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Design and Experimental Implementation of Bipedal robot

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Abstract

Biped robots have better mobility than conventional wheeled robots, but they tend to tip over easily. To be able to walk stably in various environments, such as on rough terrain, up and down slopes, or in regions containing obstacles, it is necessary for the robot to adapt to the ground conditions with a foot motion, and maintain its stability with a torso motion. In this paper, we first formulate the design and walking pattern for a bipedal robot and then a kicking robot has been developed for experimental verification. Finally, the correlation between the design and the walking patterns is described through simulation studies, and the effectiveness of the proposed methods is confirmed by simulation examples and experimental results.

Keywords

Ball kicking, biped robot, stability, walking pattern generation.

1. Introduction

Robot is a computer-controlled machine that is programmed to move, manipulate objects, and accomplish work while interacting with its environment. This project develops a Biped-walking robot used to explore a remote location by sensing the area parameters like light; temperature etc. processes it and transmits the collected data to the control station using wireless means. The robot can also detect the object/obstacles in its path by verifying the output from the IR (Infrared Sensors) and can change its path accordingly. The robot can be controlled by means of voice. This project consists of a micro controller section and mechanical section. The micro controller section stores a program that controls the movements of the robot, atmospheric parameter sensing and object/obstacle detection. The mechanical section consists of servomotors for the movements of robot. Robot has a motor- driven mechanical device and a brain in the form of a computer or a microcontroller that controls its movement. The microcontroller stores in its memory a program detailing the course the device follows. When the program is run, the controller sends signals activating the motors which move the robot. The controller is that part of the robot which operates the mechanical section and maintains contact with its environment. The device is a computer composed of hardware and software, combined to enable it to carry out its assigned tasks.

The embedded system software includes the interfacing of the sensors like temperature sensors, light sensors, distance sensors etc. to the microcontroller. The sensors give analog outputs and they have to be converted to digital values for processing. The microcontroller, which is the controlling device regularly, reads the sensor outputs. A proper communication protocol has to be established for communication between the control room and the remote system.

After the completion of data processing the robot has to communicate with the control station. To assist this, ZIGBEE a new generation wireless communication media is implemented.

2. Bipedal Design

The robot holds a mechanical structure that consisting servo motors for the movements of robot, and an electronic circuitry which acts as the CPU/ head (Intelligence) of the robot. Microcontroller acts as a Central Processing Unit, which stores an algorithm that controls the movements of the robot, ambient parameter sensing and object/obstacle detection along with Image capturing using Wireless CAM. The robot is fixed with various sensors that monitor atmospheric temperature, light intensity, 3-axis Accelerometer sensor etc. Body balancing of the robot is achieved using 3-axis.

The object is detected using Infrared Sensor module which comprise of a transmitter and receiver section. If the distance to the object from Biped robot is found less than the predefined value, the Sensor produces control signals to the CPU that changes the motion algorithm that matches to the situation and changes the path of the robot. The signals are sent to and fro via Zigbee. Since the communication used is of both to and fro, the man can also control its motion to follow a particular direction/ object from the remote location. This project is helpful for the military/ space expedition etc to verify the atmospheric situations in a particular area without any human intervention.

The embedded system software includes the interfacing of the sensors to the microcontroller, controlling the robotic movements and communicating with main system. The control station has a computer system interface which uses application software that communicates through voice with the robot.

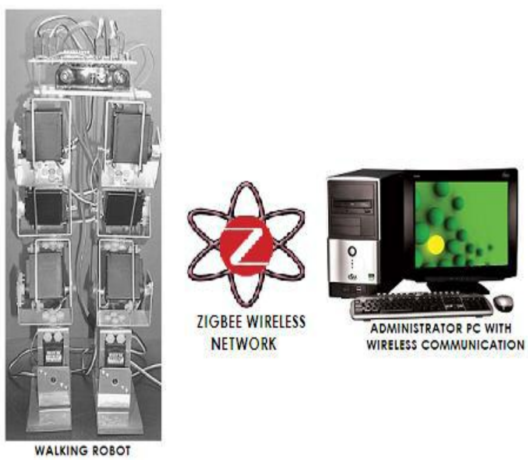


Figure 1: Over All Block Diagram

3. The Walking Robot

Now we deal with the working of the robot. The robot is completely controlled by a micro controller. To enable the movement of the robot seven servo motors have been used. For Right Ankle, Left Ankle, Right Knee, Left Knee, Right Top Joint, Left Top Joint and for Head. And now for the remote sensing purposes we have attached light sensor & temperature sensor. Distance sensors are used for the purpose of obstacle avoidance and X-Y-Z sensors for balancing purposes.

The robot is mounted with a wireless camera for video surveillance purposes. The figure below shows the microcontroller based embedded system in the robot.

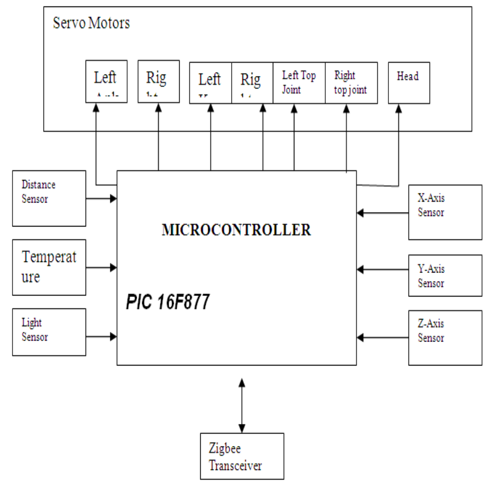


Figure 2: Skeleton of Embedded System

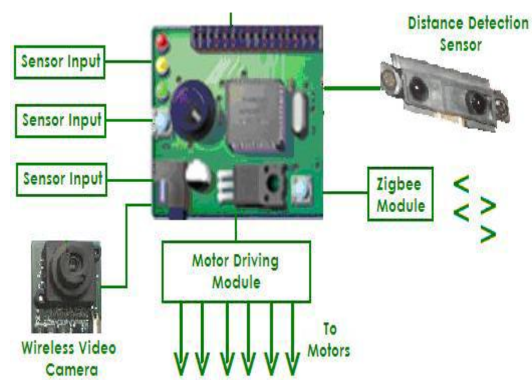


Figure 3: Microcontroller Based Embedded System in Robot

3.1. Microcontroller

Now have a look on various components used in the design of the bipedal walking robot.

3.2. Distance Sensor

It is used for sensing distances from obstacles. It is a wide angle-measuring sensor. It produces a digital Output. The range of detection is from 10 to 80 cm. It possesses a typical response time of 39 ms. Average Current Consumption is 30 mA.

3.3. Temperature Sensor

In this system a temperature sensor is used which sense the room temperature (LM35) and send these to the distant place through internet. The LM 35 is a semiconductor material with negative temperature coefficient. If the temperature increases, the resistance of the material decreases and hence the output voltage varies with temperature. Then the output of the sensor is varied, these voltage are given to the analog input of the controller. The controller converts this voltage to digital form and it calibrates and sends to the distant place.

3.4. X-Y-Z Axis Sensor (Accelerometer)

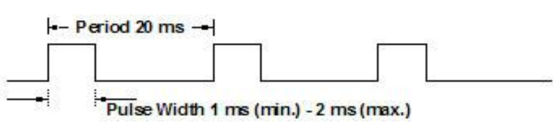
It is used for balancing purposes. The MMA7260Q low cost capacitive micro machined accelerometer features signal conditioning, a 1-pole low pass filter, temperature compensation and g-Select which allows for the selection among 4 sensitivities. Zero-g offset full scale span and filter cut-off are factory set and require no external devices.

3.5. Light Sensor

LDRs or Light Dependent Resistors are very useful especially in light/dark sensor circuits. Normally the resistance of an LDR is very high, sometimes as high as 1000 000 ohms. We are using this sensor for measuring light intensity. When light falls on it, its resistance will reduce. This causes a change in current through the resistance. This change of current produces a corresponding voltage at the output. This is too low to measure in order to strengthen the weak voltage we are using an op-amp. The amplifier amplifies the weak input voltage and sends to the micro controller. There it calibrates the input signals. Thus we can measure the intensity of light.

3.6. Servo Motors

Servos are controlled by sending them a pulse of variable width. The angle is determined by the duration of a pulse that is applied to the control wire. This is called Pulse width Modulation. The servo expects to see a pulse every 20 ms. The length of the pulse will determine how far the motor turns. For example, a 1.5 ms pulse will make the motor turn to the 90 degree position (neutral position). When a pulse is sent to a servo that is less than 1.5 ms the servo rotates to a position and holds its output shaft some number of degrees counter clockwise from the neutral point. When the pulse is wider than 1.5 ms the opposite occurs. The minimal width and the maximum width of pulse that will command the servo to turn to a valid position are functions of each servo.



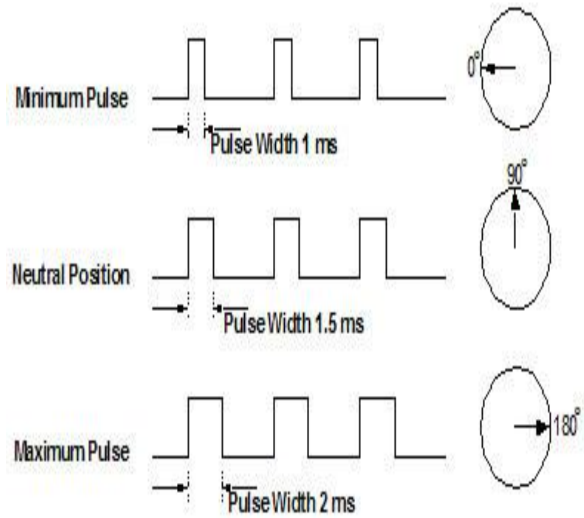


Figure 4: Servo constraints

The servo is controlled by three wires: ground (black), power (red), and command (typically white). Power is usually between 4v and 6v and should be separate from system power (as servos are electrically noisy).

Even small servos can draw over an amp under heavy load so the power supply should be appropriately rated. Though not recommended, servos may be driven to higher voltages to improve torque and speed characteristics. Servos are commanded through "Pulse Width Modulation," or PWM, signals sent through the command wire. Once the servo has received the desired position the servo must attempt to match the desired and actual positions. It does this by turning a small, geared motor left or right. If, for example, the desired position is less than the actual position, the servo will turn to the left. On the other hand, if the desired position is greater than the actual position, the servo will turn to the right.

In this manner, the servo "zeros-in" on the correct position. Should a load force the servo horn to the right or left, the servo will attempt to compensate.

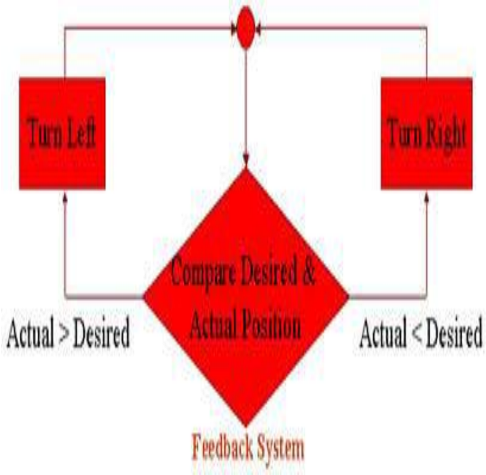


Figure 5: Matching the Desired and Actual Positions

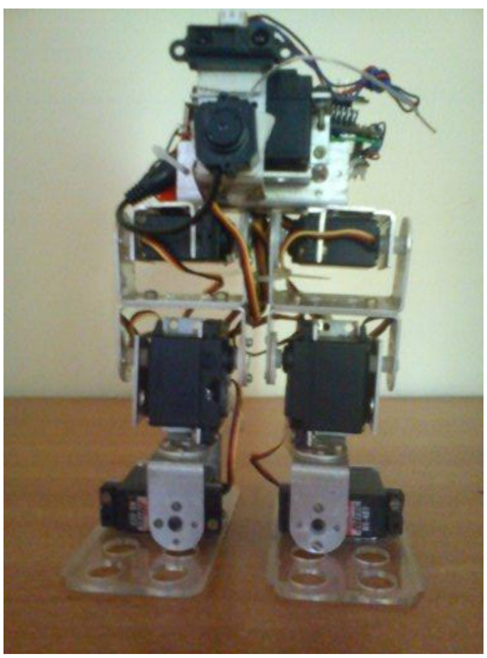


Figure 6: The Walking Robot

4. Zigbee Wireless Network

Zigbee module is used for the entire communication in this project. Mainly there are two types of communication. They are:

1. Administrator PC to robot
2. Robot to Administrator PC

Figure below shows the idea of how communication happens between the control station and the robot.

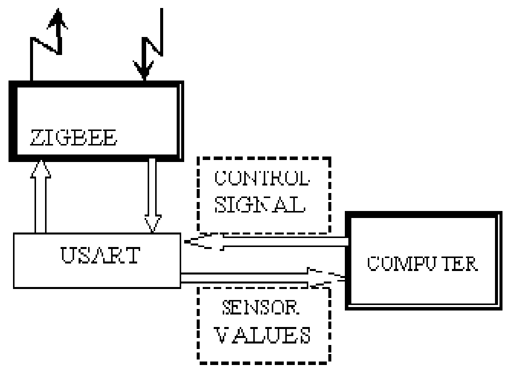


Figure 7: The Control Module

Zigbee module is used for the entire communication in this project. ZigBee is a protocol that uses the 802.15.4 standard as a baseline and adds additional routing and networking functionality.

The raw analog outputs from sensors after filtering and signal processing are directed to the ADC (Analog to Digital Converter) module. The digital output of the ADC further processing is given to the USART (Universal Synchronous Asynchronous Receiver Transmitter) communication module to transmit the acquired data. The results are automatically archived on each time interval. After the purpose full level conversion process these parameters are sent to the remote monitoring station at definite intervals using Zigbee module which is a to and fro communication device (act as both transmitter or receiver as per the requirement) connected with the hardware module. These transmitted data's are captured by Zigbee in the Receiver section. So the man in concern can view the area that covered by the robot along with the real time parameters of that particular place.

4.1. USART Module

The communication to and from the PC is done through the USART. Here after all the information is gathered from the sensors they are sent to the RS232 as an array character by character to the PC.RS232 interface is used for serial communication standard. A Max 232 is required for the voltage compatibility of the Zigbee and DB9 which is the connecter used here to interface to computer. The data transmission to the PIC and the Zigbee is done through the USART. The data transmission is done through the pin 25 and the reception from the pin 26 of the PIC.

The data to be transmitted is in the form of an array which contains all the information that the user has entered i.e. his id no, required book transaction, book no. this array is transmitted character by charter serially at a baud rat of 9600 bps.

5. Movement Control

The embedded system software includes the interfacing of the sensors to the microcontroller, controlling the robotic movements and communicating with main system. The control station has a computer system interface which uses application software that communicates with the robot.

5.1. Walking pattern

The robot follows a pattern in its walking. There are seven servo motors used, each for Right Ankle, Left Ankle, Right Knee, Left Knee, Right Top Joint, and Left Top Joint and for Head. In normal position (Resting Position), all motors will be at an angle of 90 .For a step forward, backward, left or right angular changes have to be made in each motor.

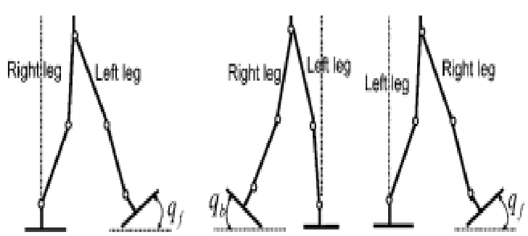


Figure 8: Hypothetical walking pattern

The sequence of servo movements which make the robot move is described here. The motors are named as given:
M1-Right Ankle
M2-Left Ankle
M3-Right Knee
M4-Left Knee
M5-Right Top Joint
M6-Left Top Joint
M7-Head
In normal position (Resting Position), all motors will be at an angle of 90^{o}

5.1.1. Step forward

For a step forward the angular changes in each motor is as given below:
M2: 110, M1: 130 - Body tilt to left
M1: 90 - Right Ankle to normal position
M3, M5, M4, M6: 120 - Stretch Right leg forward
M2: 90 and M1: 100 - Body attain the stable position
M1: 75 and M2:140 - tilt the body to Right
M2: 90 - Left Ankle to normal position
M3, M5, M4, M6:60 - Stretch the left leg forward
M1:90, M2:80 - Right Ankle to Normal position
M2:115, M1:105 - Tilt the body to Left
M1:90- Right Ankle to Normal position
M3, M4, M5, M6:120 - Stretch Right leg forward
M2:90, M1:100 - Body attain the stable position

5.1.2. Step backward

For a step backward the angular changes in each motor is as given below:
M2:110, M1:130 - Body tilt to left
M1: 90 - Right Ankle to normal position
M3, M5, M4, M6: 60 - Stretch Right leg to Backward
M2:90 and M1:100 - Body attain the stable position
M1: 75 and M2:140 - Tilt the body to Right
M2:90 - Left Ankle to normal position
M3, M5, M4, M6:120 - Stretch the left leg Reverse
M1:90, M2:80 - Right Ankle to Normal position
M2:115, M1:105- Tilt the body to Left
M1:90- Right Ankle to Normal position
M3, M4, M5, M6:120- Stretch Right leg forward
M2:90, M1:105 - Body attain the stable position

5.1.3 Turning Left

For a turning left the angular changes in each motor is as given below:
M3, M5, M4, M6: 120 - Stretch Right leg forward
M1: 75 and M2:140 - Tilt the body to
M2:90 - Left Ankle to normal position
M3, M5, M4, M6:60 - Stretch the left leg forward
M1:90, M2:80 - Right Ankle to Normal position

5.1.4 Turning Right

For a right turn the angular changes in each motor is as given below:
M3, M5, M4, M6:60 - Stretch the left leg forward
M2:115, M1:105 - Tilt the body to Left
M1:90 - Right Ankle to Normal position
M3, M4, M5, M6:120 - Stretch Right leg forward
M2:90, M1:105 - Body attain the stable position

5.1.5 Kicking

Kicking is a challenging task for biped robots. An effective kicking depends on the robot's ability to balance. During the period of kicking, the kicking leg moves very quickly and therefore the dynamics should be considered. Furthermore, during the kicking, the center of gravity of the robot moves to the front. These two factors greatly influence the balance of the robot.

The figure below shows the steps in forward movement of the robot.

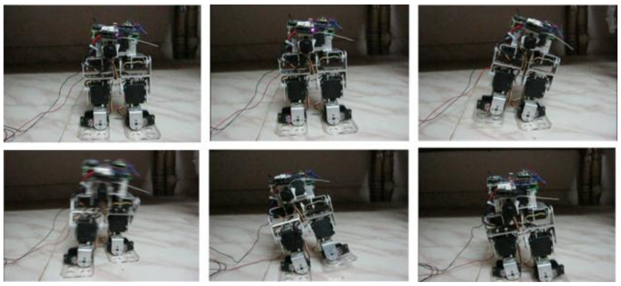


Figure 9: Robot walking

Figure 10: kicking the ball

6. Conclusion

The population of robots is growing rapidly. This growth is led by Japan that has almost twice as many robots as the USA. All estimates suggest that robots will play an ever-increasing role in modern society. They will continue to be used in tasks where danger, repetition, cost, and precision prevents humans from performing. Passive mechanisms helped make control simple, efficient and natural looking. Actuators with Negligible Dynamics are Important.

The project Biped walking robot integrates the field of robotics with wireless communication. The project provides an insight into the structure, the walking mechanism and data communication in robots. The most innovative technology, Zigbee has been used efficiently for the wireless communication between the robot and the control module. This project helps in monitoring the various parameters of a particular location. To perform its assigned tasks, the master control station located at another geographical area can constantly receive the atmospheric data. The moving robot system monitors temperature, distance, light intensity etc and send the data to the master control station at regular intervals, thus updating the data. For sensing the temperature, light etc. respective sensors are used. Data from the sensors are analyzed by the microcontroller and processed.

Biped finds many important applications in fields like defense, industry and in space exploration. Further expansions can be made to improve its performance. By adding a robotic arm it can be used for implementing the pick and place feature. A digital camera can be added to capture images of the surroundings. This robot is sure to improve the way the humans live in near future.

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