International Journal of Engineering, Science and Mathematics
Vol. 7 Issue4, April 2018(special issue NCIME)
ISSN: 2320-0294 Impact Factor: 6.765
Journal Homepage: http://www.ijesm.co.in, Email: ijesmj@gmail.com Double-Blind Peer Reviewed Refereed Open Access International Journal - Included in the International Serial Directories Indexed & Listed at: Ulrich's Periodicals Directory ©, U.S.A., Open J-Gage as well as in Cabell's Directories of Publishing Opportunities, U.S.A

AN IMPACT ON SUCCESSFUL LEARNING OF HUMANOID ROBOT USING EVOLUTIONARY ALGORITHM

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***Abstract*--Robots became irreplaceable in the modern world. Every manufacturing and production sectors are in the need of self-sophisticated environment. That will be widespread throughout the world. Latest development in the automation is robots. Biped robots are used in the process of research and technology. The step by step movement of the robots has been predicted by the desired motors. Objects will be recognized by the sensor placed in the robot. Firstly the locomotive function of the robots will be designed for the process. Collision avoidance method will be the key factor for the robots to walk without any distortion. Zero moment point helps the robots for stable walk and place the centre of gravity at a fixed point. Recognize the objects will be the main theme of the project, various applications can be added for future function. Gait pattern is very important term in the function of robot.**

Keywords-- Robot, Central Pattern Generator, Simulator, webots.

I. INTRODUCTION

The primitives of robot that can be depend on three terms sense, plan, and act. The information will be get from the sensor to the robot that will be based on sensing category, next performing one or more task at a time depends on the function of planning category, function that produce the output will be based on the act category. Gait pattern is very effective in the process of robot walking design, some of the common methods used for the walking pattern will be given in the following terms, collision avoidance method have the trajectory planning in consideration of the pushing force the arm[5].

Zero moment point helps to measure the distance between the two feet and predict the condition for the stable walking [1, 2, 4]. Parameter over the trajectory planning [6].Central pattern generator have inspired control for adaptive walking of biped robot will be helpful for motion control from workspace to joint space [9]. Dynamic concept of design and process. Human and animal locomotion are inherent and exhibit stable rhythmic movement, in spite of various sensors and actuators. The neural circuit of oscillator on spinal cord is defined as Central pattern generator to have efficient swing motion of the motor. The mathematical form of the neural oscillator for various application of robotic was first formulated by Matsuoka [7, 8].

The characteristics of the neural oscillators to generate stable bipedal locomotion by the sensory feedback signal robot joints [14].In a 2D simulation robot control became robust and able to walk or climb an upward slope and this concept will be applied in 3D simulation by webots. The important goal of the biped locomotion is stability and reliability of walking control consisting of feedback sensory circuit.

II. PROPOSED METHOD

A. GAIT LOCOMOTION

Gait locomotion is a pattern of the limbs of animals including humans, during solid substrate [13]. Central pattern generator is used to create Gait locomotion. It helps to move the robot in stable and sustained environment. The inverse kinematics of the robot played a vital role in the Central pattern generator method.

B. KINEMATICS OF THE ROBOT

In this paper, Kinematics means the analytical study of the geometry of motion of a machine, with respect to a fixed reference coordinates, without regard to the focus that causes the motion. The study of geometric and time based quantities like position, velocity and acceleration are considered. Inverse Kinematics is used to generate the trajectory ankle of the robot motion.

Fig 1.Shows the bottom structure and correspond coordinates of R1.

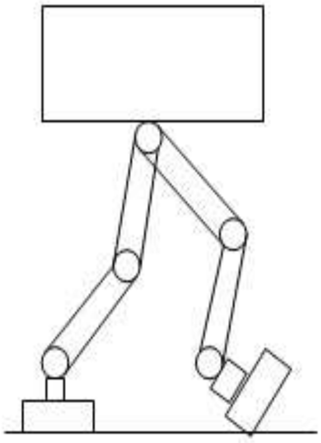


Fig 1 .Bottom structure of R1

B.1 TRAJECTORY GENERATION

In this paper, it lets the end–effector of the robot that moved from one point to another point through some specified intermediate points. The experiments in joint velocities and acceleration will overcome the cubic spines in the path.

B.2 POSITION CONTROL

If the desired point known, then the individual joints are provided with the separate system. The actual displacement is measured by sensors at with the joint. The difference signal $e_1 = \theta_1 - \theta_1$ is used to drive the joint motors, where error trends to zero and the time trends to infinity.

C. ROBOT MOTION ANALYSIS

In motion analysis the geometry of the robot bottom with the reference coordinate system, while the end-effector moves along with the path.

1. Determine the coordinates of the end-effector.
2. Determine the joint coordinates for a given location of the end-effector.

Generally, end-effector can be based on two systems:

C.1 JOINT SPACE

It will represent the position of the end-effector.

$$v_i = (\theta, a)$$

$$(L_1, L_2) \quad (2)$$

$$(\alpha, L_2) \quad (3)$$

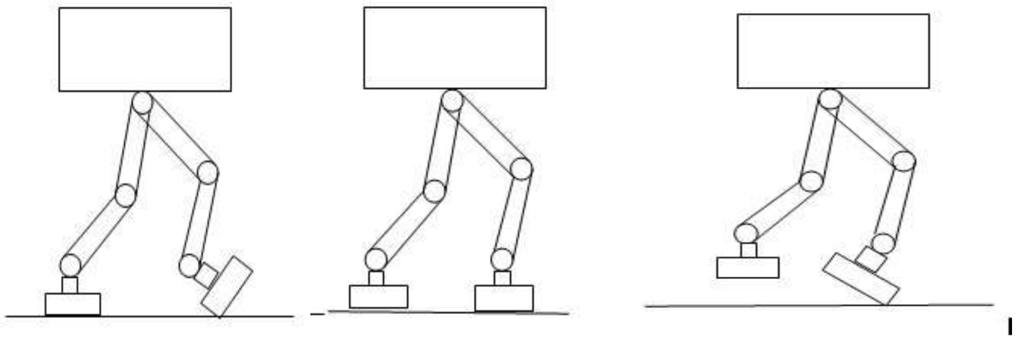
with the joint parameter. such as rotating, variable link length and twisting joint angles.

C.2 WORLD SPACE

In this paper, Rectilinear coordinates with reference to the basic system. The origin of the axes is located in the robot base.

$$= (x, y) \quad (4)$$

vw → refers to the position of the end-effector.



a b c

Fig 2 .Motion analysis of R1

D. CENTRAL PATTERN GENERATOR

The position of both ankles of a robot. Which are p_x^l, p_y^l, p_z^l p_x^r, p_y^r, p_z^r represented as:

$$p_z^l = Z_0 - A_z * q_z \tag{5}$$

$$p_z^r = Z_0 + A_z * q_z \tag{6}$$

$$p_x^l = X_0 - A_x * q_x \tag{7}$$

$$p_x^r = X_0 + A_x * q \tag{8}$$

$$p_y^l = Y_0 - A_y * q_y \tag{9}$$

$$p_y^r = Y_0 + A_y * q_y \tag{10}$$

This equation will be helpful for the motion process of the robot.

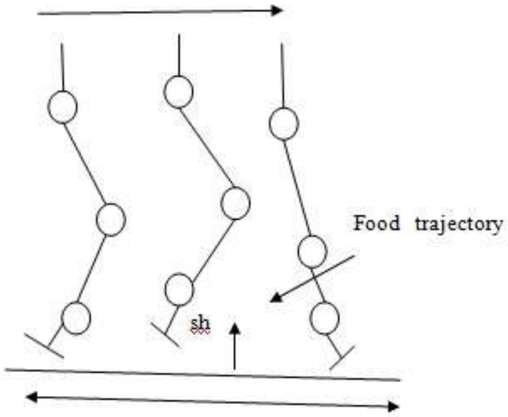


Fig 3 .Trajectory of a leg during walking of R1

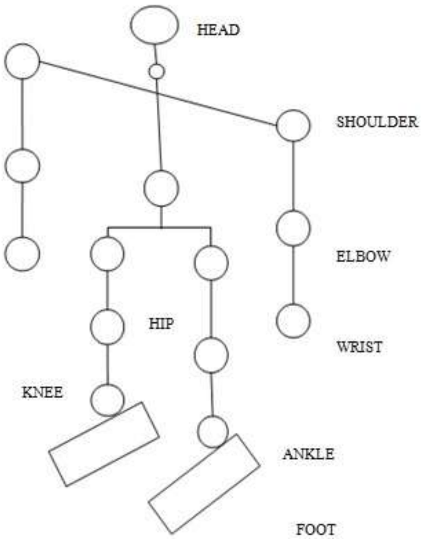


Fig 4 .Pattern of R1

III. METHODOLOGY

A.COLLISION AVOIDANCE METHOD

In this method helps the robot to stop in front of an obstacle by generating a arm force that helps to avoid crash. It must be helped by trajectory planning that will be consider as pushing force , If it movable robot can walk using Linear inverted pendulum model [15]. External orbital energy is used for robot move (or) stop (or) modify action (sensor system, control scheme). Zero moment point (ZMP) is used for pushing motion helps for stability, while modify. The upper body is same as the lower body. When object arm detect any obstacle first it will stop , second it modify trajectory ankle torque. It has parallel link mechanism such as Jacobian is used for this mechanism.

A.1. MODELLING

It has parallel link mechanism such as Jacobian is used for this mechanism.

Table 1: Modelling

Parameter	**Values**
Mass	1.624 kg
Density	872.305kg/m^3

LIPM and ORBITAL ENERGY

The dynamic of the pendulum is very simple. CoG height of robot is z_b and is constant.

The acceleration of mass is

$$ \vdots\ {}^{g}\!/_{2b} \,.\, x_b(t) \qquad (11) $$

b

→ X_b Position vector

→ E Orbital energy $E = \frac{x_b(t)^2}{2} - w^2 \frac{x_b(t)^2}{2}$ (12)

Force acting on Centre of Pressure & Zero Moment Point. It deals with the implementation of fast and dynamic walking gaits (anthropomorphic gaits) [23], CoP and ZMP are very useful.

→ CoP respect to ground feet contact force

→ ZMP respect to gravity plus inertia force

It will obtain the initial result and implementation of postural motion and static walk. The robot foot is fixed with the sensor measuring the ground foot force to exploit CoP and ZMP.

CoP Vs ZMP

1) Force exerted by contact
2) Force transmitted without contact

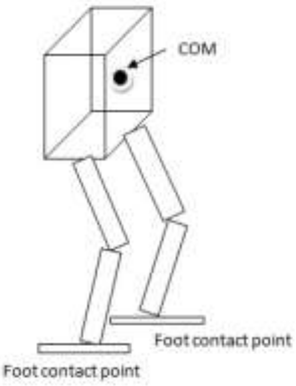


Fig 5. ZMP trajectory

There are two type of force acting on the biped robot trajectory will be former and latter. Where CoP will be consider as former and the ZMP will be consider as latter .CoP gives where the foot contact with ground, the field of pressure is equivalent to single resultant force is zero, and ZMP gives the inertia force is zero. That will support the tangential to the surface.

B. NORMAL ZMP TRAJECTORY

The key problem is walking reference trajectory generation, linear inverted pendulum mode [115] and ZMP [2, 4]. Based on the reference generation algorithm with LIMP and ZMP. Inverse Kinematic based joint space controller is used for the test of the developed reference trajectory theory full dynamic 3D simulation. 12 DOF robot model is used for simulation. IT helps for the efficiency, stability and flexibility. Intuitive criterion is used for reference generation that should be suitable for the robot. ZMP is used to generate a stable gait instead of LIMP.

Table 2: Centre of Mass

	Relative	**Absolute**
COM	-0.0104998	-0.033947
	-0.018741	0.171723
	-0.0161663	0.708671

C. STABILIZER

It modifies the pattern of walking, so that robot can walk despite modelling error and disturbance.

C.1. ARCHITECTURE

The architecture of the robot has basic of kinematics, where two type of kinematics will be used for the action of robot; they are Inverse kinematics and Forward kinematics so as,

Forward kinematics of robot is,

$$R_B^d = R_{rpy}(\qquad) \quad (13)$$

$$[P_1^d, R_1^d, P \quad (14) \quad FK(P_B^{in} R_B^d q^d)$$

R_B^d → Reference body Postural

P_B^{in} → body position that must be set to origin (zero).

For, Inverse kinematics of robot is,

$$q^s : \quad (15) \quad R_B^s P_1^s R_1^s P_2^s R_2^s)$$

When LIPM has the vector r that point from midpoint of two foot.

$$r \quad (16) \quad P^{in} \quad \frac{(P_1 + P_2)}{2}$$

$$r^{\text{'}} \quad (17) \quad \frac{-(P_1^d + P^d{}_2)}{2}$$

Table 3: Architecture model

Parameter	Description
f_i^d, τ_i^d	Foot force and moment
q^d	Joint angle
ϕ^d, θ^d, ψ^d	Body posture
$w_{\mathbf{B}}^d$	Angular velocity
$phase$	Walking phase

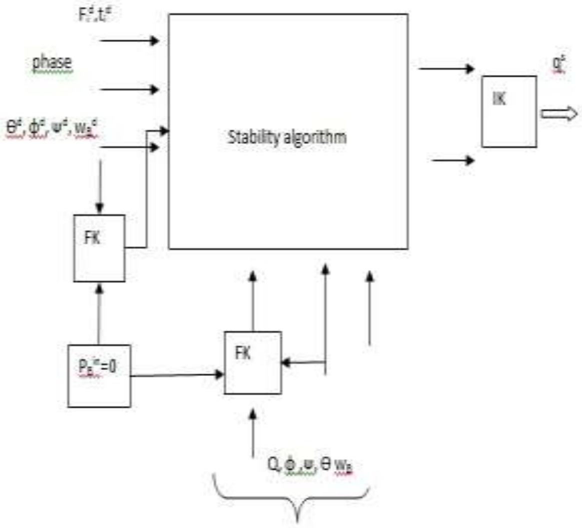


Fig 6. Architecture of stabilizer

POSTURAL CONTROL

In this process, it controls the body rotation, so actual postural (ϕ, θ) became (ϕ^d, θ^d).

$$\Delta\phi = k_B \quad (18) \quad + d_B(w^d_{Bx} - w_{Bx})$$

$$\Delta\theta = k_B \quad (19) \quad) + d_B(w^d_{By} - w_{By})$$

Inverted pendulum model represent the CoP and the coupled oscillator model (COM) [15].

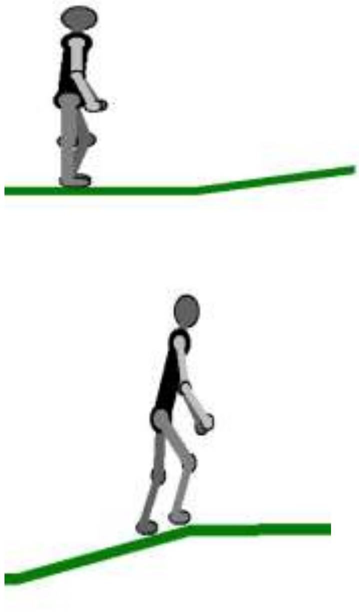


Fig 7. Postural control of R1

D. COUPLED OSCILLATOR MODEL

The process of the coupled oscillator model (COM) has two type of phase; they are phase of a biped controller ϕ_c and the phase of the robot dynamic ϕ_r . The equation of the oscillator will be as,

$$\phi_c \; \dot{} \quad (20) \quad {}_c \sin(\phi_r - \phi_c).$$

$$\phi_r \; \dot{} \quad (21) \quad {}_r \sin(\phi_c - \phi_r)$$

When $w_c > 0$ and $w_r > 0$ are the natural frequency of the controller.

$|w_r - w_c| < k_c + k_r$ → fixed two points

$|w_r - w_c| > k_c + k_r$ → No fixed points

Phase difference of the oscillator model will be have this equation ϕ^* and compromise frequency w^* as,

$$\phi^* = \phi_r - \phi_c = \sin^{-1}((w_r - w_c)/(k_c + k_r))$$

$$w^* = (k_r w_c + k_c w_r)/(k_c + k_r) \qquad (23)$$

E. PHASE DETECTION

In this function, it is a major issue in (22) ›ot controller dynamic space.

$$X = (y, y^{\bullet}, \psi^r, \psi^{\bullet r})$$

$$\phi_r(X) = -\arctan(\frac{y^{\bullet}}{y}) \qquad (24)$$

In this method the function of biped robot has controller with dynamic space of $\phi_r(X)$. Which will produce continues motion of each step in counter manner. Centre of pressure and Centre of mass will be calculated for the each stepping motion.

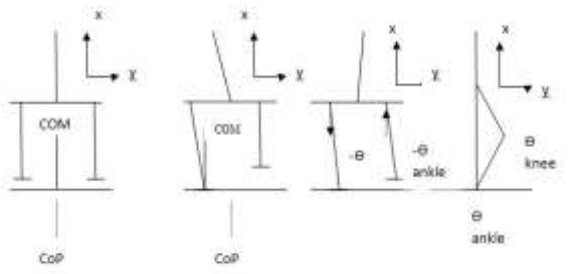


Fig 8. Phase detection

SIMPLE CoP DETECTION

Consider the force of both left and right foot and position of both the foot based according to equation,

$$y = \frac{y^1_{foot}F^1_2 + y^1_{foot}F^2_2}{F^r_2 + F^l_2} \quad F^r_2, F^l_2 \qquad (25)$$

shows the right and left ground reaction force and $y^1_{foot}F^1_2, y^1_{foot}F^2_2$ shows the lateral position of each foot.

STEPPING MOTION

This will be generated by the simulation software of RoboBASIC IDE [24] and webots [25] must be used for 3D simulation.Human machine interface (HMI) will be used to communicated with the simulator.RS232 cable is used to communicate with the HMI and the simulator. The overview of the self developement software has many relationship with the simulated design.Combine with the random flash memory, the module will be connected with the data analysis and motion execution module that can be accessed by the different multi-processor system.

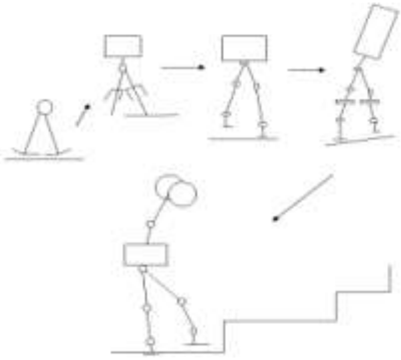


Fig 9: Stepping Motion

F. DYNAMIC BALANCE CONTROL

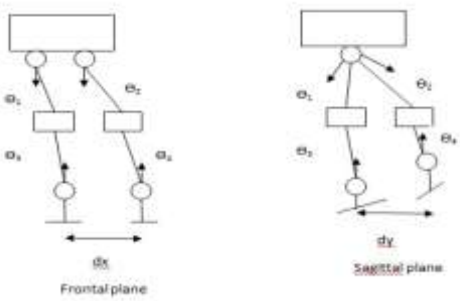


Fig 10. Dynamic balance control

In dynamic balance control, ZMP trajectory modulate both in sagittal and lateral plane makes flexible. It includes kalman filter (KF)[6] and fuzzy motion controller (FMC)[6] based on robot body balance and follow reference of ZMP. KF is used to estimate system system and reduce the effect caused by noise. Such as motion generation,gait analysis,sensory reflex[17] and locomotion planning,[14] ,ZMP [2,4],dynamic analysis and balance control[6]. It helps the robot to stand and walk without falling down. Kalman filter helps to have efficient recrusion mean to estimate the state of process by minimize mean of square error . designed with the degree of freedom DOF.

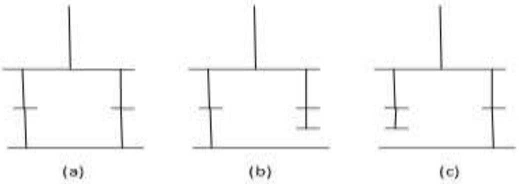


Fig 11. Degree of freedom

III. OVERVIEW OF ALGORITHM

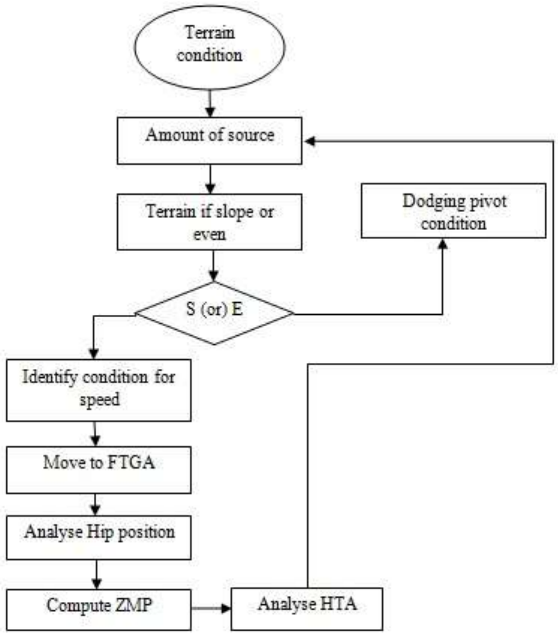
The algorithm is very efficient for the optimization process, in that different type of algorithm is used to optimize the output performance. Based on swarm activities of animal. Some similar algorithm that optimizes the performance just like PSO and ABC [11, 12] .

The potential solution of algorithm will be optimizing. In first step, the scouts are scattered about seeking among possible ranges. Then the cost causes the path and shares their information with the system. The algorithm will choose depending on the probability of each source [28]. All the notation and condition will specify the fitness and the number of source. Figure 4.shows the algorithm of the optimization process used for the robot. Fitness will be calculated for each process carried in each step of the optimization technique.

$$(26) \quad = \frac{fit_i}{\sum_{n=1}^{SN} fit_i}$$

Maximum iteration can fit the target value as stopping condition. It is a stochastic search technique .To evolvate the performance of each parent individual, fitness value will be assigned it use to generate the optimal robot walking sequence. It helps to walk in ststic and dynamic motion where it has both even and uneven terrains.

Fig 12 .Flowchart of algorithm



The hip trajectory will be observed.when hip lifted to maximum height if robot walk in uneven terrins or moving forward. While coming down the hip will be lowered enable to land the foot in the surface to estimate the walking cycle swing foot trajectory is used.

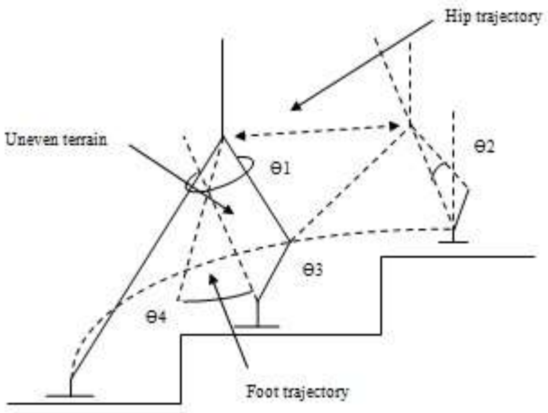


Fig 13. Hip trajectory

IV.SYSTEM INTEGRATION

The required output will be calculated by adjusting the weights of the fitness that will leads to different learning .Gait performance will be totaly different from the prospect in the condition.

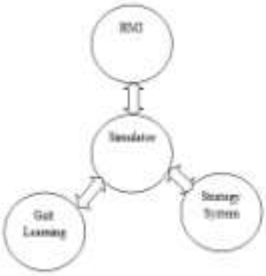


Fig 14. System integration with simulator

A. ROBOT SIMULATOR

In this section , The RobotBASIC IDE consists of an Editor screen, Terminal screen, Help screen, and Debugger screen. Each screen has many buttons and menus that facilitate the various actions required in each screen. It has been facilitate the creation,editing, and running of program.Very convenient process will be directly combine the simulator with other software . Human machine interface (HMI) will be connector to the simulator for control and information module can be assigned. According to the environment assest user's preference in the IDE V2.1 is used in the RobotBASIC simulator.

B. SIMULATION ARCHIETECTURE MODEL

In this section, the simulation archietecture model of the robot can be implemented in RoboBASIC IDE software program, solidworks[13] must be used for 3D simulation.Human machine interface (HMI) will be used to communicated with with the HMI and the simulator. The overview of the self developement software has several relationship with simulated design.Combine with the random flash memory, the module will be connected with the data analysis and motion execution module that can be accessed by the different multi-processor system.

V. EXPERIMENTAL RESULT & DISCUSSION

In this section, the Gait pattern are illustrated and obtained the result of biped locomotion of robot. Then the proposed simulator output has be addressed, by using Zero moment point , Collision avoidance method and Central pattern generator method ,various application can be added to this process to perfrom numourous task for use the simulator. RS232 cable is used to communicate

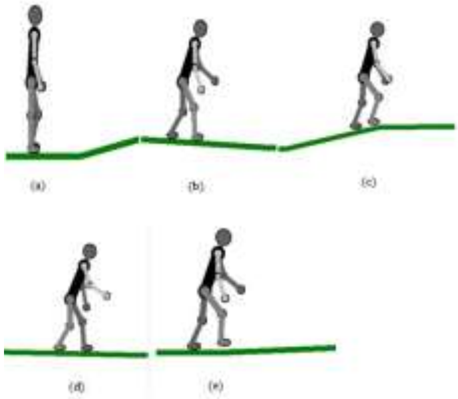


Fig 15. (a) Initial (b) second step motion (c) stepping moments (d) trajectory (e) final stopping condition

A. SIMULATION RESULT

The study of the static and dynamic of the robot was carried out by applying the webots software,which is intended for modelling, control and physical simulation of the robots.This program uses ODE(Open Dynamic Engine)[26,27] for computational forces and torque on links of the modeled robot. The model of the robot in webots must contain its geometric and physical characteristic with specific format. The extention of data file is .wbt. To specify the model in webots.That convert the direct X file, as the model provided by the ROBOTIS, into a VRML file by using softimage and deep exploration. The resulting VRML file(.wrl) contain the position and orientation of all the joints, as well as the structure of the robot and the geometric description of each links. Then, the physical properties of the robot are added. The dynamic property of links added in fields such as mass, center of mass and inertia matrix.

Table 5: Simulation model

Parameter	Θ_1(x)	Θ_2(y)	Θ_3(z)
Position	$1.50411e^{-07}$	0.00099301	-0.00013
Rotation	$-1.94946e^{-07}$	-0.0001386	0.000886

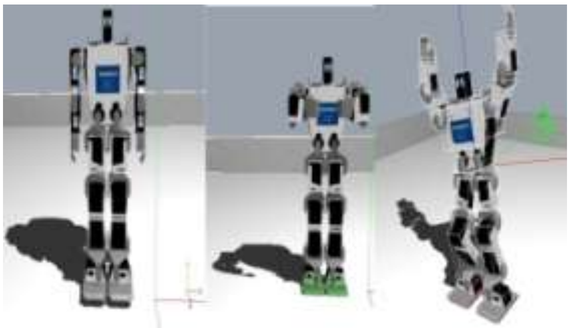


Fig 16. 3D design of robot in webots

The code for walking robot in webots are written in matlab language. The simulation process which contain the desired value of the joints for a specific walking pattern. The software virtually verify the deasibility of a trial set of walking.

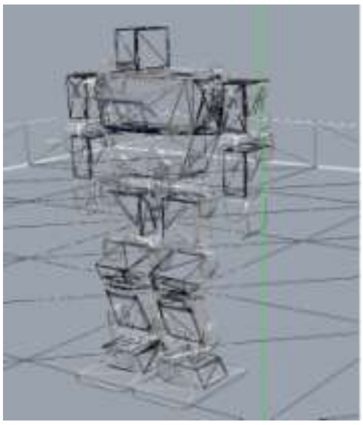


Fig 17. Orthogonal projection of robot

The accelerometer of the robot walking pattern will be obtained in the fig 17. Where graph will be based in the jjplane of XY and the time corresponding to the function of the robot.

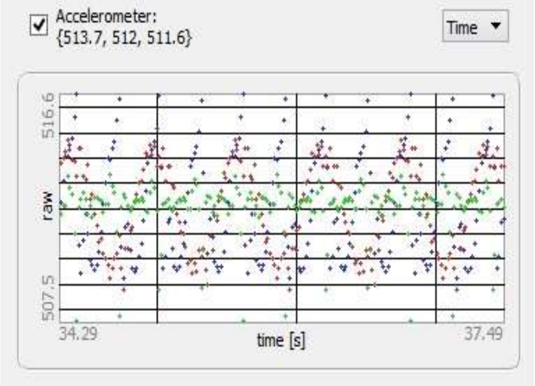


Fig 18. Accelerometer

Below fig 20. Shows that the motion analysis of various joints of the motors. This will have the output obtained in the graph plot. It consist of headS, legupper, leglower, Ankle LS, Foot LS, Arm lower LS, Shoulder RS, Arm upper RS, Arm lower RS

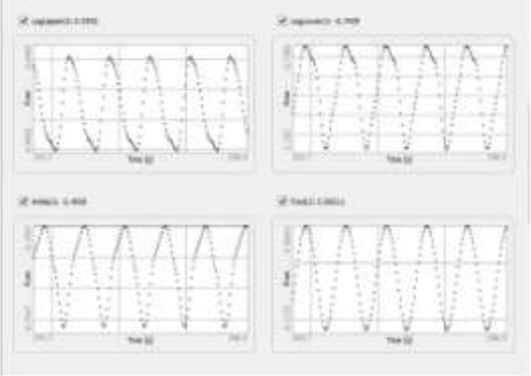


Fig 19. shows the plot of legs, anklels and foots of the robot.

Each value of the robot joints will have diffrent set of value such as Armlower is -0.5161 and Armupper . Time variation will be in the range of 290.4 to 293.6 and raw value will be obtained as -0.5161 to -0.5161 respectively.

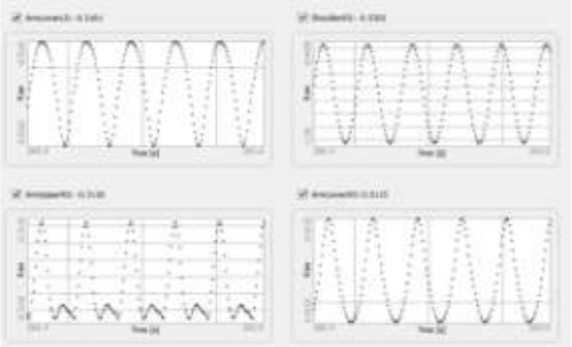


Fig 20.shows the Arm upper , lower and shoulder of the robot.

Once the process of assigning the condition for each robot joints will be in the range of time dependent. The position of the head is 0.1736 and the raw value will be in the range of 0.1736 . according to the condition Pelvls and PelYvls will be used the range of -4.185e^{-09} and -0.06189 respectively.

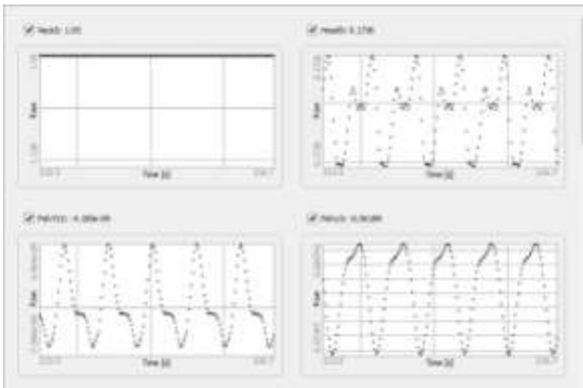


Fig 21.shows the head, PelYls and Pelvls of the robot

VI. IMPLEMENTATION

The design explain about the humanoid robot model including the DOF, then used simulator for the evaluation of the learning strategy. The successful design with the improved version of 2552RHV servos and a dual USB adapter HS is used in the AJ robot. The new servos features ICS3.5 protocol making them compatible with serial as well as PWM communication. Adaptor communicate with servos directly to configure and fine tune the servo behaviour.

Fig 22. Biped Robot

The base robot includes 17 servos(DOF) and addtion of 5 dummy servos that allows for easy expansion up to 22DOF. The robot is assembled from the start with 22 servos in place of (17+5) a feature unique in the design. The dummy servos can be prograssively replaced with the real servos to make up DOF. That helps to upgrade the performance.

The RCB-4 controller board enables the control of up to 35 serial servos. It is compatible with ICS3.5 protocol and a wide range of options. The board includes several extention ports (10X A/D and 10X PIO) enables the use of a wide range of sensors.

Maximum operating angle=270*
Maximum holding torque 14kgf

Fig 23. RCB-4 Controller board

The design of the robot can retract and stand up faster from a sitting position. The use of the materials are aluminium, polycarbonate and ABS with incorporation of glass allows for lighter get robust frames.

Fig 24. Servos

Software that newly revised for this kind of robots are Heart to Heart 4 that makes user friendly interface. It will create simple new motion and behaviour with more efficient.

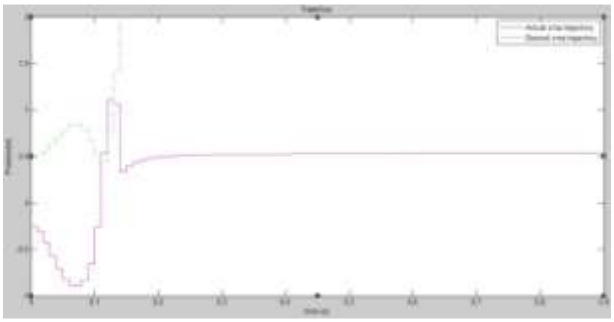


Fig 25. ZMP Trajectory

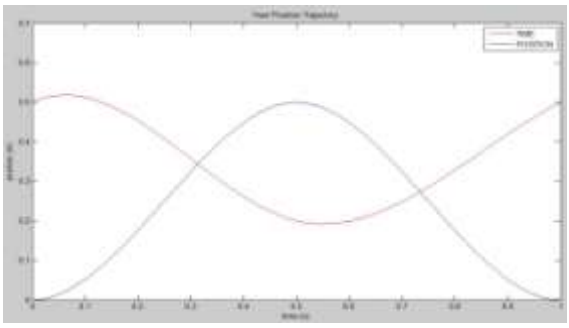


Fig 26.Heel position Trajectory

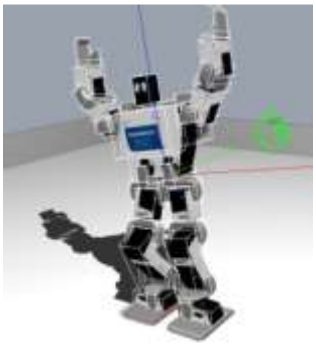


Fig 26. Walking Motion

Table 6. Parameters of walking

Parameter	Value
Step length	0.115m
Walk speed	0.1 m/s
Weight	41.5kg
Operating Volt	9v-12v

CONCLUSION

Since the Zero moment point method needs a lot of highly accurate sensor information, Central pattern generator is choose for practical way to generate biped locomotion, The dimensional output of Central pattern generator decides the position of the robot ankles and angular position of each joints can be figured out in inverse kinematics.

The algorithm helps to optimize the best Central pattern generator parameter .That will determine the fitness function is significant to maintain the gait pattern more stable. Where highly integrated 3D simulation software is used to design the imporeved version of the process. That makes the robot to walk stable with feasible condition. No efforts are carried out to obtain optimal value of the parameter. Future works will be carried out to optimize the performance of robot.

ACKNOWLEDGEMENT

We thank everyone who take part in our paper work, we would like to say sincere thanks for Department of Electronics and Communication Engineering in
Bharathiyar Institute of Engineering for Women Deviyakurichi.

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