Design and development of a mobile robot (SOBOT) driven using automatic power supply generation

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Abstract : This paper deals with the design and fabrication of a indigenously developed mobile robot named as SOBOT (solar robot) which can accomplish 2 dimensional motion on a x-y plane and move from one point to another point using a power supply which is derived from an array of solar panels. The solar array converts the solar power into electrical energy and this energy is used to drive the actuators so that the wires are avoided as in the case of a conventional power supply. A small 3-axes arm is also mounted on the mobile trolley which is used to do some mundane pick and place operations. Also a ultrasonic sensing system is designed and used which is used to avoid the obstacles in its path of motion, thus making the system more intelligent. The generated solar voltage from the solar cells is thus an add-on feature.

Keywords : Solar energy, Mobile robot, Arm, LDR, Actuators.

I. INTRODUCTION

Imagine a day in your life when you wake up in the morning and find a automatic machine walking up to you and saying 'Good Morning Sir ! Have a cup of tea'. How would you respond to such a situation ? With so much progress made in the field of science, engineering and technology, this dream is absolutely realizable in the automation age with the advent of robotization. Thus, robotics has become an interdisciplinary field that mixes various engineering disciplines such as electrical, electronics, computers, mechanical, and instrumentation into one. To move the mechanical system (robot), power / energy is required [1].

The energy is the most important issue in our modern technological world and that too the solar energy as it is the inexhaustible source of energy. Solar energy is a renewable resource that is environmentally friendly. Unlike fossil fuels, solar energy is available just about everywhere on earth. And this source of energy is free, immune to rising energy prices. Solar energy can be used in many ways - to provide heat, lighting, mechanical power and electricity. The energy is the most important issue in our modern technological world. It is the basic need of any industrial or domestic work. Therefore, the need of energy is ever increasing and traditional energy resources are seems to be lagging behind as they are not the reproductive and are limited. In this situation, the solar energy can be seen as the endless source of energy.

It is the basic need of any industrial or domestic work. In this research work, a unique 5 axes system is designed and fabricated with indigenous components starting from scratch and driven by solar cells, i.e., actuation is by solar energy. The vehicle designed is a moveable trolley, which can move in the 2D / x-y plane. It has also got a 4 axes arm mounted in the front of the vehicle which consists of a rotating base, shoulder up and down, elbow up and down and the grip open / close.

An line of tactile sensors are mounted at the inner faces of the gripper so that the gripper fingers stops immediately once the fingers touch the object. An array of obstacle avoidance sensors, viz., the ultrasonic transmitters and receivers is also mounted at the front end of the vehicle to avoid the collision of the robot with the obstacle and the walls. The power to this vehicle and the arm is driven by an array of solar cells. This array of solar cells acts as a uninterrupted automatic power supply thus supplying continuous power to the robot and avoiding the electric wires from the mains [2].

The solar cells also track the position of the sun automatically when the robot is moving in the work space or in any open area. Light dependent resistors are used for the feedback purposes. The generated solar voltage from the solar cells is thus an add-on feature of this robot. Stepper motors are used for the movement of the robot. This research work implemented can be viewed as the combination of the various sub-systems. The overall design is divided into the design of the mechanical assembly, electronic assembly and the software assembly.

So, the theme of this work is to generate the proper outputs from the various sub-systems and interconnect them properly for successful working of the robot. For the controlling purpose, a microcontroller is used, so that no additional memory interfacing is needed as in the case of microprocessor. The entire automatic maneuvering of the system with the obstacle avoidance algorithms, battery charging algorithms, etc., is burnt in a EPROM chip and used along with the microcontroller for the robotic manipulation & arm maneuvering purposes [3].

The various parts of the electrical and electronic design are the light detection unit, lux meters, the display systems, motor driving units, the microcontrollers, the solar panel arrays and the stepper motors (actuators). The designed robot is used for doing some operations such as PNP operations, picking up a explosive material in the hall and dump it outside and hence was named as 'SOBOT', which means a solar robot. A user friendly graphical user interface (GUI) was developed and this was used to perform the successful robotic manipulation task using the developed robot model.

Power is a critical resource for robots with remote, long-term missions, so this work focuses on the power generation capabilities of robotic explorers during navigational tasks, in addition to power consumption.

The paper is organized in the following sequence. A brief introduction about the system and its background literature was presented in the previous paragraphs. Secondly, the features of the work considered is presented. This is followed by the design of the mechanical assembly in section 3. Design of the electronic & software part is presented in section 4 along with the flow-chart for the control scheme. Section 5 concludes the work followed by the references.

II. FEATURES OF THE WORK

The designed, fabricated & implemented unit has the following features :

- A mobile trolley with 3 wheels having 2 DOF for carrying the entire arm system.
- A manipulator arm with 4 DOF to perform the PNP operations.
- Onboard microcontroller as the robot controller.
- Use of stepper motors to impart motion.
- A user friendly language to program the robot.
- Ultrasonic movement detectors to detect the obstacles.
- Potentiometers, LDR's, ADC to provide feedback.
- LCD display for visual display of the user program.
- Use of solar cells connected to the power supply unit.
- Usage of lux meters.

The SOBOT (Solar Robot) was designed, fabricated and implemented at 3 levels, viz.,

- Design of mechanical sub-system,
- Design of electronic sub-system,
- Design and implementation of the software & control.

III. DESIGN OF THE MECHANICAL ASSEMBLY

The 3D view of the designed and fabricated unit of the robot in pictorial form is shown in Fig. 1. Many of the features incorporated in the robot can be clearly seen here. The moveable base is made of a brown hylam sheet cut into a bullet like shape as shown in Fig. 1. Brown hylam is used as it does not get dirty because of the constant use and it acts like an insulator, light weight, yet strong. Wheels, which are actually tricycle wheels are attached at the back end while a castor, wheel supports the front portion of the robot [4].

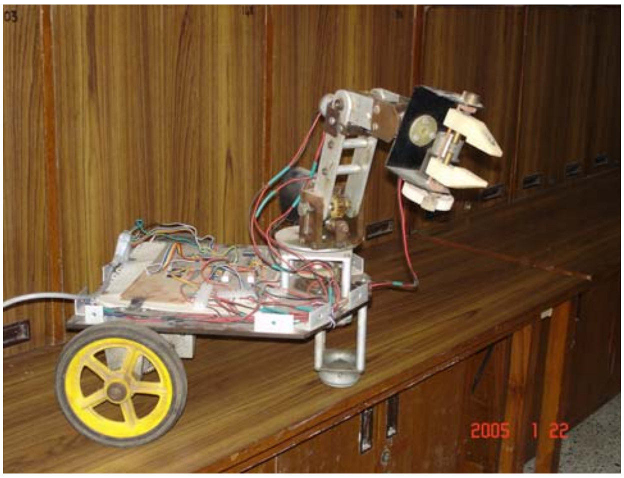

Fig. 1 : Designed & fabricated SOBOT

Steppers motors capable of generating a torque of 4 kg-cm at 60 rpm is used to drive the wheels. A 1:4 spur-spur gear arrangement is used for reducing the speed to 15 rpm and increases the torque by 16 kg-cm at the wheels. Though torque is increased at the expense of speed, this allows the mobile base to carry the entire weight (about 12 kgs) of the robot reliably at a speed of about 10 cms / sec. The SOBOT's arm has got 4 Degrees Of Freedom (DOF), i.e., it has got 4 different axes of motion which is pictorially depicted as shown in Fig. 1. The arm mounted on the trolley consists of the arm base ; arm shoulder, arm elbow and the arm roll motion with the arm grip motion.

Worm and worm wheel arrangement is used for the shoulder and elbow joints because even when the arm is in the intermediate position, it won't fall down and thus acts a locking mechanism. The gripper designed is of a parallel jaw type, which will work on the principle of left-hand / right-hand screw. The LH / RH screw is made by tapping a brass rod with LH die from one end and RH die from other end so that gripper jaws will move in opposite direction, that is jaws will move either towards each other to grip an object or away from each other to release it. Here, the tip position, 'p' remains constant when the gripper moves inwards or outwards [5].

IV. DESIGN OF THE ELECTRONIC AND SOFTWARE PART

The electronic system involves many electronics cards to take care of functions like control, drive, interface, display and feedback. Electronic design consists of various cards like the power supply card, controller card and driver card, interfacing card, display card, sensing and the feedback card, light detection card, etc.,. The heart of the system is shown in the form of a block-diagram in Fig. 2. In this context, only a few cards are being dealt with.

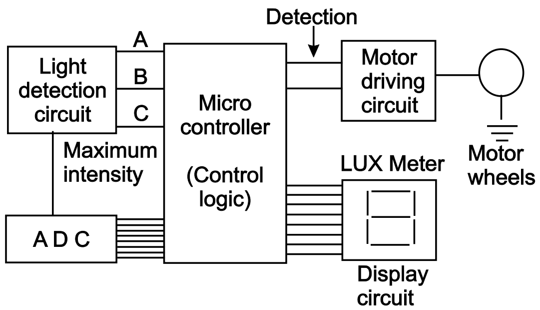

Fig. 2 : Heart of the SOBOT

The excitation sequences for driving the stepper motors is summarized in Table 1.

	Wave Drive				Normal full step				Half-step drive							
Phase	1	2	3	4	1	2	3	4	1	2	3	4	5	6	7	8
A	•				•			•	•						•	•
B		•			•	•			•	•	•					
$\bar{A}$			•			•	•				•	•	•			
$\bar{B}$				•			•	•						•	•	•

Table 1 : Excitation scheme for driving the steppers

Light detection circuit detects the highest intensity light direction amongst the four ADC & converts the maximum intensity light into the digital readout for lux meter. Motor driving circuit provides the necessary driving current for the motor (wheels), also controllers the speed of the motor. The display, functioning as a lux meter provides the digital readout. The "heart" rather "brain" of the work is "microcontroller 89C51" which accepts all the inputs, processes them with the help of software stored in the internal memory and generates the necessary control signals.

The term 'automatic power supply generation' describes that the power to drive the system is obtained from the solar array which is mounted on the top of the robot, which navigates or tracks the position of the sun & converts the solar into electrical energy. In the work considered, the main purpose is to collect the solar power efficiently. There are many approaches to achieve the same objective & one of them is based on the solar calendar where the position of the in the sky throughout the year is programmed into the computer and the computer guides the solar panels to a particular direction at a particular day. In these systems, no feedback is needed as the position of the system is fixed. But in mobile solar robotic navigation systems, the feedback is required continuously from the light sensors as the position of the navigation system from the sun is not fixed. This is the main theme of our work to have a continuous feedback to reposition the system and supply the power continuously to drive the actuators [6].

To have a feedback, we have used light dependent registers (LDR's) as the light sensors. The final position of the solar panel is achieved throughout two roll motions: - one in the horizontal direction and the other in the vertical direction. To achieve the horizontal motion, 4 LDR's are used which detects the maximum horizontal component of the light source, once the horizontal component is detected the vertical component is scanned and thus the final position is achieved. The generated solar voltage is displayed as an add-on feature.

A microcontroller AT89551 from ATMEL is selected as the main controller. The software port is developed using "MICROVISION 2 "from Keil software systems. The program is developed in C and is complied using keil compiler. It was really helpful in debugging and testing. The theory is tested practically by programming the microcontroller. To test the light detection circuit, the motors and the ADC circuit, 2 routines are programmed which is the part of the main program. The light detection circuit which consists of LDR ports and comparator LM 324 generates the proper signals. The ADC IC (ADC 0804) was also accurate enough. The stepper motors, especially base motor was demanding more current (about

1000 mA), but the driver IC ULN 2803 was able to drive the motors. The whole circuit is mounted on the rotating structure to avoid the wiring to jumble especially for the arm [7].

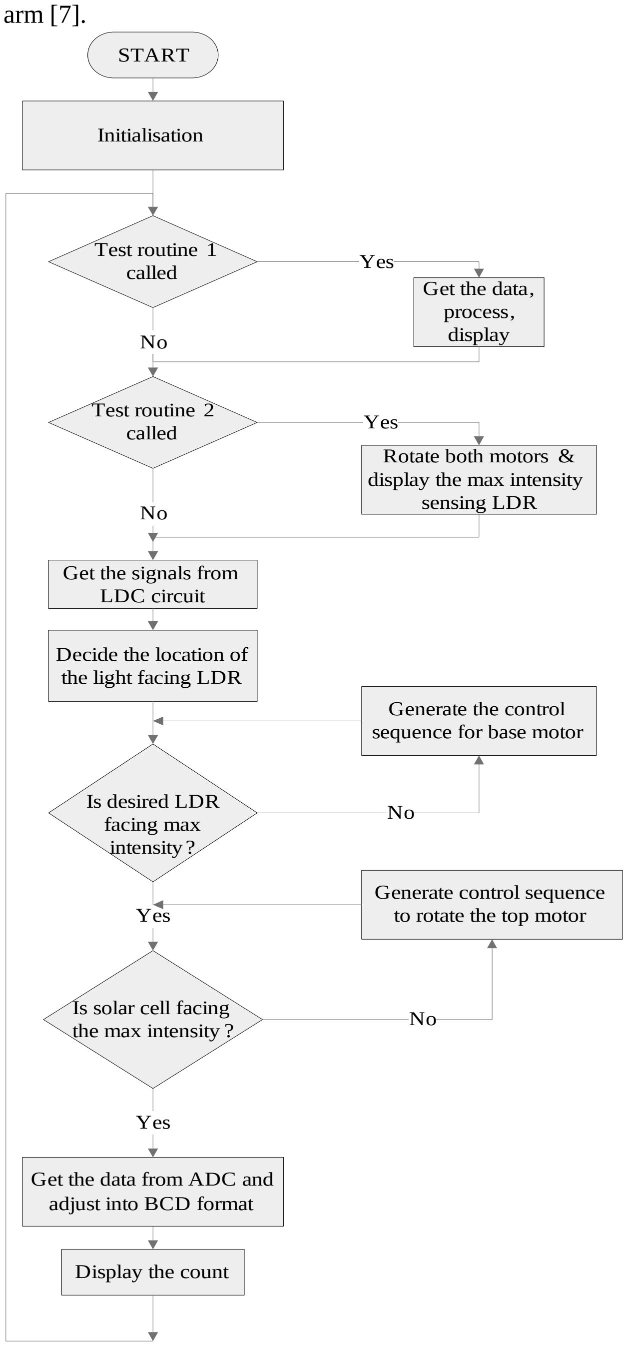

Fig. 3 : Flow chart for the control scheme of SOBOT

The add-on feature of the work is design of the lux meter, which shows the current maximum intensity received by the LDR's. For that, we have to convert the analog intensity variation represented by the proportional voltage in the digital form. Commonly available 8-bit ADC 0804 from Texas Instruments is used here for conversion of analog intensity variations to digital readout [8]. The intensity response of the LDR is converted into the proportional voltages. The maximum amongst them is filtered out by the "Light Detection Circuit" This voltage is applied as an input to the ADC. ADC which is configured in "free running" mode converts the analog input voltage into 8-bit digital data. This digital data is applied to the port of the microcontroller which processes the data to display the digital readout [9].

V. CONCLUSIONS

A Solar Mobile Articulated Robotic System named as SOBOT was indigenously designed, fabricated and implemented and tested to do PNP operations and to avoid the obstacles in its path of motion. We have been successful in achieving our primary objective. The accuracy and repeatability of 'SOBOT' was quite good. The objective of finding the direction of the sun (or the light source) was achieved with fairly good amount of accuracy. The precision in orientation can be increased by increasing the number of light sensors. We hope that this work gives the impetus to the future students and they will also undertake many more challenging works. We desire that this new techno-savvy generation bring India on par with the developed nations.

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