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K3S Bipedal Robot

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Abstract—Human body is one of the most versatile creations by nature. A robot mimicking this body structure will be capable of many things. This is the field of biomimetics. Biomimetics will help in designing better and more capabilities in the robot. However the biggest problem it faces is the balancing condition. In this paper, we discuss an 8 DOF bipedal robot created using 3D printing. This robot will be a cheaper alternative to conventional robots and will make robots a common affair.

I. INTRODUCTION

For robots to be a part of the daily lives of humans, the technology should be feasible. However scientists are only focused on making a robot which possesses the same capability as a human. Even companies are neglecting the use of service robots. This is mainly because of the fact that a robot is very expensive to create. By the use of 3D printing we can ensure that a feasible robot can be manufactured. Robots are usually made of aluminum and in this research we have replaced it with PLA plastic. Even though its strength is an issue by using better technologies it is easy to create a robot which is as capable as one made of aluminum. We have also ensured that it is capable of walking and obstacle detection.

II. BLOCK DIAGRAM

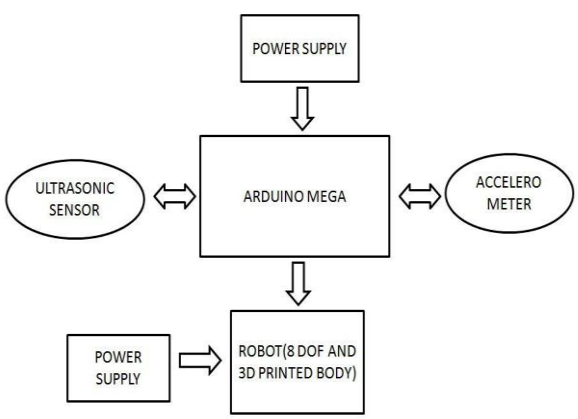

Fig. 1. BLOCK DIAGRAM.

III. STRUCTURE

A. 3D Printing

The structure was made with the help of servo brackets and servo motors. The servo brackets were manufactured using 3D printing. The advantages of 3D printing when compared to conventional method are numerous. 3D printing allows ideas to develop faster than ever. Being able to 3D print a concept the same day it was designed shrinks a development process from what might have been months to a matter of days, helping companies stay one step ahead of the competition. Prototyping injection mold tools and production runs are expensive investments.

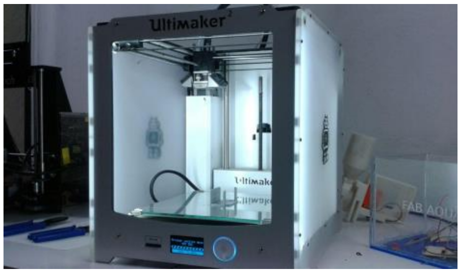

Fig. 2. 3D Printer-Ultimaker 2.

The 3D printing process allows the creation of parts and/or tools through additive manufacturing at rates much lower than traditional machining. Being able to verify a design before investing in an expensive molding tool is worth its weight in 3D printed plastic, and then some. The limitations of standard machining have constrained product design for years. With the improvements in additive manufacturing, now the possibilities are endless. Geometry that has been historically difficult or impossible to build; like holes that change direction, unrealistic overhangs, or square interior cavities, is now possible and actually simple to construct. Being able to test ideas quickly and discover what doesnt work accelerates discovery leading to an ideal solution. 3D printing allows a product developer to make breakthroughs at early stages that are relatively inexpensive leading to better products and less expensive dead-ends.

3D printing was done with the help of Ultimaker 2 machine(shown in Figure 2) and PLA(poly acid)plastic. PLA plastic is a bio-degradable material made from renewable sources like sugarcane. It provides adequate strength and its easier to shape or mould. It took a total of 2 days to finish the printing. The creation of a 3D printed object is achieved using additive processes. In an additive process an object is created by laying down successive layers of material until the object is created. Each of these layers can be seen as a thinly sliced horizontal cross-section of the eventual object.

For starting the printing, we needed to make a 3D model of the brackets required in stl format. This was then uploaded into the machine using a memory card. The machine will give the time required to complete it, so we can estimate the duration. The problem with this machine is that it is slow and that we can not upload multiple files.

B. Assembly

We used 6 multipurpose brackets used to hold the servo motors, 2 combined foot and multipurpose brackets, 4 long-C brackets used to connect between ankle-knee and knee-thigh, 2 offset bracket for assembling the 2 limbs and a channel used to connect the limbs. These brackets are positioned such that, we can mimic the structure of human limbs. Thus we have a 8 DOF bipedal robot

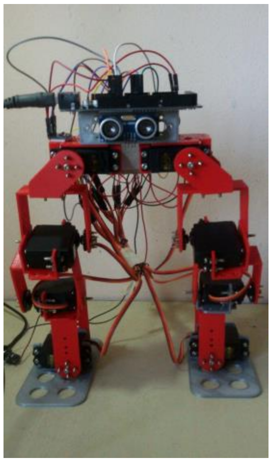

Fig. 3. K3S Bipedal Robot.

IV. BALLANCING AND WALKING PATTERN

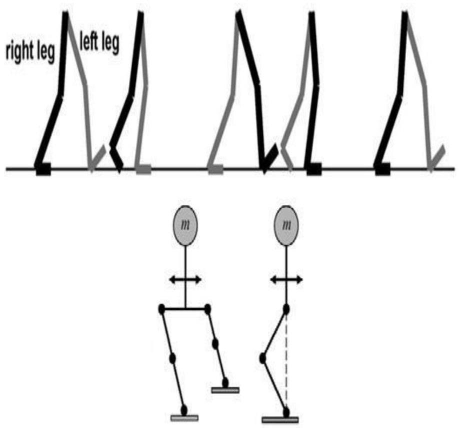

Fig. 4. K3S Walking pattern.

Zero Moment Point (ZMP) is an important concept in the motion planning of a bipedal robot since they are balanced on only two points. Therefore their motion has to be planned concerning the dynamic stability of the whole body.

The objective is to maintain the CoM in line with the ZMP and this is achieved by adjusting the posture of the robot.The walking pattern (see Figure 4)begins with the stand phase. The second step involves raising one limb forward, achieving a Single Support Phase(SSP).The SSP forces the ZMP to the centre of the foot in contact with the ground,this causes the robot to be in an off balanced position so in order to attain balance the hip angles are varied such that the CoM is back in line with the ZMP.In the next phase the raised limb is placed forward on the ground during which the altered hip angles are brought back to their initial position. The robot is then moved to an intermediate stand position in the next phase which is a Double Support Phase(DSP) where the CoM lies in line with the ZMP. This pattern is followed for the next limb to make the robot move forward.

V. HARDWARE

A. Arduino Mega 2560

Arduino mega 2560 is used as a primary controller. It is a microcontroller board based on the ATmega2560. It operates with a voltage of 5V, has flash memory of 256 KB, 8 KB SRAM, 4 KB EEPROM. It has 54 digital I/O pins out of which 14 can be as PWM outputs, this in turn means that 14 servo motors can be connected and controlled. It has 16 analog inputs, 4 UARTs(serial ports), 16Mhz crystal oscillator, a USB connection, a power jack, an ICSP and a reset button. The Arduino Mega 2560 has a 8Kb bootloader which provides ICSP capability. The SDA (pin no.20) and SCL (pin no.21) of the Mega is used for I2C mode of digital interface. The Arduino requires a power supply of 5V and 1A and this is provided via USB from PC. Each I/O pin provides 5V and 40 mA and 3.3V pin provides 50mA. Arduino Mega 2560 has a resettable polyfuse that protects PCs USB port from shorts and over current, if more than 500 mA is applied to USB port, the fuse will automatically break until the short or overcurrent is removed.

B. MG995 Servo motor

MG995 is a metal gear dual ball bearing servo. It has a stall torque of 8.kgf/cm. It has an operating voltage of 4.8V. It has 3 wires-5V, ground and a control digital pin. It is capable of 180 degree rotation.

C. Accelerometer ADXL-345

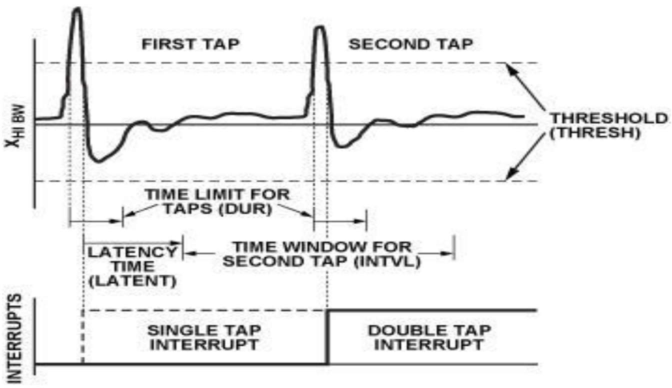

Fig. 5. Single and double tap detection.

It is a 3-axis digital accelerometer that can be operated on SPI or I2C mode of digital interface. We use the tap detection property for implementing a stepping strategy. The tap detection is implemented by considering the following parameters-tap detection threshold, maximum tap duration, tap latency time and time window(shown in Figure 5). It is operated on I2C mode, making use of the SDA and SCL pins of the accelerometer. The parameters mentioned above are modified so as to detect a well-defined tap or double tap. ADXL-345 has two interrupt pins-INT 1 and INT 2. Here INT 1 is used. The single tap is used to push the robot forward and the INT 1 is a function which makes the robot step forward with one leg and then return to standing position after a delay, this ensures that the center of gravity is stable.

ADXL-345 is also used to improve the static balancing of the robot.ADXL-345 output is fed to the arduino when the robot is placed on an inclined surface. The ardunio is programmed to control the servo motors so as to compensate the shift in centre of mass caused by the inclination. The ankle motors are rotated to maintain the balance. The motors also comes back to stable position once the inclination is removed.

D. Ultrasonic Sensor

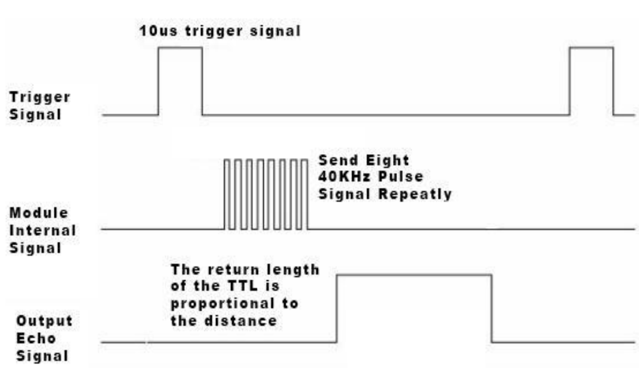

Fig. 6. Timing diagram

We used HC-SR04 ultrasonic sensor to detect obstacles. HC-SR04 provides 2cm - 400cm non-contact measurement function while the ranging accuracy can reach to 3mm. The modules includes ultrasonic transmitters, receiver and control circuit. The basic principle is to use an IO trigger for at least 10us high level signal which causes the module to automatically send eight pulses and detect whether the pulse signal back(see Figure 6). The time taken for pulse to reach back is obtained in microseconds. Then by using the following equation, we can get the distance.

Test distance = (time(s) velocity of sound(cm= s))=2cm (1)

VI. CONCLUSION

A 3d printed robot shows the same capability as the one manufactured using aluminum. The difference in durability of the 3d printed model is offset by the many advantages it possesses. The 3d printing will help students, entrepreneurs and researchers to penetrate easily into the robotics industry. The innovation is always high for open source materials. The K3S robot is economically feasible. The total cost almost comes to 7000 rupees which is much cheaper compared to all other models. It showed the capability of human motion, however the balance still has not completely reached the capability of humans, but with more time and resources we will be able to make K3S reach the same capability as that of human beings.

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