International Journal of Mechanical and Production Engineering Research and Development
Vol.1, Issue 1 (2011) 16-50

DESIGN AND FABRICATION OF HUMANOID ROBOT WITH 21 DOF (*GNANO-369*)

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ABSTRACT

Controlling the direction of balance for a two legged walking robot typically means mimicking the human form and its walking locomotion. Even though the human locomotion approach is taken as the ultimate reference, gaits can be developed using less sophisticated methods The paper describe the design and build a humanoid that can duplicate the complexities of human motion, decision making, be able to help people and even accomplish tasks that cannot be carried out by humans. The architectural constraints on our working and living environments are based on the form and dimensions of the human body considering the design of stairs, cupboards and chairs; the dimensions of doorways, corridors and benches. A robot that lives and works with humans in an unmodified environment must have a form that can function with everyday objects. The only form that is guaranteed to work in all cases is the form of humanoid. The robot itself is currently under construction, however the process of designing the robot has revealed much about the considerations for creating a robot with humanoid shape. The mechanical design is a complete CAD solids model, with specific motors and transmission systems selected. The electronic design of a distributed control system is also complete, along with the electronics for power and sensor processing.

Keywords: *Humanoid robot, Design, Fabrication, Servo motors, control panel, Bipedal walking.*

INTRODUCTION

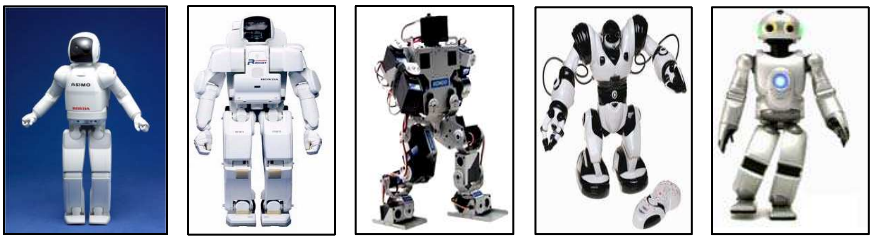
The motive behind building humanoid is simply to design a robot that can duplicate the complexities of human motion and genuinely help people. Although the motive is this simple, the task is never easy. For example it took Honda's ASIMO more than 18 years of persistent study, research, and trial and error before Honda engineers achieved their dream of creating an advanced humanoid robot [17]. Walking process can be branched into two main groups as static and dynamic walking. Static walking in bipedal humanoids involves the complete shifting of the COG of the body over to the base foot area when the other is lifted to move forward. Such robots are designed and controlled from a kinematic standpoint (trajectory, or displacement-controlled), and as a consequence, they have relatively large feet and walk at a slow speed. Where as in dynamic walking, the center of gravity is outside the supporting leg base area, a walking maneuver where static balance is intentionally terminated. Considering these two walking processes we are going to start the design and fabrication of humanoid robot initially with "static walking" concept which will be shifted later to "dynamic walking" a dominant style of human walking. Naturally, the walking program for the robot was developed according to data on human walking. The active walking program was then integrated into the robot's controlling system to achieve a stable, human like walking pattern.

Ales Ude et-al [1], discussed the formulation and optimization of joint trajectories for humanoid robots is quite different from this same task for standard robots because of the complexity of humanoid robots' kinematics and dynamics. Zhe et-all [2] was developed a method for 3-D walking movements based on a model of a typical humanoid robot with 12 DOFs on the lower body. Thomas Buschmann et-al [3], discussed about the humanoid robot LOLA, its mechatronic hardware design, simulation and real-time walking control is presented. The goal of the LOLA-project is to build a machine capable of stable, autonomous, fast and human-like walking. LOLA is characterized by a redundant kinematic configuration with 7-DoF legs, an extremely lightweight design, joint actuators with brushless motors and an electronics architecture using decentralized joint control. Takahiro et-al [4] describes a method is to control robots with a hybrid controller that combines the functions of a communication behavior controller and body balancing controllers. Keun et-al [5] integrated approach successfully leads to the development of a prototype of Bonobo with a relatively low time and investment cost. Genci et.al [6] presents a new method for real time gait generation during walking based on neural networks. The minimum consumed energy gaits similar with human motion, are used to teach the neural network. Furuta et.al [7] presented the design and construction of compact body humanoid robots and various biped locomotion control strategies implemented onto them in the ESYS humanoid project at the Engineering Systems Laboratory. Hirohisa [8] introduced humanoid robotics platform that consists of a humanoid robot and an open architecture software platform developed in METI’s Humanoid Robotics Project. Several authors [9-13] developed some of the methods for co-evolving morphology and controller of bi-pad humanoid robots. Jerry et-all presented the mechanical design of a bipedal walking robot named M2V2. Gordon et.al [15], described the design of an autonomous humanoid robot. A high fidelity graphical simulator has been developed, providing important early feedback on critical design decisions. Ogura et.al [16], described the macro-walking instruction strategy for a biped humanoid robot to memorize complex walking patterns systematically and effectively. In teaching various walking motions, auditory sensors are employed. This work aims at designing and fabrication of the humanoid with 21DOF. After the completion of this, the work of the project deals with the representation of static walking of the humanoid robot. This static walking is achieved through programming. The controlling of the robot is done mainly through the execution of serial commands from the personal computer. Finally the work proceeds to achieve the stable static walking through programming and showing all the DOF movements in the humanoid.

HUMANOIDS

A humanoid robot is a robot with its overall appearance, based on that of the human body, allowing interaction with made-for-human tools or environments. It took Honda's ASIMO more than 18 years of persistent study, research, and trial and error before Honda engineers achieved their dream of creating an advanced humanoid robot (ASIMO) [17].

Humanoid robots are created to imitate some of the same physical and mental tasks that humans undergo daily. Scientists and specialists from many different fields including engineering, cognitive science, and linguistics combine their efforts to create a robot as human-like as possible. The creators' goal for the robot is that one day it will be able to both understand human intelligence, reason and act like humans. If humanoids are able to do so, they could eventually work in cohesion with humans to create a more productive and higher quality future. Figure1 shows the different types of robots manufactured by the different organizations



a) Honda Asimo b) Honda P3 c) KHR-I d) Wow Wee e) Sony QRIO

Fig.1. Humanoid Robots

Sensors: A sensor is a device that measures some attribute of the world. Being one of the three primitives of robotics (besides planning and control), sensors plays an important role in robotic paradigms. Sensors can be classified according to the physical process with which they work or according to the type of measurement information that they give as output.

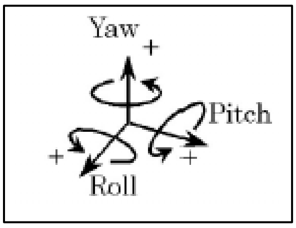
Actuators: Actuators are the motors responsible for motion in the robot. Humanoid robots are constructed in such a way that they mimic the human body, so these use actuators that perform like muscles and joints, though with a different structure. To achieve the same effect as human motion, humanoid robots use mainly rotary actuators. These can be electric, pneumatic, hydraulic, piezoelectric or ultrasonic. In the present work 7 kg-cm and 2 kg-cm torque capacity servo motor are used at appropriate points following the design

Planning and Control: In planning and control the essential difference between humanoids and other kinds of robots (like industrial ones) is that the movement of the robot has to be human-like, using legged locomotion, especially biped gait. The ideal planning for humanoid movements during normal walking should result in minimum energy consumption, like it happens in the human body. For this reason, studies on dynamics and control of these kinds of structures become more and more important. To maintain dynamic balance during the walk, a robot needs information about contact force and its current and desired motion. The solution to this problem relies on a major concept, the Zero Moment Point (ZMP).

Design of Humanoid

Mechanical Design of Humanoid: The Mechanical design forms the basis for developing this type of walking robots. The mechanical design is divided into a) Determining the Mechanical constraints b) Conceptual Design c) Specification and Fabrication of the model. Stability is achieved through programming.

Specification and Fabrication of the model



There are various design considerations when designing a humanoid robot. Among them, the major factors that have to be considered are Robot's size selection, Degrees of freedom (D.O.F) selection, Link Design and Stability. It is designed with the knowledge gathered from developing previous humanoid models. This design has got total 21 D.O.F. For each leg Hip is actuated in all the three (Pitch, Roll and Yaw) an orientation, Knee is actuated in Pitch orientation and Ankle joint is actuated in Roll and Pitch orientations. For each hand Shoulder is actuated in Roll and Pitch orientations where as Elbow and Wrist is actuated in Roll orientation only. Finally head is actuated in Yaw orientation. This design has more stability with equal weight distribution on both the legs. Optimal distance was maintained between the legs to ensure that legs don't hit each other while walking. In this humanoid the ankle joint is mainly actuated in Roll orientation in order to shift the centre of mass and also helpful for the other leg to lift up easily. The entire robot structure has been fabricated from 0.9 mm thickness of aluminum sheets. The fabricated model is shown in the figure 2. Actual weight of the robot excluding batteries is 800 grams.

Figure 3 shows the overall dimensions of the humanoid robot and rotation of ankle joint (by 10^0) towards right hand side and left hand side respectively. Each part of the humanoid robot having different degrees of freedom as follows:

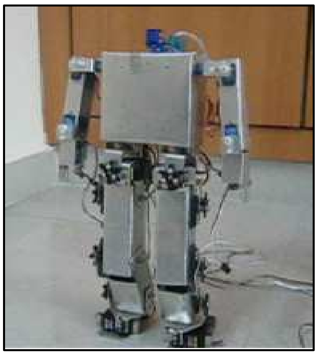


Fig.2. Fabricated Model

Dimensions:

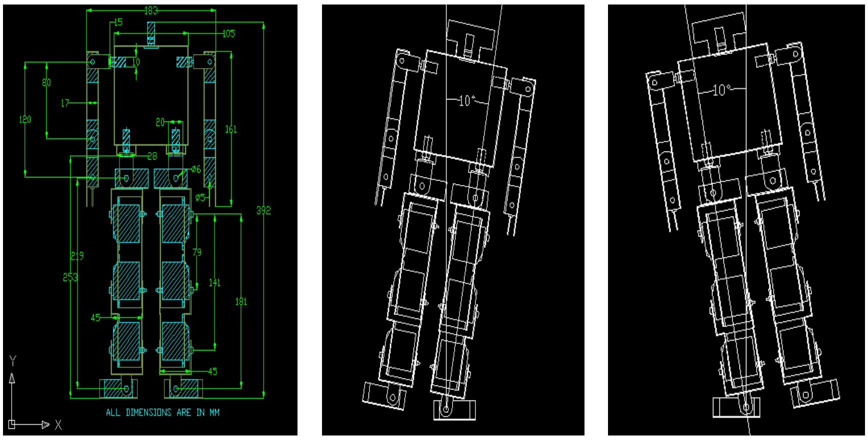
Humanoid Height – 390mm,

Humanoid Width – 190mm

Leg Length – 260mm Hand Length – 160mm

Leg Width – 45 mm Hand Width – 36mm

Total weight of the robot = 1.180 Kg approx.



a).Overall Dimensions b) 10^0 rotation of left ankle joint c) 10^0 rotation of right ankle joint

Fig. 3 Auto-Cad Models of Human Robot (Gnano-369)

Torque calculation at the foot

Torque $T = FrSin\theta$

where F = 1 Kg, r = 24.5 cm and θ=10^0

∴T = 3.89 Kg.cm; with factor of safety 2 the required torque is 7.66 Kg.cm.

Two types of actuators are used in this work at appropriate points following the design. One of them is a high torque capacity servomotor and the other one is medium torque capacity servomotor.

7 Kg-cm Capacity

2 Kg-cm Capacity

Specifications	*Specifications*
Gear Type: All Nylon Gears	Gear Type: All Nylon Gear
Motor Type: coreless motor	Motor Type: coreless motor
Connector Wire Length: 304.8 mm	Connector Wire Length: 150 mm
Stall Torque (4.8V): 5.5 kg-cm	Stall Torque: 2Kg-cm at 4.8V
Operating Voltage: 4.8-6.0 Volts	Operation Voltage:3.0-7.2Volts
Dimensions: 41x20x36 mm	Dimension: 22 x 12 x 29 mm
Temperature Range: -10^0 to 60^0 C	Temperature Range: -30^0 to 60^0 C
Operating Speed (4.8V): 0.20sec/60^0	Operating speed (4.8 V): 0.12sec/60^0

Controlling of robot

The SSC-32 Servo Controller hardware is shown in figure 4. Information, command formatting, servo move or group move, software position offset, output information, reading digital and analog inputs are involved in controlling the robot. With the exception of Mini SSC-II mode, all SSC-32 commands must end with a carriage return character (ASCII 13). Multiple commands of the same type can be issued simultaneously in a Command Group. All of the commands in a command group will be executed after the final carriage return is received. Commands of different types cannot be mixed in the same command group. In addition, numeric arguments to all SSC-32 commands must be ASCII strings of decimal numbers, e.g. "1234". Some commands accept negative numbers, e.g. "-5678". Programming examples will be provided. ASCII format is not case sensitive. As many bytes as required can be used. Spaces, tabs, and line feeds are ignored.

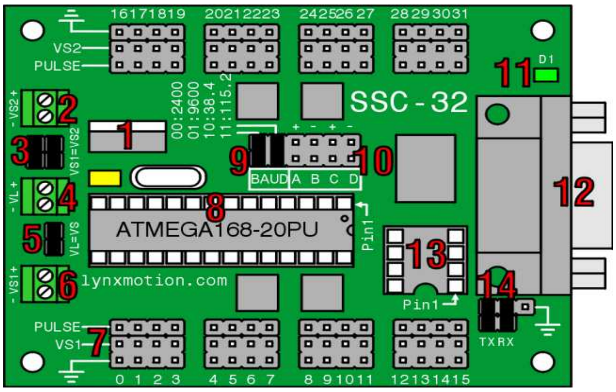


Fig. 4 SSC-32 Servo controllers Board

Command Types and Groups

1 Servo Movement	7 Read Analog Inputs
2 Discrete Output	8 12 Servo Hexapod Gait Sequencer
3 Byte Output	9 Query Hex Sequencer
4 Query Movement Status	10 Get Version
5 Query Pulse Width	11 Go to Boot
6 Read Digital Inputs	12 MiniSSC-II Compatibility

RESULTS AND DISCUSSIONS

Figure-5 represents the application part of a program which includes the buttons like Home, Forward, Right, Left, Back and Stop. These buttons are used to navigate the motions of robot in a controlled manner. Setup command in the pull down menu bar is used to create a virtual COM port in the PC through which serial command signals are sent from PC to actuators through the Servo controller. The Sequence Generator command is used to generate a sequence of commands to achieve stable walking.

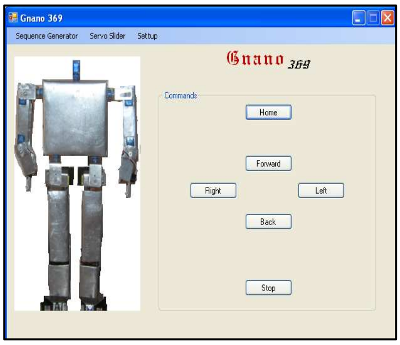


Fig.5 Programmed window

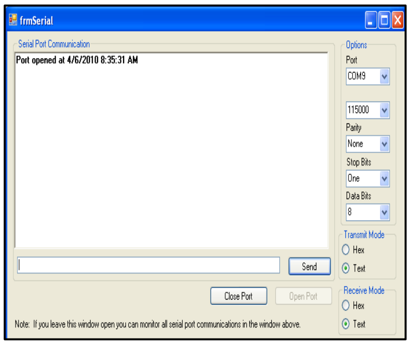


Fig. 6 Virtual COM port in a PC

Figure-6 depicts the creation of virtual COM port in a PC. This creation of COM port is very much essential regarding the controlling of robot through the programming commands. Figure-7 represents the main application part of programming which includes the sequential execution of commands in a cycle of operations and it also actuates the actuators in the order in which the program possess or orders.

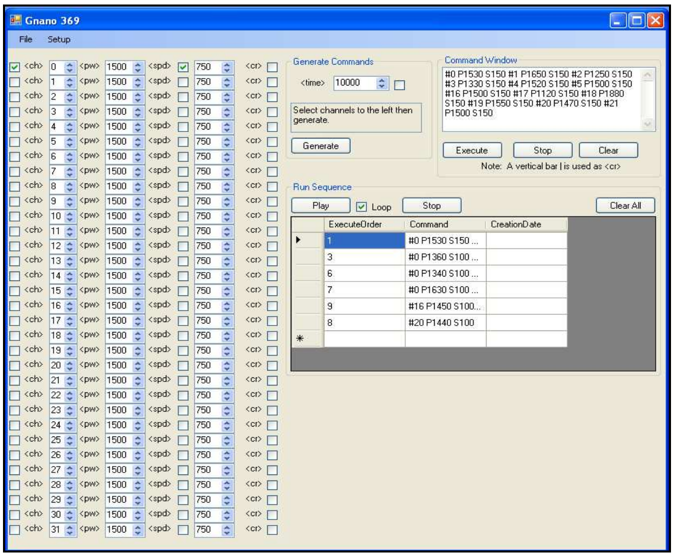


Fig.7 Application part of programming

Execution order of SSC-32 commands for a cycle of walking pattern of the humanoid:

<ssc32Commands ExecuteOrder="1" Command="#0 P1530 S150 #1 P1650 S150 #2 P1250 S150 #3 P1330 S150 #4 P1520 S150 #5 P1500 S150 #16 P1500 S150 #17 P1120 S150 #18 P1880 S150 #19 P1550 S150 #20 P1470 S150 #21 P1500 S150 #22 P1013 S150 #6 P2090 S150 #9 P2200 S300 #25 P1450 S300 #23 P800 S300 #24 P1550 S300" />

<ssc32Commands ExecuteOrder="2" Command="#0 P1360 S100 #16 P1360 S100 #2 P1300 S100 #17 P1110 S100 #18 P1890 S100 #22 P1253 S100" />

<ssc32Commands ExecuteOrder="3" Command="#0 P1340 S100 #1 P1680 S100 #2 P1160 S100 #3 P1180 S100 #4 P1570 S150" />

<ssc32Commands ExecuteOrder="4" Command="#0 P1630 S100 #1 P1670 S150 #2 P1250 S100 #3 P1350 S100 #16 P1600 S100 #22 P1013 S100 #6 P1831 S100" />

<ssc32Commands ExecuteOrder="5" Command="#16 P1450 S100 #19 P1630 S100 #17 P1200 S100 #18 P1900 S100 #19 P1650 S100" />

<ssc32Commands ExecuteOrder="6" Command="#20 P1440 S100" />

Figure 8 shows the experimental results on GNANO’s static walking on a plain smooth surface. Nine photographs were taken sequentially every five sec. From these it is observed that GNANO was successfully able to walk on the plain smooth surface. The Robot is walking at foot step length of 20 mm; it is taking 10 sec per each foot step.

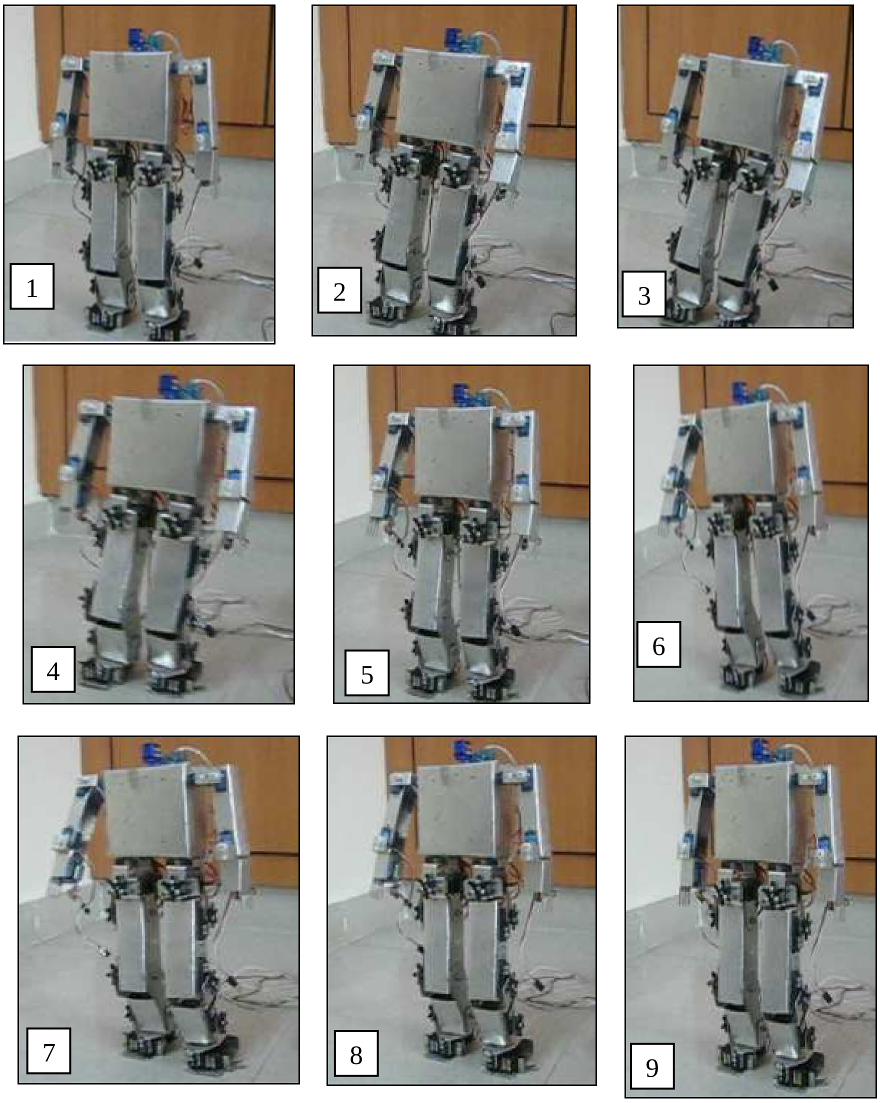


Fig. 8 Sequence photographs of Robot walking on plain surface (5 sec/frame)

CONCLUSIONS

Initially, a brief review of the research work carried out on humanoid robot development has been presented. Later, conceptual humanoid robot designs are introduced and they were evaluated against several design criteria. The conceptual design, kinematic model development and analysis of a biped humanoid robot are presented, named Gnano-369, is capable of biped and quadruped walking as well as configuring itself from one mode into the other. Successfully designed and developed the humanoid robot with 21 DOF and tested the same. Robot is able to walk properly and able to do various actions as per the program. In future, robot can be made more sensible by adding touch, vision, distance measuring, accelerometer, gyroscopic sensors. Currently a computer is used to control the robot, in the future computer can be replaced with a microcontroller fitted directly in the robot to reduce the cost and increase the flexibility.

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