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International Journal Of Engineering And Computer Science ISSN:2319-7242
Volume 3 Issue 6 June, 2014 Page No. 6432-6437

Design and fabrication of low cost intelligent wheelchair

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Abstract— A novel approach is proposed in this paper to impart intelligence to a low cost smart wheelchair based on embedded system. The sensors give the perceiving power to the wheelchair and scientific inference engine in the microcontroller gives the intelligent power of decision making and its implementation to the wheelchair. This approach is very effective as it does not involve the wastage of the computational and working power of PC/Laptop, rather by using the microcontroller based specific system we have saved the operating power as well as the cost involved in designing. This paper constitutes the circuit diagram of the proposed prototype of the intelligent wheelchair with the algorithms for decision making, table of comparison of features and the cost of the final product.

Keywords- scientific inference engine; embedded system; intelligent wheelchair.

I. Introduction

Throughout the world, a number of persons lost their limbs in accidents, wars and injuries of spinal cord. These people have to rely on the aid of wheelchairs. There are many wheelchairs available in the market with automatic power supply in the wheels and touchpad/joysticks for the control of navigation. Most of these wheelchairs require manual operation and an extra person to look after the safeguard of the amputee. In most of the cases persons suffering from such disabilities are likely to go under emotional distress state and may take the abnormal decisions which may result fatal. Further the commercially available wheelchairs are expensive and devoid of distinguishing between the user normal psychological states and mentally disturb psychological state as well as between the normal environment and the continuously changing ambient environment. With advancement of technology the persons can control the wheelchair simply by their voice action, joystick and touchpad. The Voice controlled wheelchair is determined by creating a speech recognition system utilizing a speech recognition board and a microcontroller [1]. Likewise touchpad [2] and joystick [3] can be implemented but the guardian help is still required for the safeguard of the patient. Moreover the amputees or aged persons may or may not be effectively use these systems [4]. There is another big issue of distress state which make the implementation of unusual decisions. Thus, to find out a way to control the wheelchair without involving the hands and imparting a decision making power, could be of a great help to such persons. Here the most perfect solution comes out to be the voice control, physiological state analyzing and environmental state analyzing, self decision making wheelchair. This motivates us to work in the direction of design and implementation of prototype of low cost intelligent wheelchair by distinguishing emotion, illness and environment for elderly and physically challenged. Following are the situation where traditional wheelchairs fail:

Handling Joystick/Touchpad: For the persons who suffer from spasms and paralysis of extremities, the joystick or touchpad is a useless. So, the voice command system may be the good information transmission means to control the navigation of the wheelchair by such users.

Emotional Distress/Disease State: Except the normal wheelchair control, the morbidity and the exceptional emotion also need to be considered fully. The wheelchair's operation depends upon the instruction provided by the user. Under the influence of Emotional Distress/Disease state the instruction may result fatal. Thus users need to be continuously monitored for such bad emotions or states.

Sudden change in Ambient Environment: The outside environment and the risk cannot be decided completely by the old and the disabled. A sudden introduction of any moving object in path of wheelchair causes sudden decision reaction of the user which in general case is a disable, old person with slow response. In such case Wheelchair's intelligence can lighten user's burden, to provide the safe movement safeguard.

Physiological Change in the User Health: While ambulate if any physiological change happens, it could not easily be detected until the user report the problem and doctor diagnose. This may take a long time which may be crucial for the user. Traditional wheelchairs lack such monitoring system.

II. LITERATURE SURVEY

In early nineties PSUBOT (Portland State University ROBOT) - a computerized electric wheelchair commanded by voice was purposed. In this wheelchair control algorithms, navigation, and human interface were described using 8086 based personal computer [5]. Ronald H. Rockland purposed the Voice Activated Wheelchair Controller (VAWC) to develop a feasibility model for activating a wheelchair using a low-cost

speech recognition system HM2007. A microcontroller was programmed to provide user control over each command for navigation [6]. Kayoko KOMIYA realized that for the people who suffer from spasms and paralysis of extremities, the joystick is useless device as a manipulating tool. They cannot operate the joystick smoothly at all. So, he purposed voice command system [7]. G. Pacnik et al purposed the development of the intelligent wheelchair lab prototype "VOIC". VOIC was designed for physically disabled person, who cannot control their movements and control the wheelchair with the joystick [8]. Masato Nishimori et al developed a voice controlled wheelchair. The user could control the wheelchair by voice commands. A grammar-based recognition parser named "Julian" was used in their system [9]. T. Z. Qi, T. J. Moir presented a novel in-car design to recognize the driver's voice and control in-car devices with non-stationary noise car environment, a speech recognition kit with speech recognition chip HM2007 [10] was used and With an adaptive Wiener filter [11]. Akira Murai et al. proposed a functional voice activated wheelchair with the solution of collision avoidance function CAF by which wheelchair avoids the wall or obstacle without voice command by using the information from two kinds of sensor [12]. H.Uchiyama developed a semi-autonomous wheelchair prototype, which increases independent mobility for individuals with multiple disabilities, specifically those who are wheelchair-bound and severely vision impaired, by providing perceptual and navigational capabilities [13]. Yuhong Zhu proposed in his paper, a novel approach of designing a wheelchair by using simple voice commands to control operations. A health diagnosis function was used in his method to find the disease paroxysm of users, to distinguish psychological and physical state, and to avoid abnormal operation risk by disease and emotion [4]. Rajesh Kannan Megalingam in his work proposed an Intelligent Home Navigation System (IHNS) which comprises of a wheelchair, voice module and navigation module [14]. Mohammed Faeik Ruzaij et al succeed in developing an intelligent wheelchair to help patients using speech recognition system to control the movement of wheelchair in different directions by using voice commands and also the simple movement of the patient's fingers with keypad control. Automatic obstacle detection is done using an ultrasound system [1].
Different parameters cause different effect on the vital statistics of human body. People suffering from various physiological and psychological disorders have body condition differ from normal healthy people [15]. Different Sensors [16] and their fusion help in driving Scientific Inference [17] which results in control of the navigation of the proposed model of the wheelchair.

III. PROPOSED MODEL

The proposed model (Fig.1)consists of four modules viz. the Sensing module, the User Control module, the Scientific Inference module and the Navigation and Alert module.

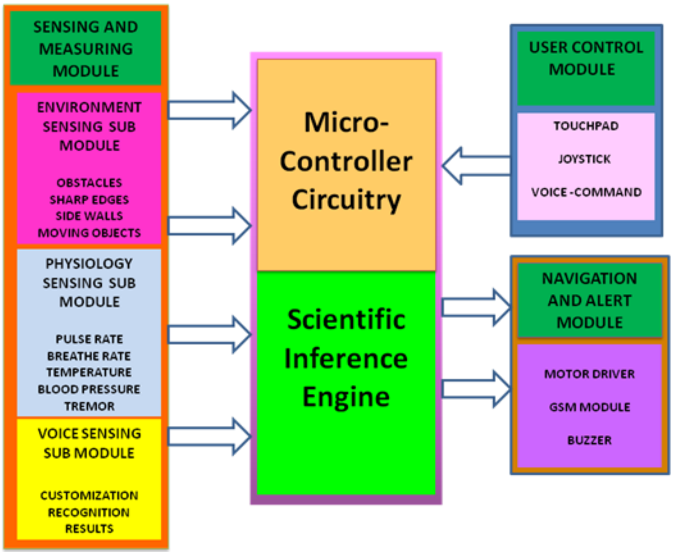

Figure 1. Block diagram of Proposed Intelligent wheelchair

A. *Sensing and Measuring module:*

The purposed Sensing and Measuring module consists of three sub module viz. Environment sensing, Physiology sensing, and Voice sensing sub modules. The Sensing part helps to determine the different input data which are analyzed in Scientific Inference part to determine the disease or mental distress state i.e. physiological state to psychological state as well as the environmental conditions to take the final decision for navigation and generation of alert signal.

Environment sensing Sub module: The Environment sensing sub module consists of four types of sensors. These sensors perceive the surrounding information for the intelligent wheelchair which is analyzed to assist the navigation.

1. Obstacle sensing: Obstacles can be sensed by IR Proximity sensor. The output of this sensor is fed to Scientific Inference part to take further step [18].
2. Fast moving objects sensing: Ultrasonic Object Detecting & Ranging sensor can be used for sensing the sudden introduction of fast moving objects [19].
3. Sharp edge sensing: Sharp edges can be detected by using Sharp IR Rangefinder [20]. The output is analog signal which is converted in digital form for further processing.
4. Fences and walls sensing: IR proximity sensors [18] can be used to monitor the vicinity of the walls or fences by mounting them at the sides of the wheelchair .

Physiology sensing Sub module: Physiological parameters are sensed and measured by different sensors as given below:

1. Breath rate measurement: An elastic neck clip with an air bag can feel carotid directly and a thermister probe is fixed on this clip by a holder. The number of pulses is counted in microcontroller [21]. The normal range is 15 breaths per minute. If the number of pulses increase beyond 18 it is infer to disease state and alarm is raised if the rate is higher than 20 breaths/minutes with an alert signal to the guardian.
2. Pulse rate measuring: Pulse rate can be measured by Heart beat sensor of Sunrom Technologies, Isanpur,

Gujarat, India [22]. Normal range is 72 beats/ minute. The alarming range is 80 beats per minute.

3. Blood pressure measuring: Blood pressure can be measured by modified Oximeter [21]. Normal Blood pressure range is 120/80 systolic/diastolic. The alarming range is 160/120.
4. Temperature measurement: Temperature can be measured by thermopile sensor, which can be accurate to a tenth of a degree. The thermopile sees the eardrum and measures its infrared emissions. The emission is converted into digital form [21]. Normal body temperature is 37℃ the high temperature considered in the proposed intelligent wheelchair is beyond 40℃.
5. Tremor sensing: For detecting Tremors, fits, epilepsy etc special sensors can be incorporated in the elastic neck clip [23]. If tremors are detected both alarm and alert signal are raised.
6. Voice: To recognize the voice, HM2007 voice recognition module [10] of Sunrom technologies, Isanpur, Gujarat, India is used. The voice is an important parameter to determine the physiological state of the user by careful analysis.

These physiological parameters can be used to infer about the psychological state of the user and to take the final decision for the movement of the intelligent wheelchair.

B. *User Command module:*

The user can direct/command the intelligent wheelchair for navigation by Joystick, Touchpad or by Voice commands. Here Voice command module is used for command purpose. The voice commands given by user can be recognized by the HM2007 speech recognition module [10].

It is to be noted that voice is used here in two modules. First to determine the psychological state of the user under physiological parameter, and Second to command the wheelchair for navigation.

C. *Scientific Inference Engine module:*

It is the most significant module that imparts actual intelligence to the wheelchair. Scientific inference is an approach by which theories are constructed and logically tested against the available facts. Scientific Inference starts with theoretical statements and tested against the observations to derive the final conclusion [17]. At every measured and sensed value a limit of minimum or maximum is set; if the limit is crossed then navigation as well as alert and alarm decision is taken by infer in if-then-else conditions of particular situation. It may be important to indicate here that the single parameter alone cannot be able to infer correctly the psychological state of the user; so it necessary to consider a combination of physiological states to derive a final psychological state and to take the final decision.

1. Infer disease state: Abnormality of breath, quicker pulse, higher temperature, high/low blood pressure may be disease precursors. These physiological situations from the physiology sensing sub module can infer the psychological state of the user. Likewise different physiological parameters taken together along with the knowledge of patient history can be used to predict the most likely state of the disease.
2. Infer emotional anomalies: During emotional state there are significant physiological changes in the body of a person. These may include sudden rise or fall in heart beats (pulse rate), breathing rate, blood pressure etc. along with abnormality in usual voice commands [15]. There is a significant role of voice in detection of emotional anomalies like length, strength, quality and clarity of the spoken words.
3. Infer abnormal environmental situations: The sensors sensing and measuring the environmental parameters directly report the abnormal environmental situation in initial as well as during the navigation state to take the necessary control steps, alarm and alerts by the Scientific Inference engine and the microcontroller.

Scientific Inference is derived at each point of time of the operation of the intelligent wheelchair. With every navigation command given by the user, the environmental and the physiological parameters are sensed and infer to oblige or to deny the command. Here it should be note that it is not at all necessary to predict the actual disease but to detect only the anomaly which could be reported to microcontroller for taking the decision of further navigation of the wheelchair. Fig. 2 shows the flowchart of Scientific Inference engine implemented using Assembly Language Program (ALP) on 89S52 microcontroller. This flow chart of Scientific Inference engine shows the elimination of the need of an extra person (attendant) who assist the disable person for navigation. The data from various sensing and measuring sub modules as well as from the user control module serve as the input to the Scientific Inference engine (Fig.2).

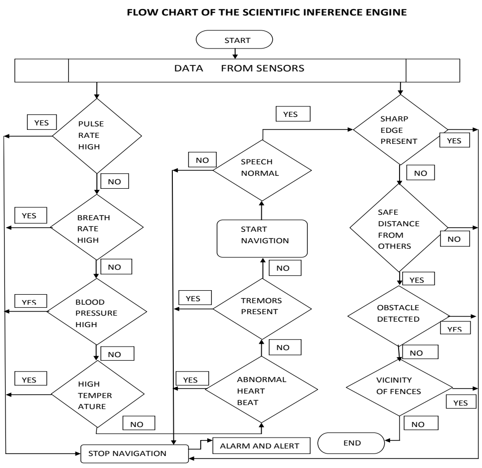

Figure 2. Flow chart of Scientific Inference Engine

The Scientific Inference engine at each step of input, compare the data with the prefixed value and decides to go for further steps following the same routine of comparison. First all the physiological parameters are checked and then with the beginning of the navigation all environmental parameters are monitored. If any of the parameter violates the prefixed value then navigation is stopped and alarm and alert signal is raised. If all the parameters are up to the safe limits then the navigation command of the user is followed to guide the intelligent wheelchair.

D. *Navigation and Alert Module:*

Navigation and Alert module consists of two sub modules viz. Navigation sub module and Alert sub module.

Navigation Sub module: It has Motor driver L293D IC which finally execute the decision of the intelligent wheelchair by controlling the direction of rotation of the motors attached with the wheels. L293D IC is actually an H-bridge circuit controlled directly by the microcontroller [25].

Alert Sub module: Alert sub module has GSM module [26] to inform the guardian by sending an SMS on his mobile on behalf of the user when alert is evoked. It has an alarming signal too in the form of a Buzzer. Buzzer is raised when there is violation of the prefixed parameter infer by the Scientific Inference engine. Buzzer is raised for few seconds but if the situation is not changed it automatically evoke the alert sub module which send SMS to the guardian for immediate help.

IV. RESULTS AND DISCUSSIONS

This section discusses the results obtained after designing and fabrication of the intelligent wheelchair prototype. It includes circuit diagrams, software implementation and the performance analysis in detail along with the table of cost of the proposed work. The Scientific Inference Engine which gives capabilities of intelligence to the wheelchair system is implemented on the IDE Keil Software Version3. The program codes are written in Assembly Language Programming and the circuit diagrams are designed using the Express PCB Electronics Design Software.

Circuit Diagram and Working: The purposed intelligent wheelchair consists of 9 sensors including the speech recognition sensor module, connected at different ports and

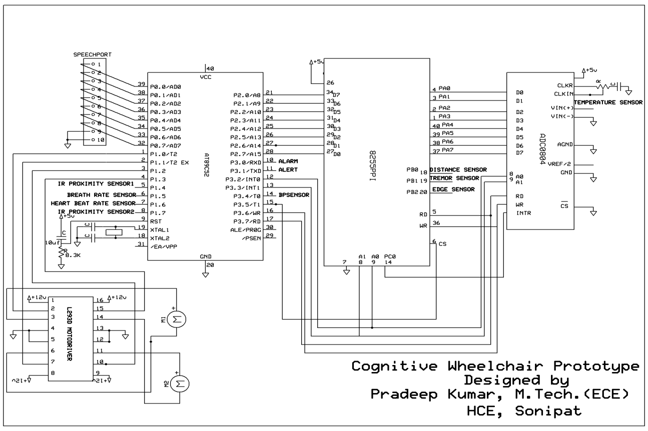

Figure 3. Circuit diagram of Intelligent Wheelchair

pins of 89S52 microcontroller as shown in the circuit diagram of the purposed intelligent wheelchair (Fig.3)., The peripherals execute navigation are connected at Port1.0, Port1.1, Port1.2 and Port1.3. To execute 'stop' all bits are set include 8255PPI, ADC0804, L293D motor driver IC, crystal oscillator of 11.0592MHZ etc. The data from the sensor and the command from the user is converted into digital coded form(where necessary) and fed to microcontroller where these get stored at different memory locations and scientific inference module take the final decision based on the received data. The data is continuously updated by the sensors while in navigation or at rest. The decision is implemented by the motor driver by performing navigation. If any anomaly appears whether in physiological, environmental or user command and last for more than the predefined time then alarm and alert signals are evoked. HM2007 is attached to Port0. The body temperature is measured in analog form and converted in digital form using ADC is connected at Port2. The motors to to move in 'forward' direction all positive polarity are high, to move in 'reverse' all negative polarity are high and so on.

Inference Anxiety Results: Inference Anxiety results are shown in flow chart form and implemented using ALP (Fig.4). The Inference Anxiety is derived from the combination of parameters of pulse rate, breath rate, blood pressure, body temperature and voice of the user. If all parameters reported to have deviation from the normal pre-stored values then Inference, user is suffering from Anxiety is derived and navigation is not carried out else Inference, user is mentally Sound is derived and command from the user is followed for navigation of the wheelchair. Program is written in Assembly language and Inference is derived for each possible situation. Here the Simulation and results of Inference Anxiety and Normal situation are shown Fig. 5 to Fig.7. The breath rate sensor and heart beat rate sensor are connected to Port1 with pinP1.5 and P1.6 respectively.

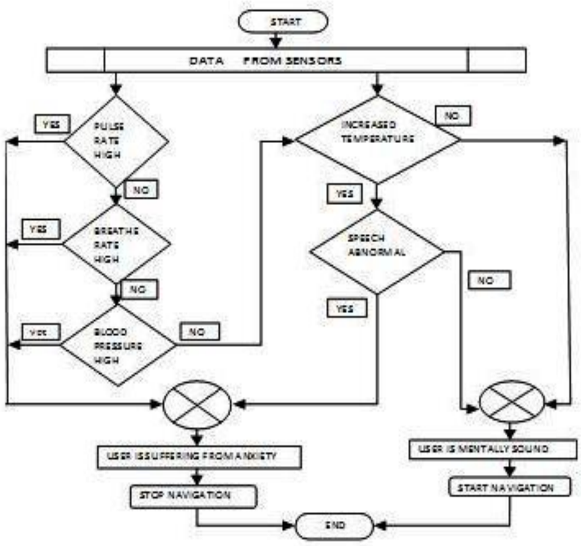

Figure 4.Flow chart of Inference Anxiety

For normal condition:

Port0: Forward command ; Port1: Pulse rate, Brearh rate, Motor ; Port2: Temperature normal; Port3: B.P sensor

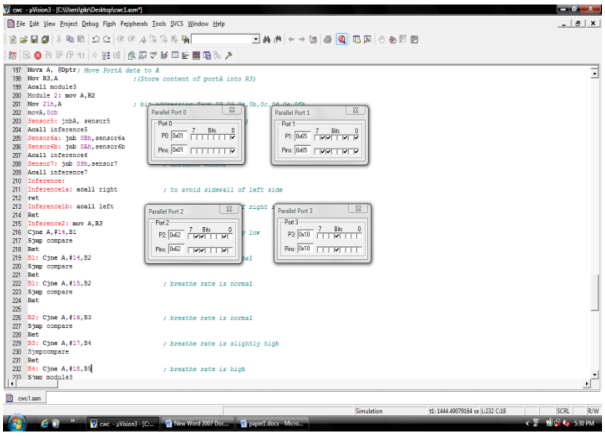

Figure 5. Software Result of Inference Normal

For Normal Condition with different command:

Port0:Stop command; Port1: Pulse rate, Breath rate, Motor control; Port2: Temperature normal; Port3: B.P sensor

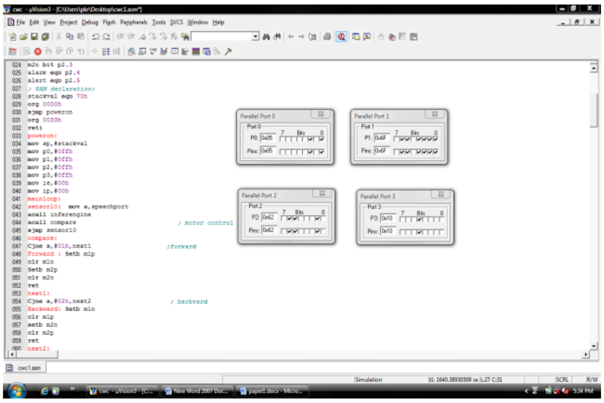

Figure 6. Software Result of Inference Normal with different command

Abnormal Condition: Anxiety

Port0: Mismatch Speech; Port1: Pulse rate, Breath rate, Motor control; Port2: Temperature is slightly high; Port3: B.P sensor

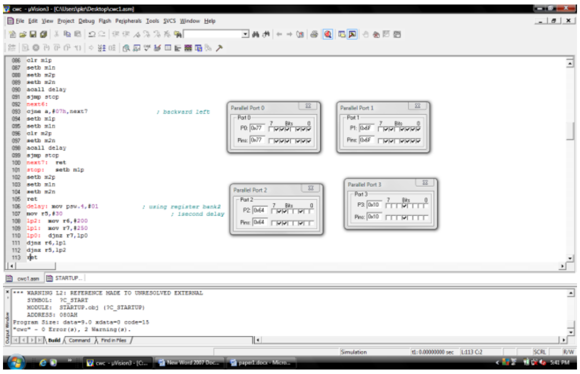

Figure 7. Software Result of Inference Anxiety

V. PERFORMANCE EVALUATION

Performance evaluation can be done on the basis of the following four categories each. These are:

Ease of operation: With the incorporation of various sensors to recognize the user commands, mental state and the environmental situations, it become easy to operate the intelligent wheelchair without the support of others hence it is user friendly. Voice commands simply avoid the use of Touchpad/Joystick and ambient environment sensors keep the safeguard of the user.

Size of extra hardware: Purposed intelligent wheelchair extra hardware is reduced by the use of microcontroller as compared with the smart PC incorporated wheelchairs. The weight of smart PC ranges in 2.0 kilograms to 3.5 kilograms while intelligent PCB weighs less than 0.5 kilograms.

The computational power of PC: The designing of the specific embedded system saves the computational as well as the working power of the PC that are used in smart wheelchairs for controlling the navigation.

Niche of the intelligent wheelchair: Here are few possible situations and the working reactions of different wheelchairs are compared in tabulate form (Table I) to show the niche of the proposed intelligent wheelchair.

Cost of product: The cost of the prototype intelligent wheelchair excluding the chassis and power unit comes to be TABLE I. NICHE OF INTELLIGENT WHEELCHAIR

Situations with user and environment	Wheelchairs Responses					
	Wheelchair with joystick [3]	Wheelchair with touchpad [2]	Wheelchair with voice control [1]	Wheelchair with environment sensors [27]	Computer based wheelchair [28]	Proposed Intelligent wheelchair
Only lower limb affected	Yes	Yes	Yes	Yes	Yes	Yes
Upper limb is also affected	No	No	Yes	No	Yes	Yes
Speech is affected	Yes	Yes	No	Yes	Yes	No
Abnormal mental condition	No	No	No	No	Yes	Yes
Handling in Tremors	No	No	No	No	Yes	Yes
Avoid Pits/Obstacles	Hard	Hard	Hard	Easy	Easy	Easy
Safe distance from others	No	No	No	Yes	Yes	Yes
Speed control	Yes	Yes	No	Yes	Yes	No
Evoke alarm/alert	No	No	No	No	Yes	Yes
Self navigate	No	No	No	No	Yes	Yes
Monitor health	No	No	No	No	Yes	Yes
Processing speed	High	Slow	Slow	Slow	Very High	Slow

INR 9,940 in july 2013 (TABLE II).

S. NO.	ITEMS AND COST			TOTAL
	ITEM NAME	***QUANTITY***	***COST/ITEM***	
1.	***IR PROXIMITY SENSOR***	***3***	***100***	***300***
2	***BREATHE RATE SENSOR***	***1***	***40***	***40***
3	***DISTANCE SENSOR***	***1***	***800***	***800***
4	***TEMPERATURE SENSOR***	***1***	***60***	***60***
5	***BLOOD PRESSURE SENSOR***	***1***	***250***	***250***
6	***TREMOR SENSOR***	***1***	***40***	***40***
7	***PULSE RATE SENSOR***	***1***	***900***	***900***
8	***SHARP EDGE SENSOR***	***1***	***600***	***600***
9	***SPEECH PROCESSOR***	***1***	***5000***	***5000***
10	***BUZZER***	***1***	***30***	***30***
11	***GSM MODULE***	***1***	***1500***	***1500***
12	***MICROCONTROLLER***	***1***	***70***	***70***
13	***ALLIED CIRCUITRY***	***-***	***350***	***350***
	SUM(INR)			***9,940***

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