7, 1994.