VitalBot

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II. Table of Contents

III. Abstract

VitalBot is a rugged mobile robot for indoor and outdoor terrain. It is integrated with a vital signs sensing system capable of detecting a human's heartbeat and it is designed for search-and-rescue missions. VitalBot is capable of exploring a certain area and uses radar from the vital signs system to detect human presence. It is able to avoid obstacles and communicates with an operational base station (laptop computer) using dual Xbee boards. The base station receives data from the vital signs system, uses the data to determine whether a human has been detected, and transmits behavioral commands to the robot. VitalBot is also equipped with a wireless web camera allowing a remote user to drive the robot from the base station using a Nintendo Wii controller.

IV. Executive Summary

To be included in final report.

V. Introduction

Imagine a portable system that can monitor a person's breathing and heart rate automatically via a wireless signal, with no need for cords or plugs, and then transmits the signal over a cell phone or internet connection. The goal is to make it easy for people to check their own vital signs, and then transmit them to medical personnel from the comfort of their homes as easily as possible. The system consists of a miniaturized Doppler radar housed inside of an iPod-sized metal box holding fingernail-sized antennas. High-frequency waves broadcast by the radar bounce off a person, scanning the in-and-out movement of the chest and the more subtle, but also detectable, motion of the heartbeat against the chest wall.

Currently, there are remaining challenges and further research work required which includes upgrading the hardware and software to enhance the system's resolution so multiple heartbeats can be detected and distinguished simultaneously, as well as improving its range and sensitivity. This technology has many other applications in the real world. For example, engineers might be able to tune it to "observe" the vibrations of a speech-impaired person's throat and then translate those vibrations into computer-produced speech. Outside the field of medicine, it is possible for law enforcement officials to use the system as a surreptitious indicator of a subject's nervousness, noting when his or her heart rate or pulse picks up in response to certain questions.

The proposed project, for the scope of this research paper, involves a multidisciplinary research platform combining the field of robotics, wireless communications, radar, and sensors. VitalBot is a mobile surveillance robot that communicates using wireless technology and navigates any given indoor or outdoor terrain. Furthermore, the robot will carry the vital signs sensing system mounted as part of its design. Given the current size of the vital signs sensing system, the integration of the technology onto any medium-sized robot is not an issue.

VI. Integrated System

The integrated system of this project consists of two units. The first unit is the medium-sized robot VitalBot and the second is a base station composed of a laptop computer. These two units communicate with each other using dual Xbee communication boards.

The VitalBot system is operated using a Mavric-IIB board from BDMicro with an Atmel ATMega128 microprocessor and is connected to an array of sensors including: sonar, bump, and the vital signs system. VitalBot also has LCD and LED feedback and is connected to multiple servos for the steering mechanism, camera pan and tilt (?), and radar antenna rotation. The Mavric-IIB board has two serial ports that are used to transmit and receive to the base station through dual Xbee boards. VitalBot has its own dual motor driver board and connects to two Maxon motors for navigation in any terrain. A webcam will also be mounted on the robot.

The Base Station consists of a laptop computer running Windows XP Pro. The computer is connected to two Xbee transceiver using USB ports and this creates an invisible wireless communication tunnel between the computer and VitalBot. An audio/video receiver for the webcam connects to an external LCD display using RCA cable connections. A LabVIEW control software interface has been developed to receive the data from the vital signs sensing system and data collected will be used to determine whether or not a human has been detected by VitalBot. LabVIEW will send commands to the robot based on the information from the vital signs system. In addition to LabVIEW, a C# program has been developed in Visual Studio Express 2005 to connect with a Nintendo Wii controller using a Bluetooth adapter and it will allow a remote user to control the robot from the base station.

A block diagram of the system will be added here.

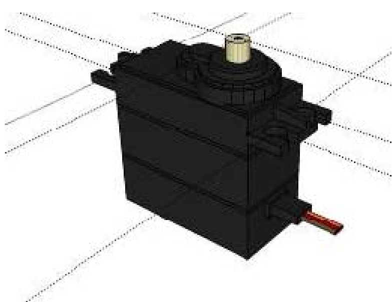
VII. Mobile Platform

Design in progress.

VIII. Actuation

A. Servo Control

The selected servo for this project is the GWS S04 Metal Gear 2x Ball Bearing Servo. The servo will be used in the rack and pinion mechanism to steer the front wheels either right or left. The servo will also support the steering and keep the wheels centered when necessary. This servo is bigger than average and is often used where torque needs are high and cost is a factor. The torque exceeds 150 oz/in and the servo is pictured here.



B. Motor Control

Choice of motors is still pending. Maxon motors are desired for the robot and a few different options are currently being explored based on power rating, price, and availability.

IX. Main Sensors

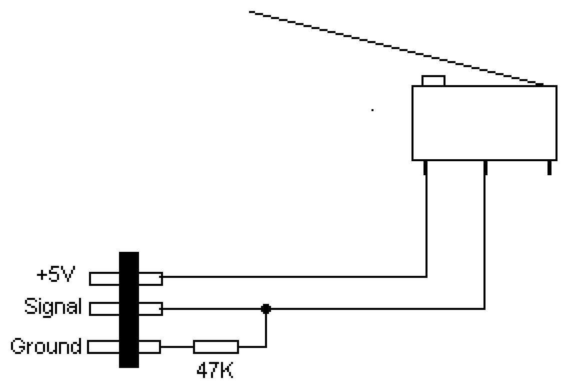
A. Overview

The world we live in is a complex place. We have many senses to help us to understand our surroundings, but in order for robots to roam around safely sensors are also required to understand their environment. The easiest way of doing this is to add simple sensors to you robot. A number of sensors are connected to the VitalBot microcontroller, ranging from an array of sonar finders, bump sensors for collisions, and a special sensor featured: a vital signs sensor. Each sensor is described in detail below.

B. Bump

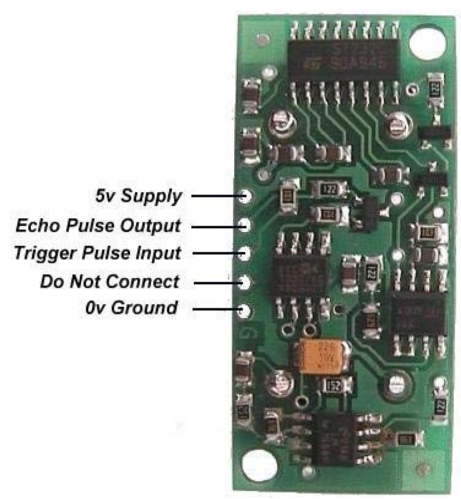
VitalBot is happily driving around but in the case it keeps colliding with obstacles and getting stuck, it will need a way to detect collisions and move around objects. Enter the bump sensor. A bump sensor is probably one of the easiest ways of letting your robot know it's collided with something. The simplest way to do this is to fix a micro switch to the front of your robot in a way so that when it collides the switch will get pushed in, making an electrical connection. Normally the switch will be held open by an internal spring. Micro switches are easy to connect to microcontrollers because they are either off or on, making them digital. Bump sensors are easily connected to the ATMega128, simply plug them into any available input/output pin.

The following diagram shows a typical circuit for a bump sensor. The resistor is important because it holds the signal line at ground while the switch is off. Without it the signal line is effectively 'floating' because there is nothing connected to it, and may cause unreliable readings as the processor tries to decide if the line is on or off.



C. Sonar

An array of Devantech SRF05 sonar range finders will be used to monitor the lateral proximity of the robot with any obstacles. The SRF05 is the low-cost successor to the extremely popular SRF04 detector. Improvements in the design and manufacturing have allowed the price to come down. Also, better features are included such as an LED status indicator that blinks when the sonar fires as well as a new single-wire mode of operation. The range has also increased to 4 meters. The SRF05 is featured here.



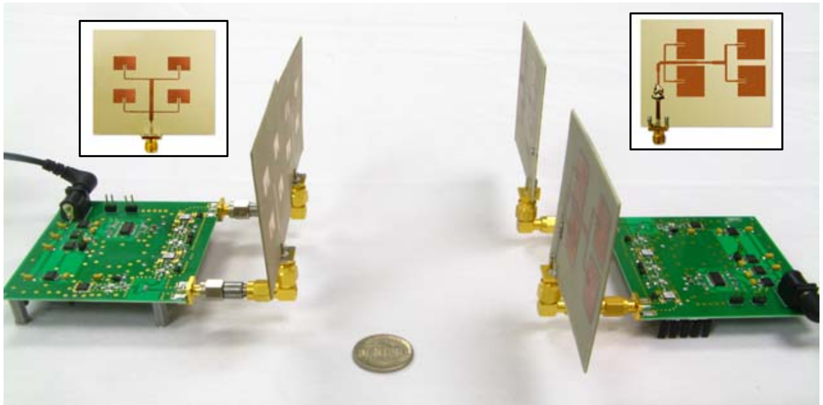
In addition to an array of SRF05 sensors, a Devantech SRF08 sonar range finder will be used for the front of the robot. The SRF08 is the smarter cousin of Devantech's popular SRF04 sonar sensor. It provides twice the sensing range of the SRF04 plus an on-board MCU which handles the critical timing functions and distance calculations. The SRF08 can report up to 17 echoes from each ping, allowing VitalBot to identify the shape of a target or identify an open doorway. Echoes can be reported as inches, centimeters or time of reflection. Its overall range is approximately 1" to 18'. The SRF08 is interfaced using an I2C bus and is featured here.

D. Vital Signs

The current system is accurate to within about nine feet, more than adequate if installed on a laptop or cell phone, or in this case, on VitalBot. The system which transmits only one microwatt of radio power adds an insignificant load to VitalBot and poses no threat to human health.

One of the applications of having the vital signs sensing system mounted as part of a mobile robot is the need for greater technology used in search-and-rescue missions. Search-and-rescue robots are already being used along with microphones and camera technology to detect possible human presence within ruins or disaster sites, such as the World Trade Center location a few years ago. The system on VitalBot creates an autonomous or remote controlled "life detector" to determine if someone is buried in rubble following an earthquake or building collapse. The current system operating in the Ka-band is able to penetrate one-inch particle boards, but concrete could be more of an impediment that lower microwave frequency will be used.

Experiments have been performed in the laboratory to verify the complex signal demodulation and the random body movement cancellation techniques. The measurements were performed by 5–6 GHz portable radars, which integrate quadrature transceivers, a two-stage baseband amplifier, and a power management circuit on a single Rogers printed circuit board (RO4350B) with a size of 6.8 cm × 7.5 cm. The amplified baseband output signals were sampled by a 12 bit multifunction data acquisition module (DAQ) and were fed into a laptop for real time signal processing by LabVIEW. The figure below shows the antennas and the identical transceivers used for experiments.



There are two identical vital signs sensors depicted in the figure above. The board requires a 6-9 volt input and the outputs are two-channel baseband analog signals, since it is quadrature detection system. The board outputs are 12-bit analog samples that will be sent to the Base Station using an A/D converter of at least two channels (or two single-channel A/D converters). The specifications for the Mavric-IIB board include a 10-bit A/D converter, instead of a 12-bit converter. Further testing is required to determine whether or not a signal is still detected using the 10-bit converter and to observe how much the accuracy / resolution of the system decreases.

X. Behaviors

A. Autonomous

The objective of the Intelligent Machines Design Laboratory course is to design, build, and demo a working autonomous robot capable of carrying out a specific task. VitalBot is a search-and-rescue robot that uses radar to detect a person's heartbeat and it will be used for search-and-rescue missions. The robot will be free to roam around any area using its sensors to avoid obstacles. Once it encounters an obstacle, it will stop and it will enable the vital signs sensing system. The vital signs data collected from the sensor is inputted into an A/D converter on the Mavric-IIB board and sent to the Base Station computer running a LabVIEW control program. The LabVIEW control software displays the data in the form of a graph on screen and determines whether or not a human has been detected by the radar due to variations in the 12-bit data stream collected. LabVIEW will then send a 'human detected' byte to the robot using one of the system's Xbee boards and VitalBot will flash its lights or turn on a siren. If LabVIEW determines a human has not been detected, it will send a 'human not detected' byte to the robot and VitalBot will continue roaming the area using its sensors until it finds a human.

B. Remote Control

The autonomous behavior of VitalBot is determined by the sensors mounted on the robot but also by the control commands and communication between the robot and the Base Station. The option of disabling the motor commands being sent from the LabVIEW program will be available and this will enable a remote user at the Base Station to drive the robot using a keyboard. In addition to driving the robot using the keyboard, the feature of driving VitalBot using a Nintendo Wii controller will be added. Microsoft Visual Studio Express 2005 was used to develop a C# program to connect to the Wiimote using a Bluetooth adapter and the accelerometer data and keys on the Wiimote will be mapped to movements of the robot.

Include table with accelerometer data and mapped keys to motor commands (bytes sent) here:

XI. Experimental Layout

To be included in final report.

XII. Conclusion

To be included in final report.

XIII. Acknowledgements

To be included in final report.

XIV. Appendices

To be included in final report.

XV. References

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XVI. Pictures

To be included in final report.