Design of Prototypic Army BOT for Landmine Detection and Control Using Hand Gestures

Ch. Katyayini, Shaik Meeravali

Abstract – ***This paper presents three different gesture recognition models which are capable of recognizing seven hand gestures, i.e., up, down, left, right, tick, circle and cross, based on the input signals from MEMS 3-axes accelerometers. The accelerations of a hand in motion in three perpendicular directions are detected by three accelerometers respectively and transmitted to a PC via Bluetooth wireless protocol. An automatic gesture segmentation algorithm is developed to identify individual gestures in a sequence. To compress data and to minimize the influence of variations resulted from gestures made by different users, a basic feature based on sign sequence of gesture acceleration is extracted. This method reduces hundreds of data values of a single gesture to a gesture code of 8 numbers. Finally the gesture is recognized by comparing the gesture code with the stored templates. Results based on 72 experiments, each containing a sequence of hand gestures (totaling 628 gestures), show that the best of the three models discussed in this paper achieves an overall recognition accuracy of 95.6%, with the correct recognition accuracy of each gesture ranging from 91% to 100%. We conclude that a recognition algorithm based on sign sequence and template matching as presented in this paper can be used for non-specific-users hand-gesture recognition without the time consuming user-training process prior to gesture recognition.***

Keywords: Gesture recognition, Interactive controller, MEMS accelerometer, Humidity sensor.

I. INTRODUCTION

Millions of landmines are still buried under the ground surface all over the world causing threats to the lives and economy of mine-affected nations. Humanitarian landmine detection and removal has become a serious global issue. In order to make this mission successful, landmine detection and removal rate should be nearly 100%. The manual landmine detection and removal is still carried out for reasons of the reliability, however it is very slow method. In addition, the detection rate is very poor and at the same time, it is very dangerous for the life of the operating personnel. Our research team has developed a robot assisted mine detection method that is safe, more accurate and faster than manual method (Nonami, K. et al. 2003). Metal detectors are considered as the most reliable sensors for mine detection work.

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However, landmine detection performance of the metal detectors is highly dependent on the distance between the sensor heads and the buried landmines. Therefore, the landmine detection performance of the metal detectors could be substantially improved if the gap and attitude of the sensor heads can be controlled. In case of robots assisted land mine detection, this function can be performed in a convenient manner where the sensor heads should accurately follow the ground surface maintaining almost uniform gap between the ground surface and the sensor heads by controlling the gap and attitude of the sensor heads. Few mine detection robots that have the capability to recognize ground surface and can control the gap and attitude of the sensor heads are reported in (Armada, M.A. et al. 2005), (Chesney, R. et al. 2002), (Nonami, K. et al. 2003). In recent years, the significance of low cost and sustainable technologies for mine detection and mine neutralization has been increasingly recognized by many organizations and universities in different countries. The current solution for removing landmines from civilian areas is the use of trained technicians who manually search for buried objects using a prodder and a metal detector. This process is rather slow (20-50 square meters per hour), dangerous, and expensive; thus, investing in a mechanized solution will be both humane and economic. Since the risk of mine clearance missions is primarily related to the lack of knowledge about the location of the mines, researchers have mostly focused on finding a mechanized solution for mine detection [1-4]. When the mines are located, neutralization may become a less hazardous procedure. Mine neutralization is outside the scope of this research. There are two methods for detecting hidden landmines: prodding and remote sensing. In prodding, a probe is gently inserted into soil to examine the existence of a buried object. Although there have been several attempts to mechanize prodding, a practical solution is still unavailable. Dawson et al., propose the use of a sharpened probe but do not describe the approach in detail [5]. Shahri et al., describe a mechatronics solution for measuring the stiffness of soil using a bayonet attached to adexterous manipulator [6]. The most recent work on this method proposes the use of a robot to insert a comblike series of ultrasonically vibrating probes into the soil [7]. The probes are in the form of hollow tubes that not only measure the stiffness of the soil but also scratch the surface of the buried objects and transfer the dust to a miniature onboard mass spectrometer to determine whether the surface is a plastic, metal, wood, or other material that can be used in landmines. Remote sensing is the other methodology in which the presence of an unexpected object on or underneath the surface is examined using sensors such as electromagnetic induction sensors (EMI)

[8-10], X ray backscatter radiography [11], ground penetrating radar (GPR) [8,10,12], infrared cameras (IR) [13], and thermal neutron analyzers. Although prodding may yield more reliable results, remote sensing is considered more appropriate for robotics applications because it is significantly faster, safer, and more attainable. Meanwhile, the reliability of remote sensing may be improved by fusing synergistic measurements of different types of detectors [8,10,14,15]. Recent advances in the development of accurate and reliable sensors for mine detection are so promising that researchers have become interested in the development of unmanned ground vehicles and robotic systems that can carry the sensors with the minimum interaction of human operators. There are different system configurations available for both handheld and vehicle-mounted sensors. Typically, the vehicles are equipped with large GPR and IR systems and a series of metal detectors to search for antitank landmines buried in roads and broad fields [16]. These are usually used in military missions to provide a safe route through minefields. On the other hand, robots are more suitable for off-road missions and antipersonnel unexploded ordnance (UXO) detection. Specifically, robots are useful for civilian mine clearance missions whose reliability must be above 99.6% as defined in the UN agenda. Manipulated by a robotic arm that is adequate in term of the degrees of freedom, one or a group of the sensors can precisely scan the terrain and provide sufficient information to determine the existence of an anomaly in the soil. Since most landmines are made of metal or at least have a piece 3 of metal (e.g., a detonator), metal detectors are commonly used to detect landmines.

A metal detector is essentially a coil that generates a pulsing electromagnetic field and measures the eddy currents induced by a metal object moving in the field [17]. The performance and reliability of a metal detector, determined by signal to noise ratio, largely depends on the distance, orientation, size, and scanning speed of the sensor. Although other types of sensors may adopt different sensing methods, they all have common requirements, as far as the robotic manipulation is concerned. For example, a GPR consists of a radio transmitter and receiver that are connected to a pair of antennas coupled to the ground (host dirt). The transmitted signal penetrates to the ground and is reflected from any object that has different electromagnetic properties than the host dirt. The antennas are in the form of 25×25 cm plates that must face the ground for scanning [18]. Therefore, remote sensing requires a terrain scanning robot capable of moving relatively large sensors at a constant speed while maintaining the sensor at a constant distance from the ground and parallel to the surface (the detector plate normal must be parallel to the local terrain normal). Such manipulation in an unstructured environment can be a difficult task for a mobile robot. This research has focused on the development of a generic algorithm for terrain modeling and path planning of a terrain scanning robot to carry out such manipulation autonomously and in real time. The result of the research has been implemented into a mine detector robot named MR-2 [1,19,20]. MR-2 is a dual-arm mobile manipulator capable of autonomously scanning unstructured terrain using a typical mine detector in a manner similar to a human operator. The mine detector closely follows terrain undulations using an articulated robotic arm mounted on a mobile robot platform. The autonomous motion may be synthesized based on a 3D model of the terrain that is developed in real time using rangefinders carried by another articulated arm, also mounted on the platform of the robot. MR-2 has been manufactured by Engineering Services Inc. (ESI) in a project supported by Defence R&D

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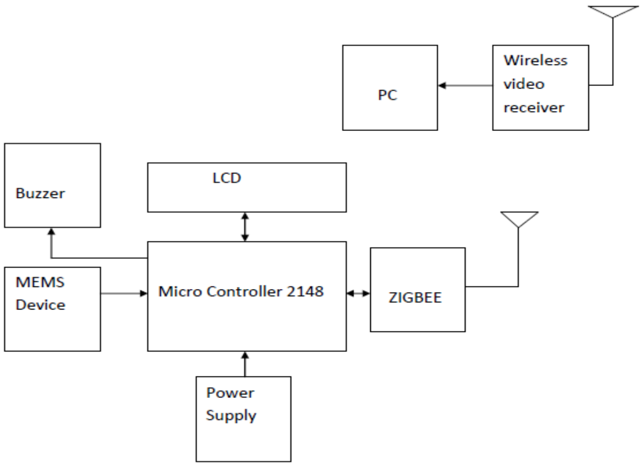

Figure 2.1 Block Diagram of Transmitter Section

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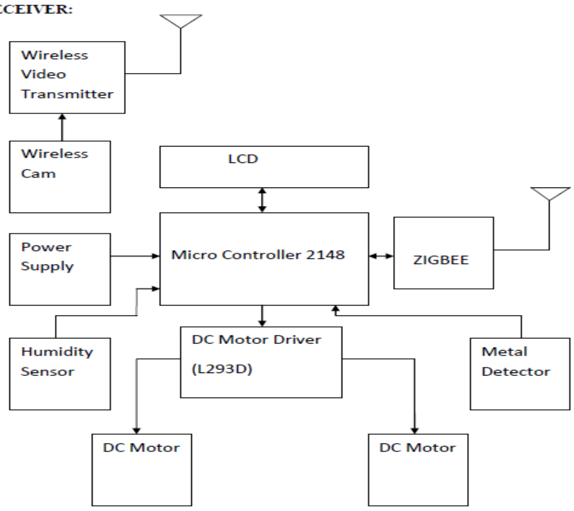

Figure 2.2 Block Diagram of Receiver Section

II. LPC2148 MICROCONTROLLER:

LPC2148 microcontroller board based on a 16-bit/32-bit ARM7TDMI-S CPU with real-time emulation and embedded trace support, that combine microcontrollers with embedded high-speed flash memory ranging from 32 KB to 512 KB. A 128-bit wide memory interface and unique accelerator architecture enable 32-bit code execution at the maximum clock rate. For critical code size applications, the alternative 16-bit Thumb mode reduces code by more than 30% with minimal performance penalty. The meaning of LPC is Low Power Low Cost microcontroller. This is 32 bit microcontroller manufactured by Philips semiconductors (NXP). Due to their tiny size and low power consumption, LPC2148 is ideal for applications where miniaturization is a key requirement, such as access control and point-of-sale.

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GESTURE MOTION ANALYSIS:

Gesture motions are in the vertical plane (as defined by the x-z plane in Fig. 1(a)) or the projection of the motions is mainly in the vertical plane, so the accelerations on x- and z-axes are adequate to distinguish each gesture. Therefore, the acceleration on y-axis is neglected to reduce computational requirement.

We propose that the exact shape of the acceleration curves is not critical, but only the alternate sign changes of acceleration on the two axes are required to uniquely differentiate any one of the 7 gestures: *up, down, left, right, tick, circle* and *cross.*

III. GESTURE SEGMENTATION

A. Data Acquisition

To collect reliable hand gesture data for the sensing system, the experimental subject should follow guidelines below during the data acquisition stage:

a. The sensing device should be held horizontally during the whole data collection process (i.e., the x-y plane of the sensor chip in Fig. 2 pointing towards the ground).
b. The time interval between two gestures should be no less than 0.2 seconds so that the segmentation program can separate each one of the gestures in sequential order.

1) Data Pre-processing

a. Raw data received from the sensors are pre-processed by two 2 processes: a) vertical axis offsets are removed in the time-sequenced data by subtracting each data points from the mean value of a data set, hence a data set shows zero value on the vertical axes when no acceleration is applied;

a filter is applied to the data sets to eliminate high-frequency noise data.

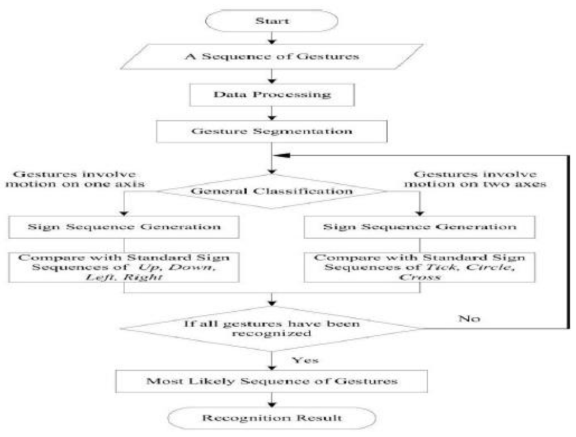
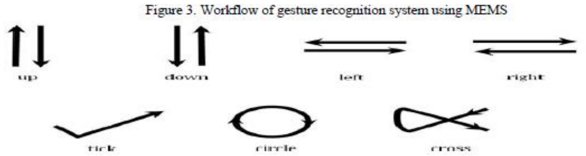


Figure 3. Workflow of gesture recognition system using MEMS



GESTURE RECOGNITION BASED ON SIGN SEQUENCE AND TEMPLATE MACHING:

The recognition algorithm of this model is very similar to that of model one, except that no Hopfield network is used, and hence encoding sign sequence into different combinations of −1"s and 1"s is not necessary. All the sign sequences are represented by −1, 1 and 0 as shown in Table 2. The workflow of Model III is shown in Fig.3. Since the algorithm is based on the feature of acceleration sign changes which is generalized from gesture motion analysis, it is not limited to specific users. Therefore, there is no requirement to train the system by specific users before using it.

TABLE II GESTURE CODES OF MODEL THREE

	X axis				Z axis			
Left	1	−1	1	0	0	0	0	0
Right	−1	1	−1	0	0	0	0	0
Up	0	0	0	0	1	−1	1	0
Down	0	0	0	0	−1	1	−1	0
Tick	−1	1	−1	0	−1	1	0	0
Circle	1	−1	1	−1	−1	1	−1	1
Cross	1	−1	1	0	−1	1	−1	1

IV. LPC2148 MICROCONTROLLER:

LPC2148 microcontroller board based on a 16-bit/32-bit ARM7TDMI-S CPU with real-time emulation and embedded trace support, that combine microcontrollers with embedded high-speed flash memory ranging from 32 KB to 512 KB. A 128-bit wide memory interface and unique accelerator architecture enable 32-bit code execution at the maximum clock rate. For critical code size applications, the alternative 16-bit Thumb mode reduces code by more than 30% with minimal performance penalty. The meaning of LPC is Low Power Low Cost microcontroller. This is 32 bit microcontroller manufactured by Philips semiconductors (NXP). Due to their tiny size and low power consumption, LPC2148 is ideal for applications where miniaturization is a key requirement, such as access control and point-of-sale.The LPC2148 Microcontroller Architecture. The ARM7TDMI-S is a general purpose 32-bit microprocessor, which offers high performance and very low power consumption. The ARM architecture is based on Reduced Instruction Set Computer (RISC) principles, and the instruction set and related decode mechanism are much simpler than those of micro programmed Complex Instruction Set Computers (CISC). This simplicity results in a high instruction throughput and impressive real-time interrupt response from a small and cost-effective processor core.

Pipeline techniques are employed so that all parts of the processing and memory systems can operate continuously. Typically, while one instruction is being executed, its successor is being decoded, and a third instruction is being fetched from memory. The ARM7TDMI-S processor also employs a unique architectural strategy known as Thumb, which makes it ideally suited to high-volume applications with memory restrictions, or applications where code density is an issue.

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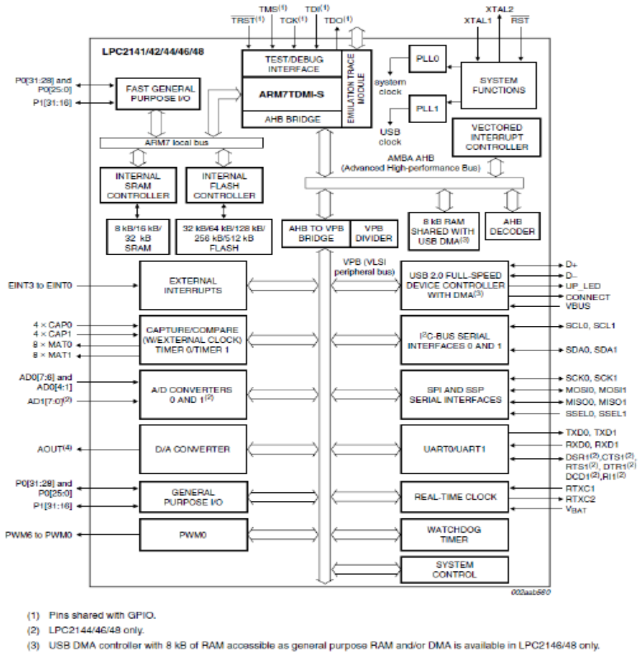


Block Diagram of ARM7

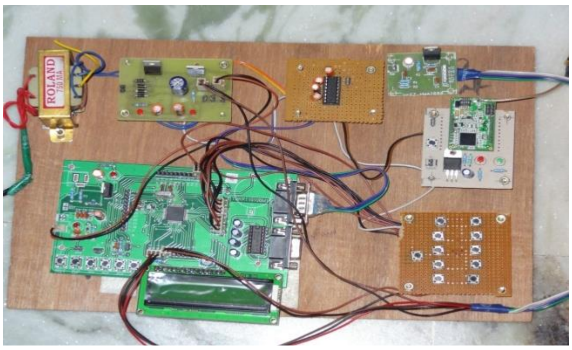
The Thumb set's 16-bit instruction length allows it to approach twice the density of standard ARM code while retaining most of the ARM's performance advantage over a traditional 16-bit processor using 16-bit registers. This is possible because Thumb code operates on the same 32-bit register set as ARM code. Thumb code is able to provide up to 65 % of the code size of ARM, and 160 % of the performance of an equivalent ARM processor connected to a 16-bit memory system.

The particular flash implementation in the LPC2141/42/44/46/48 allows for full speed execution also in ARM mode. It is recommended to program performance critical and short code sections (such as interrupt service routines and DSP algorithms) in ARM mode. The impact on the overall code size will be minimal but the speed can be increased by 30% over Thumb mode.

V. EXPERIMENTAL RESULTS

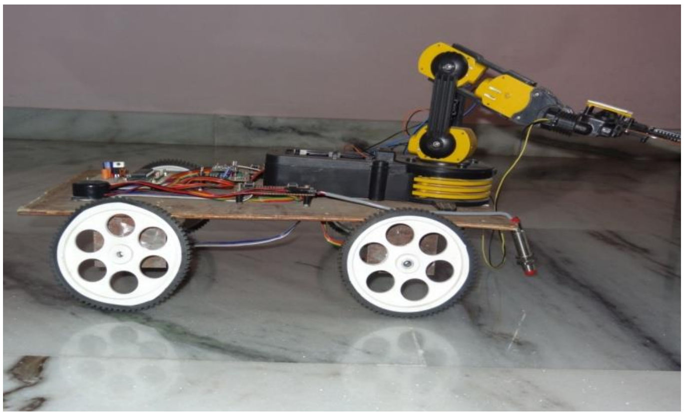
The main purpose of the robot is to detect any Landmine in its path and provide the information to the controller and handle the device to defuse. The operation of the robot is based on the hand movements of the MEMS free fall detection accelerometer is being displayed on the LCD section and this is been shown in pictorial representation.

THE CONTROL SECTION



Control Section

ROBOT SECTION



Robot Section

VI. CONCLUSIONS

The project on "Design of prototypic army bot for Landmine detection and control using hand gesture" has been successfully done and tested for efficient performance of the vehicle. The Prototypic design modules are being presented and every unit of the device is elaborately explained. The robot is equipped with ARM interfaced with 8051 in the vehicle section, controlled through MEMS accelerometer, detect through camera and metal detector and defusal done through an advanced robotic arm. Equipped with such high end technological ancillaries, this type of EOD vehicle is about to occupy a special place in the field of ordnance robots.

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