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# DESIGN AND DEVELOPMENT OF A FLIPPING ROBOT

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## ABSTRACT

*A humanoid robot is an electronic machine which looks like a human being and can be programmed to do a self motivated task. In this paper a robot is modeled and built. This work describes the conceptual development of a humanoid robot that can flip. This paper gives an idea on the modeling and design procedure of a humanoid robot starting from links and component design. The paper also describes the way how the robot joints and parts work. Basic stamp programming is used as command information for the robot. The algorithm described in this paper is useful to control a robot and provides a full-fledged knowledge to make the robot flip.*

## INTRODUCTION

Robotics is an interesting subject where one can make something which does work and interact with the environment without human intervention. A significant amount of research is carried out around this field, and various kinds of these self working machines are made all over the world. Robots are often widely used for different applications in Engineering and related fields. A Robot may be used for pick and place objects, while assembling an Automobile or may use for some remote work where the environment may be hazardous.

Robots are built according to the requirements of an application. The basic knowledge needed to build any robot is understating its job, and then sketching out its kinematics. Then come controlling the heart of the robot, which include controllers, servos, and programming. Framing links and joints in a unique way is named as a manipulator. Based on the work it does, a robot manipulator can be defined. If the mechanism is used to do a task in a single direction serial manipulators are used. For spatial jobs parallel manipulators are more adaptable.

Humanoid robot is a special kind of all robots, which has extra fame, as it imitates human attires. Previous studies related to these robots say about individual mechanisms incorporated in a biped robot. Basic kinematics of a humanoid robot is studied by many researchers. The clock turning gait synthesis for humanoid robots in which schematic structure of the lower body of the humanoid Robot is described [5]. Running and jumping mechanisms are focused by some people and claimed that the pneumatic servos are more reliable and efficient for manlike robots. The control to run a manipulator mechanism in a self interactive environment is also studied while building humanoids.

Some of the past works are related on testing the physical characteristics of the robot like stiffness. The challenging task while building a humanoid is its stability. Very little information is available regarding the stability of the robot. Most of the times it is a random procedure to achieve the stability of a biped, but at the same time the specifications, the size and type of links, posses significant control over stability of a humanoid.

Design and Control of a 3 DOF- parallel actuated mechanism for biped application: the structure in this paper gives the terminal body the ability to move within a cone from nominal position and permits unlimited rotation about the cone pointing access. A biped robot with parallel hip and ankle mechanisms was developed. Power consumption economy is achieved due to the cooperation between the actuators during its walk. The forward and inverse kinematics is studied in this paper and a geometrical method is proposed for forward kinematics and analytical form is designed to the inverse. Also optimizations are processed on the mechanism to fit for the application.

A controller network for a humanoid Robot: Design and construction of a distributed controller network for a humanoid robot is described [1]. The design of robot consists of 2 DOF per leg and 1 DOF per arm. The network consists of 3 subnet works; each includes a set of dedicated processing nodes interconnected by Can Bus. An integrated approach to dynamic biped walking and dynamic Object manipulation at and abstract level is described by Borhan and his team from university of Iran, Tehran. Dynamic object locomotion of the lower part of the robot is presented [2]. 3D biped dynamic walking of a humanoid can be realized by implementing the proposed biped control strategies on them [3].

Embodied basis of invariant features in execution and perception of whole body Dynamic actions-knacks and focuses of Roll-and-Rise motion: in this paper multi-approach investigation is done for Roll-and Rise motion [4]. After studying the Roll and Rise motion concepts, the robot is built and tested. It is observed that energy input timings effect the success of the robot incorporated with Roll-and-Rise motion concepts. Master control processor, using its external optical or tactile sensor data, calculates the trajectories for several joints of the robot [6]. Radio control processor is used for remote control and maintenance. It is directly connected to the MCP. Audio control processor is used to support speech output. Proprioceptive sensor control incorporates all the sensors for measuring internal states like body acceleration, orientation, posture, and ambient temperature and charge condition of the battery. Limb control processor receives global data sets which specify the future positions to which the joints have to reach. The JCP's (joint control processor) perform the control of the motors and sensors applied to their joints. Keun Park and his team from school of mechanical engineering design; national university seol, presented the procedure to develop hardware of a mid-size humanoid robot [7]. The design process started by 3D Modeling and then analysis is made before developing the hardware.

## FLIPPING ROBOT HUMANOID

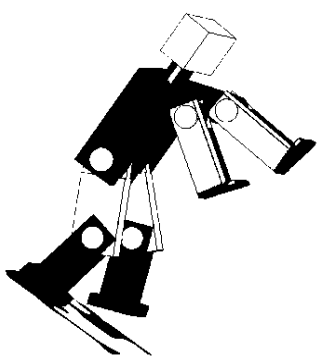

Figure 1. 3D Model of Humanoid

A humanoid is designed and developed as a part of the project for a course at florida international university. The concept of designing a humanoid robot arises from the through study of the past work on humanoids. Most of the works explained the modular design of the robot or in other words concentrated on some technical aspects, like mechanism or control. Few more related publications covered the biped motion, but rarely can find the jump and flip. Even if it flips, getting the stability is again a problem. In this project a trail is made to design the biped for is stability, and then it will walk and flip. It consists of total 6 degrees of freedom to do these tasks comfortably.

The idea in this work is to make the humanoid walk and flip, but there is neither exact end effecter data nor formulated array of final positions. In other words a Bottom – up approach is tried in building the robot. The trail and error method provide the stability for flipping. The kinematic motion is basically provided by the servo rotations. The relative positions of the links are observed and tested for a complete balanced flip.

The robot possesses 6 joints and all the joints are revolute joints with 1DOF each. The kinematics is similar for all joint as the whole robot is built by symmetric links and joints.

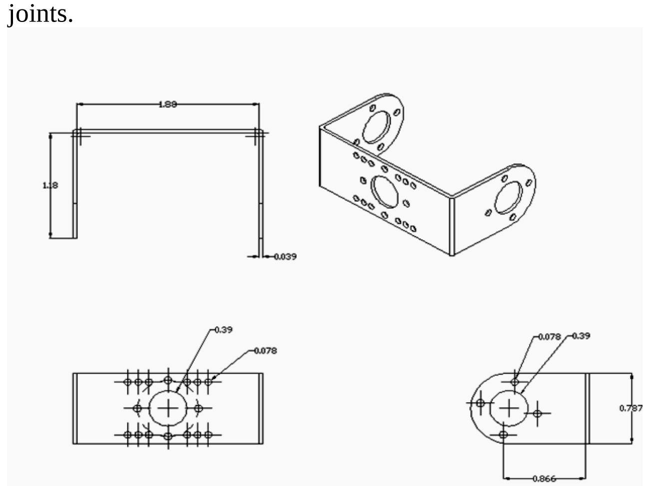

Figure 2. 2D Drawings of Bracket

## KINEMATIC ANALYSIS

The design process has started with the 3D assemblage of the assumed concept in solidworks. As shown in Fig.1, the total sis degree of freedom includes two at shoulders and each two at the hips and knees. The idea of the platforms as palms and the feet, to achieve more stability arose from this 3D model. The actual robot made is not so much different from the model that we assumed. But as a practical thing, a known approach is used to build the robot. The links which are available readily in the market, which are compatible for the servos and other components, are collected for this purpose. The assembly is again re-modeled according to the links and components possessed. Part drawings of the links and clips used in building the biped are shown in Fig.2.

Figure 3. Bracket and Clip Used for Biped

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## CONSTRAINTS

A humanoid robot with 6 DOFs has many possible gaits in 3-D space. A feasible flipping gaits needs to identify the constraints between these DOFs.

(1) Hip and knee of 1 DOF each constitute one plane for each leg.

(2) Arm of 1 DOF each constitute one plane for each arm.

In designed flipping motion path all the planes are parallel to each other. The trajectories of the leg and arm along with the exact timing of their motion play a vital part in the generation of exact required flipping motion.

The flipping cycle starts with the motion of hip joint, then arm joint and finally knee joint. Trajectories of hip joint are dependent on the knee joint trajectories.

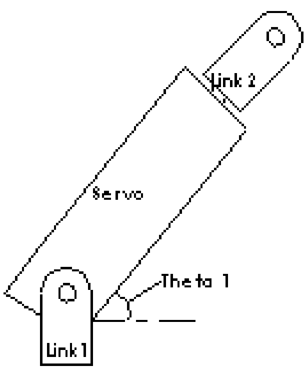


Figure 4. Servo Link Attachment

Knee joint trajectories obtained by solving

$$X_{Hk} = (l_1 + S_1)\cos\theta_1$$
$$Y_{Hk} = (l_1 + S_1)\sin\theta_1$$

Where, $l$ = link length

$S$ = servo length

$\theta$ = angle between the link and the servo

Knee trajectories and arm trajectories are same in this case. Altogether gives the desired flipping motion of the robot. The next step is to generate the hip trajectories. The mass distribution of the humanoid robot is mainly in the upper body. The hip motion mainly determines the trajectory of the center of gravity (COG) or the ZMP of the robot. The humanoid model has a left hip joint and right hip joint with a hip link between two hip joints. The center of the hip link is the pelvis.

Hip trajectories are obtained from the knee trajectories by solving the following equations

$$X_{Hh} = X_{Hk} + (l_2 + S_2)\cos\theta_2$$
$$Y_{Hh} = Y_{Hk} + (l_2 + S_2)\sin\theta_2$$

## MAJOR COMPONENTS

The main components of our robot include the links, servos and electronics. The brackets are used as links and clips are used to support the links while building the robot. Each heat treated Bracket is of 50X25X25 mm size as shown in Figure.2. Heat treated Clips are also used in between the links to facilitate servos to move freely. The Supporting attachments to connect servos with the links are customized and made according to the requirement and situation. A total of 6 servos are used to provide motion at the eight joints of the robot. All servos are ordered from the Hi-tech Corporation whose rotations are specified by a maximum of 300 degrees. A servo controller with 16 ports is used to control the servos. A BS2 micro controller is fixed to the biped to run the basic stamp program on it. The programming is done on the basic stamp 2 editor for generation of the flipping motion. A 9 volt battery is used as a power source for the bs2 carrier board.

## PROTOTYPE DEVELOPMENT

Platforms: Four platforms are fixed to serve as palms and feet for the robot. These platforms are made by connecting pieces of a plastic board with the brackets. A soft material stripe is added to the other end to make the foot or palm more flexible while flipping.

Figure 5. (a) Platforms (b) Joint with Servo

Joints: The brackets which are served as links for Biped are connected in different ways to build the robot. Servos are attached at the joints concentrically for two consecutive inks. Developing such joints in a top-bottom approach will lead to the subassemblies of the Robot like legs, arms, and hips. The subassemblies are then attached together to complete the building process.

A basic stamp2 micro chip is used on a carrier board and is connected to the torso portion of the humanoid. A servo controller is also attached to the carrier board from where all the servos are connected using the cables, connected to the respective pins of the servo controller.

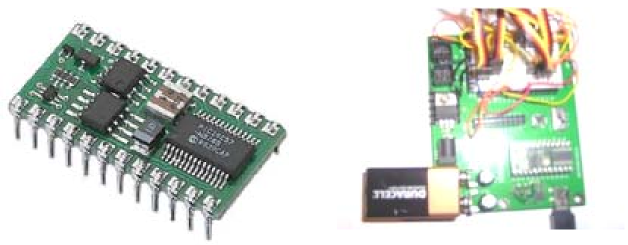

Figure 6. (a) BS2 Microchip, (b) Micro Controller and Battery

## SOFTWARE DEVELOPMENT

The steps from defining the variables and to reversing the leg in order to flip the humanoid using the basic stamp programming are shown in Figure 7.

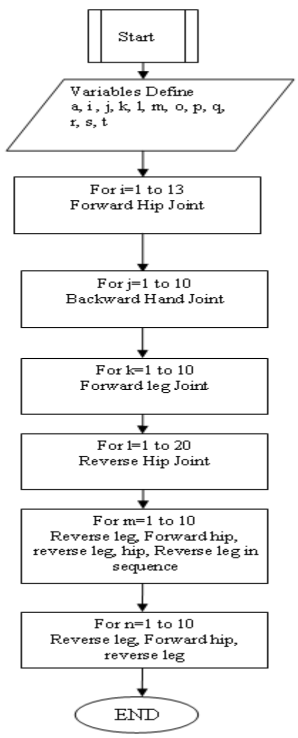


Figure 7. The Flow Chart

## ALGORITHM

The code for this project is generated using the following procedure. Thirteen variables are defined first to provide pulse counts for various parts of the robot. For every link motion, the pulse counts are given as a range of numbers. The range is proportional to the angular movement of the servo motor. The relative angular displacements of the joints are shown in Table 1.

Table 1. Servo Positions (Degrees)

| Leg | Hip | Hand |
|---|---|---|
| Forward | Forward | Backward |
| 180° | 120° | 90° |
| Rev | 90° | Rev |
| 120° | Rev | 90° |
| | 120° | |

The sub routine in basic stamp to achieve the hand joint motion is given here.

```
label1:
FOR n=1 TO 10    'hand
PULSOUT 15, 850
PULSOUT 14, 850
NEXT
RETURN
```

The subroutine titled label 1 describes how the hand rotates when the pulse count is from 1 to 10, which indirectly relates to the angle through which the servo rotates. The program also contains subroutines for rotations of other joints (hip, knee) in appropriate directions to finally achieve the flipping motion.

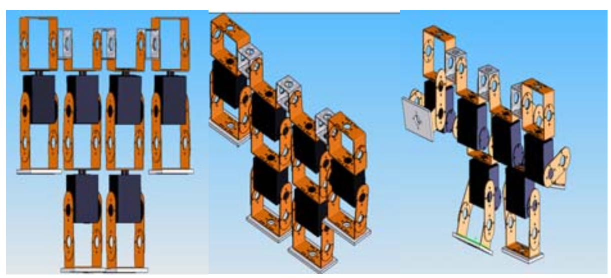

Figure 8. Actual Model of the Robot

## CONCLUSIONS AND FUTURE WORK

In this work, a 6-DOF humanoid robot design is presented. Specifically, the work has initially concentrated on designing and constructing the biped of the humanoid. After the conceptual design, sub assemblies of the legs, hips, and arms are tested by connecting them to the corresponding pins on the controller. The tests on subassemblies while building the robot have been successful. The biped is then trained to flip and it is observed that it accomplishes the task.

The degrees of freedom of the present robot may be increased in order to accomplish more complicated tasks. Qualities such as speech recognition, reaction to speech recognition and image recognition can be incorporated to this biped to enhance the design.

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