# Humanoid Robots Using Optimization Technique - A Brief Review

**Varsha B, Yogesh Kumar, Ayush Dogra, Varun Dhiman**

**Abstract:** This paper explains a brief history of humanoid robots on their development perspective that was effectively started from past few years in the areas of education, automotive and biomedical engineering. Bipedal robots require a flat surface to move or walk with the help of actuators. Measuring joints in robots require set of encoder's, sensor's for balancing of robot require gyroscope's, accelerometer and ground reaction, forces are needed to be calculated for fingers, sensors like ultrasonic distance robot or proximity sensor's etc. Humanoid robots have been facilitated with different types of expressions such as speech, facial, arms, hands body language etc., and using different types of sensors. Dexterity in the sense of position and orientation is important in robots. Feasible versions of special humanoid robots are Sophia, HUBO, KIBO, Robonaut2, IROMEC, KASPAR, L2TOR, FY1998, Biorobo etc. Trajectory planning like feasibility, safety, comfort and optimization helps in exact motion of robot which is complicated and difficult. Genetic, simulated annealing, ant colony are found modern methods of optimization.

**Index Terms**: Humanoid robot, Sophia, robonaut, optimizations, HUBO, KIBO

## 1. INTRODUCTION

In today's scenario robot, and robotic applications are used in all the industries e.g. automotive, chemical, petroleum, medical instrumentation, education etc. Initial versions of robots such as manipulator arm, starts with 1 degree of freedom (DOF) to 6 degree of freedom. Developing a humanoid robot which is programmed to act like human features. Advantageously, humanoid robot can obtain information from the environment around it and can work physically according to circumstances. Humanoid robots are offered in different size, weight and height. Some robots are remotely operated and are capable of assisting humans in every environment. An 'Astro-boy' was created by a cartoonist in Japan. In the last decades a humanoid robotic technology looked like a doll which is used to serve tea and once tea is severed it comes back to its first position [1]. Usually, humanoid robot has two legs, two hands which can do different work like humans. It is possible with discrete sensors, actuators, artificial intelligence. Sensors help them to correlate with the environment in an efficient way. The main of a humanoid robot is robot design, locomotion and behavior learning [2]. On the other side surgical robots are more in medical industry these days. These robots help in surgery like laparoscopy, tele rounding, rehabilitate and patients assist [3]. Designing a robot for entertainment, domestic purpose, it is important to relate human-to-robot. For this purpose, actually the work is being done in the field of human-computer relation that should be very qualitative to create faith between human-robot relations. Human-robot relation can be studied with the help of psychological and artificial intelligence. Robots designed for entertainment, domestic purpose should be flexible and engineer should see all the possibilities for designing flexible features in robot [4]. Humanoid robot can adapt any changes in the environment and achieves the objectives. Other robots are designed for a specific task to be performed in an industry. Humanoid robots require more sensing, actuating, planning, control and simulate human behavior in the robot. These robots are more complex than mechanical robots [5].

## 2. IMPORTANT ISSUES OF CONSTRUCTION AND CONTROL IN HUMANIOD ROBOT

### 2.1 Bipedal

Walking and running on two legs is simple for human but difficult for humanoid robots. Prominent robots have ZMP controls, which include Honda ASIMO and Sony Qrio. Honda ASIMO is in a position to 6 km/hr running; this robot needs flat, stable surface for running, walking and climb stairs. Humanoid robot has ability to walk on terrain and this is demonstrated like quadruped big dog. Hydraulic actuators are the actuators which consist of fluid motor which provides hydraulic power for mechanical operation in pneumatic actuators i.e. lucky, was designed in Brussels. These are used to implement joints in which walking was still not easy task.

### 2.2 Perception in humanoid robot

To measure robot joints using encoders, sensors etc. Balancing of the robot is important. This is done with the help of gyroscopes and accelerometers. Some humanoid robots calculated ground reaction, forces at hand fingers. These robots use ultrasonic distance sensor or proximity sensor. The essential features like a camera used for vision humanoid robot interface with computers for image interpretation and it interlinks with authentic environmental image. When interpreting audio signals with microphones the main problem interfacing with humans is extra noise. Microphone arrays are utilized to hear and speech recognition system has more error rates. Due to problems in perception, humanoid robot use in teleportation, where signals are stored in the robot and interfaced by a human e.g. Robonaut by NASA and PR1 by Stanford [6].

### 2.3 Human-robot interface

Human, robot communication should be like ball and player interaction. In humanoid robot different type of expression i.e. speech, facial, arms, hands body language etc., this is possible with the help of different sensors. Robot has to fulfill social expectations of communication with the environment. Some examples are kismet and Leonardo designed by MIT. The emotions part can be done with the help of pitch, movement, speed and speech which are difficult to attain with humanoid robots [7].

### 2.4 Dexterity in robots

Position and orientation of the robot at a location within the workplace should be known as orientation and position of hands and legs. At a point, it is impossible to operate the orientation of the robot. We can position the robot at a place but its orientation is very complex [8].

## 3. INDUSTRY USING HUMANIOD ROBOT

In the early era, Leonardo da Vinci designed a mechanical man (1495). Later he designed a humanoid robot which was automatic and mechanical living entity in Egypt, Greece and China. After Vinci's another invention called Iliad which was known as the golden maid.

### A. Social

Sophia, a social robot which is designed by Hong-Kong based company known as Hanson robots. Danvid Hanson and team activated Sophia in 2016. The features used in Sophia are artificial intelligence, visual data processing and face recognition. Due to which it can attain upon 60 expressions e.g. grief, happy, anger, joy, amazementetc. Frubbet (silicon) is the material that is used to make her skin. Sophia is a robot which has a complete blend of human emotions as well as electronic synthetic voice and possesses anthropomorphic skills [7]. HUBO robot developed in 2004, and has 6 DOF in head, 6 DOF at each arm, 6 DOF at each leg, actuator used in DC motors, controller used in the single board computer, battery for power supply. This robot was capable of real time climbing. KIBO robot has 5 DOF in eye, 2 DOF in neck, 5 DOF in lips, arm has 3 DOF in shoulder, 1 DOF in elbow, 2 DOF in wrist, and legs have 3 DOF in hip, knee in 2 DOF, ankle in 2 DOF in walking control. KIBO has stereo cameras, inertia sensors, microphones, ultrasonic sensors and many more. The appearance of KIBO robot is childlike, intelligent tasks, emotional communication and human-robot interface [9

.

### B. Space

**Robonaut 2**

Humanoid robot replacing human to enter into space, the NASA researcher work together with General motors to create a humanoid robot which was sent to international space station in 2011 and known as Robonaut 2[10].

### C. .Health

**IROMEC & KASPAR**

Humanoid robot in hospitals is used for assisting nurse and help people to communicate in hospitals. This assistance is specifically for those patients who cannot walk or move. These two robots are designed for autism children who cannot interact, communicate, imagination i.e. daily routine of those children [11].

### D. Education

**L2TOR**

A robot which is actually a tutor, is designed in softback robotics by European project known as L2TOR. Their work is to teach students various language other than English [12]. Humanoid robots for children are being made to learn spelling, storytelling, nutrition, general sciences. These robots are used with human teachers [13]. Biorobo robot is a teaching systems used connect to human body [14]. This robot uses a VSMF method like data sorting and smooth work of robot.

### E. Home

Humanoid robot prototype is designed with MEMT (ministry of economy, trade and industry) FY1998. This robot is designed for home management in Japan which was controlled by a remote. It is a sensor based tele-operation system, so that it will do all the work [15].

## 3 FABRICATION OF ROBOTS

Robots need some basic components for fabrication.

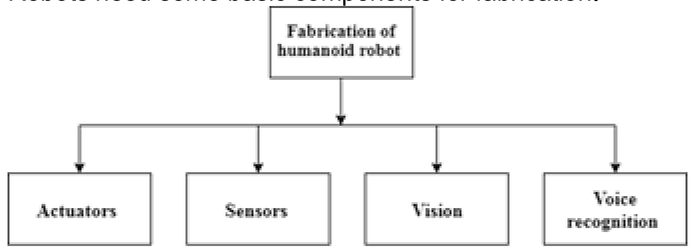


***Fig 1:*** *shows fabrication of Humanoid robot*

Actuators are muscles and joints for motions in a humanoid robot. Hydraulic, electric actuators are strict behavior actuators. High speed low load electric motors are used for complicated task. In case of hydraulic motors, these are used for minimizing speed and high load applications. In case ultrasonic actuators, which are designed for movements with frequency (20 kHz), in these types of actuators, which controls the vibration, positioning and switching. In pneumatic actuators compressed gas is used for various motions specifically used for linear motions/trajectory at minimal speed and simple application. Sensors are very important part of humanoid robot as they help the robot to interface with the environment. For this purpose, sensors can be classified on the basis of sensing mechanism e.g. example positions sensors, tactels sensors (vision sensors), and proximity sensors. In position sensors orientation is used to control the position of limbs, joints and motions in humanoid robot. Tactile sensors are used for visualizing the environment of robots and arrays are used to feel sense of touch or detection of physical interaction with objects. These sensors are used to control force and torque in humanoid robot. Proximity sensor is also referenced as a distance sensor. It helps to avoid obstacles in the environment without any physical contact as this sensor emits electromagnetic field radiation and estimates changes in returned signals [16].

## 4. WORKING OF HUMANIOD ROBOT

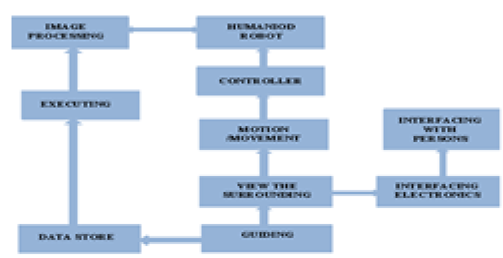


***Fig 2:*** *working process of humanoid robot*

In the above Fig 2, the working process of humanoid robot is shown.

## 5. TRAJECTORY PLANNING

Trajectory defines Cartesian space (position and orientation) using a teach pendant program in which the velocity between space i.e. position, orientation and maximum system is different for Cartesian as well as joint space motion shown in fig 3 [17]. Significance of trajectory planning are feasible, safety, comfort and optimization etc.

A) B)

***Fig 3*** *Cartesian space trajectory: a) robot run into itself in Cartesian space, b) change in joint angles [20].*

Joint space trajectory planning, joint space trajectory has different types such as different orders of polynomials and parabolic blends with linear function [20].

1. 3-order polynomial trajectory plan;

The initial location and orientation of the robot can be identified using inverse kinematic equation that helps to find joint angles. The joint angles for a particular position and orientation with coefficient of a 3 order polynomial;

$\alpha$ (T) = $\boldsymbol{b_1 T + b_2 T^2 + b_3 T^3}$

Initial and final condition $\alpha(T_j)$=$\alpha_j$; $\alpha(T_k)$ =$\alpha_k$;

$$\alpha(\dot{T_j}) = 0$$
$$\alpha(\dot{T_k}) = 0$$

First derivative of equation;

$$\boldsymbol{\alpha(\dot{T}) = b_1 + 2b_2 T + 3b_3 T^2}$$

$$\begin{bmatrix}\alpha_0\\\alpha_1\\\alpha_2\\\alpha_3\end{bmatrix}=\begin{bmatrix}1 & 0 & 0 & 0\\0 & 1 & 0 & 0\\1 & T_j & T_j^2 & T_j^3\\0 & 1 & 2T_k & 3T_k^3\end{bmatrix}\begin{bmatrix}b_0\\b_1\\b_2\\b_3\end{bmatrix}$$

2. 5-order polynomial trajectory plan;

Equation allows to calculate coefficient of 5th order polynomial with initial, ending positions, acceleration and velocity is;

$$\boldsymbol{\alpha(T) = b_0 + b_1 T + b_2 T^2 + b_3 T^3 + b_4 T^4 + b_5 T^5}$$

Differentiating this equation 2 times, we get;

$$\boldsymbol{\alpha(\ddot{T}) = 2b_2 + 6b_3 T + 12b_4 T^2 + 20b_5\ T^3}$$

These are equation of 5th order polynomial for position, acceleration and velocity.

3. Higher order

The position, velocity and acceleration at each point to plan for continuous trajectory plan. Equation;

$\boldsymbol{\alpha(T) = b_0 + b_1 T + b_2 T^2 + \ldots\ldots + b_{n-1} T^{n-1} + b_n T^n}$

The above equation used to calculating joint position, joint angles (each joints) which is very tenuous.

Planning motions of humanoid robot is a very complex task similarly footstep planning can reduce the computational burden [18].In literature, using foot step planning; the locomotion of humanoid robot is a vague step to procedure to handle. Humanoid robot plays important role in tackling the obstruction while walking on the surface and also planning on foot step angle while stepping. Kuffners algorithm is used for motion planning and also have a discrete set of statically stable footstep locomotion for a humanoid robot [19].

## 7 MODERN OPTIMINZATION METHOD

The methods are based on the characteristics and behavior of biological, swarm of insects, neurobiological and molecular systems. The methods are discussed as follows:

### 7.1 Genetic optimization

Optimal design is characterized by mixed continuous, discrete variable, discontinuous and non-convex design. Non-linear programming techniques are inefficient and expensive. Genetic optimization is used for calculating optimal solution for robots and robotic applications [16]. Objective function and constraints for genetic optimization are Fitness function G(y), Objective function g(y), Maximize, G(y) = g(y), Fitness function G(y) = 1/1+g(y), Fitness function G(y), Genetic algorithm obtained: G(y) = 1/1+θ(y), where y is design vector and θ angle difference.

### 7.2 Simulated annealing

In this method, heating of metal is done. When a metal is heated at high temperature then the atoms of molten metal move freely. As the temperature is reduced, the atom movement is restricted and atoms form crystals at minimum internal energy. If the molten metal is quickly cooled then it cannot form a crystalline form as this phenomenon is called annealing [19]. Boltzmann probability distribution:

A (F) = $e^{-F/Bt}$

Energy (F) of the system, Thermal equilibrium temperature (t), Probability of achieving A (F), B is Boltzmann constant.

Boltzmann constant as scaling factor in simulated annealing, ($F_{j+1}$) designed point depends on energy state's

Hence A ($F_{J+1}$) = [$e^{-\Delta F/Bt}$]

### 7.3 Ant colony optimization

Ant colony optimization is a method which helps in finding the shortest path. This method is developed by Doriya in 1990. Please refer Fig 3 to understand the multilayer optimization methods.


***Fig 3:** calculated the shortest path from office to home [21]*

### Ant searching behavior

Ant h, node j, pheromone trail $\alpha_{jk}$ , θ is degree, B is ant searching, $M_j^h$ is set of neighbor nodes

$$B_{jk}^{(h)} = \begin{cases} \frac{\alpha_{jk}^{\theta}}{\Sigma \alpha_{jk}^{\theta}} & if\ K \in M_j^{(h)}, if\ K \in not\ M_j^{(h)} \\ 0 \end{cases}$$

### 7.4 Fuzzy optimization

This is an optimization technique in mathematics. The real problems, design data, objective function and constraints function is given below [20][21]. Let Z set of objects called universe ,Generic element by z ,Subset B of Z ,Characteristic function $\alpha_B$ from Z to [0,1],

$$\alpha_B(z) = \begin{cases} 1 if\ z \in B \\ 0\ ifz\ \in not\ B \end{cases}$$

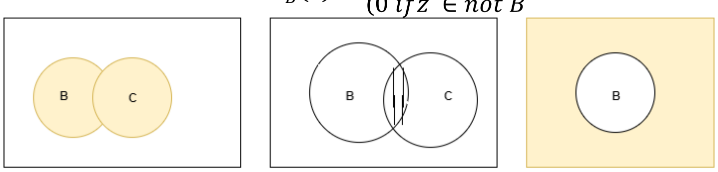


***Fig 4:** a) B or C or both; b) B&C; c) not B [21]*

**Result:**

Intersection of the fuzzy sets with B &C Minimization;

$$\alpha_{B\cap c} = \alpha_B(z) \cap \alpha_c(z)=[\mu_B(z), \mu_c(z)] = \begin{cases} \alpha_B(z) if \alpha_B < \alpha_c \\ \alpha_c(z) if\ \alpha_B > \alpha_c \end{cases}$$

Genetic and fuzzy algorithms are found more efficient as modern tool to complete optimal solution in robotic systems.

## 4 CONCLUSION

Humanoid robot is everywhere in the industries i.e. healthcare, education, space, social etc. The concept of humanoid robot needs sensors, actuators to teach, inform robot to acquire human nature i.e. expression, head, body, legs etc. Humanoid robots have been developing for last few years in every industry some of examples are Sophia, HUBO, KIBO, Robonaut 2, L2TOR, Biorobo, honda ASIMO etc. Trajectory planning is key feature in walking, stair climbing, stair descending, bipedal etc. Modern method optimization techniques like Genetic algorithm, Simulated annealing, Ant colony optimization and fuzzy optimization are found best techniques for optimal solution.

## REFERENCES

[1] Akhtaruzzaman, Md, and Amir A. Shafie. "Evolution of humanoid robot and contribution of various countries in advancing the research and development of the platform." In ICCAS 2010, pp. 1021-1028. IEEE, 2010.

[2] Ting, Chen-Hunt, Wei-Hong Yeo, Yeong-Jin King, Yea-Dat Chuah, Jer-Vui Lee, and Wil-Bond Khaw. "Humanoid robot: A review of the architecture, applications and future trend." Research Journal of Applied Sciences, Engineering and Technology 7, no. 7 (2014): 1364-1369.

[3] Azeta, Joseph, Christian Bolu, Abiodun A. Abioye, and Fetus A. Oyawale. "A review on humanoid robotics in healthcare." (2017).

[4] Lund, Henrik Hautop. "Modern artificial intelligence for human-robot interaction." Proceedings of the IEEE 92, no. 11 (2004): 1821-1838.

[5] Gupta, Parul, Vineet Tirth, and R. K. Srivastava. "Futuristic humanoid robots: An overview." In First International Conference on Industrial and Information Systems, pp. 247-254. IEEE, 2006.

[6] Behnke, Sven. "Humanoid robots-from fiction to reality?." KI 22, no. 4 (2008): 5-9.

[7] T.Fong, Terrence, Illah Nourbakhsh, and Kerstin Dautenhahn. "A survey of socially interactive robots." Robotics and autonomous systems 42, no. 3-4 (2003): 143-166.

[8] Kim, Jung-Yup, Ill-Woo Park, and Jun-Ho Oh. "Experimental realization of dynamic stair climbing and descending of biped humanoid robot, HUBO." International Journal of Humanoid Robotics 6, no. 02 (2009): 205-240.

[9] Lee, Sangyong, Jung-Yup Kim, and Munsang Kim. "Development and walking control of emotional humanoid robot, KIBO." International Journal of Humanoid Robotics 10, no. 04 (2013): 1350024.

[10] Niku, Saeed B. Introduction to robotics: analysis, control, applications. John Wiley & Sons, 2020.

[11] Fong, Terrence, Illah Nourbakhsh, and Kerstin Dautenhahn. "A survey of socially interactive robots." Robotics and autonomous systems 42, no. 3-4 (2003): 143-166.

[12] Aditi pansari, Akrati Singh, Anoushka pathak,"Review on advanced robotics and humanoid robot",International

journal of innovation and advancement in computer science, vol 7,feb 2018, ISSN 2347-8616.
[13] Leng, Chuntao, Qixin Cao, Bo Fang, Yang Yang, and Zhen Huang. "Development of Humaniod Robot Teaching System Based on a RGB-D Sensor." In Nature-Inspired Mobile Robotics, pp. 317-324. 2013.
[14] https://builtin.com/robotics/robotics-in-the-classroom accessed on [11-12-2019].
[15] Choudhury, Avishek, Huiyang Li, Dr Greene, and Sunanda Perumalla. "Humanoid Robot-Application and Influence." Avishek Choudhury, Huiyan Li, Christopher M Greene, Sunanda Perumalla. Humanoid Robot-Application and Influence. Archives of Clinical and Biomedical Research 2, no. 2018 (2018): 198-227.
[16] Sawasaki, Naoyuki, Toshiya Nakajima, Atsushi Shiraishi, Shinya Nakamura, Kiyoshi Wakabayashi, and Yusuke Sugawara. "Application of humanoid robots to building and home management services." In 2003 IEEE International Conference on Robotics and Automation (Cat. No. 03CH37422), vol. 3, pp. 2992-2997. IEEE, 2003.
[17]https://www.dis.uniroma1.it/~deluca/rob1_en/13_TrajectoryPlanningJoints.pdf accessed on [31-12-2019]
[18]https://en.wikipedia.org/wiki/Humanoid_robot#Actuators accessed on [14-12-19].
[19] Zhao, Ran. "Trajectory planning and control for robot manipulations." PhD diss., 2015.
[20] Niku, Saeed B. Introduction to robotics: analysis, control, applications. John Wiley & Sons, 2020.
[21] Rao, Singiresu S. Engineering optimization: theory and practice. John Wiley & Sons, 2019.