Walking, Balancing and Grasping Control for Humanoid Robot

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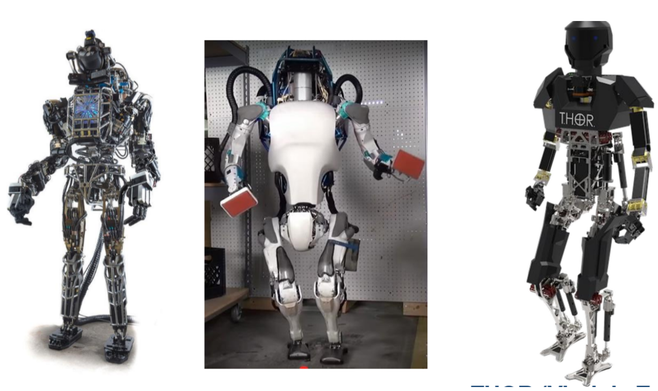
***Abstract*—Humanoid robot is a complex topic in control theory. The stability controller in two legged robot must recollect sensors information and compute a control law, based on any programming language. Perception, Walking, Motion planning, grasping, etc are some of the topics studied deeply nowadays. In this case, I will give some detail of theory control for humanoid robot, to understand the fundamental of walking and stability.**

***Index Terms*—ZOM, DOF, ZOP, IKL,Dynamic.**

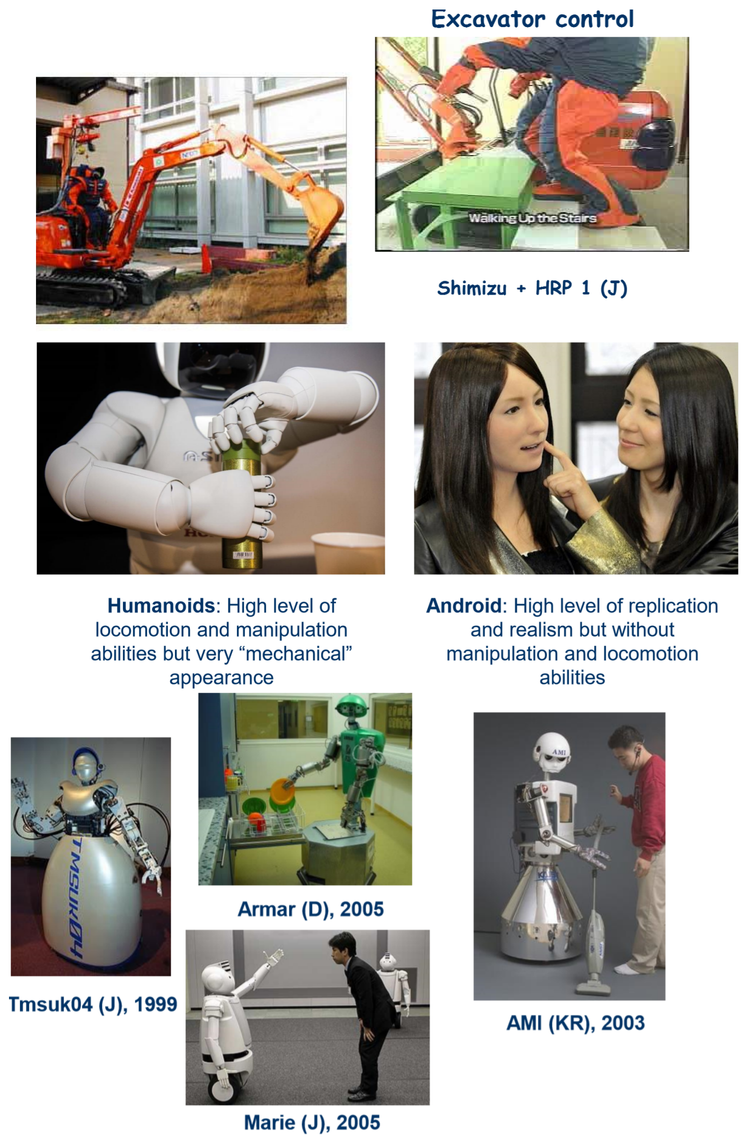
I. Introduction

The robots have been studied from many decades ago. Humanoid robot always was a complicated topic to solve. Because the condition that has to expose through the environment.
Asimo one of the most sophisticated humanoid robots is able to make movements like human body. Technology is growing everyday and robotic technology as well.
Stability for humanoid robot means keeping the ergonomic body position, facing the environment effect like: gravity, friction, wind, etc.
There are some theory concept for stability that require environment information through sensors like : IMU, Pressure, Torque, Velocity, Acceleration, Force and so on. While more information and redundancy sensor more trusty it will be.
In this article some solutions are going to be mentioned.
Grasping is the action to grab objects. Humanoid robot as human will be more useful for application if is capable to manipulate stuff making complex motion. Grasping control is tedious and there are solutions mentioned into the literature.
Perception is the ability to catch the environment information using visual sensor like: camera, Depth camera, stereo camera. The cameras as human eyes are in charge to get information and process with algorithm in the inner controller of robots.



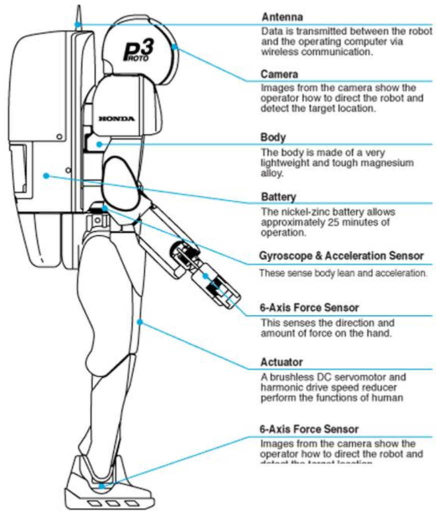
A. Applications

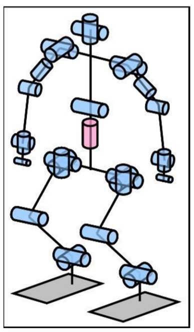
This kind of robot has many application as human. This is obviously. Human being has to interact with this robots as another human.
In this figure is showed some application of humanoid robot.



B. Degrees of Freedom

The humanoid as other kind of robot is designed based in sensors, actuator, link, joints.





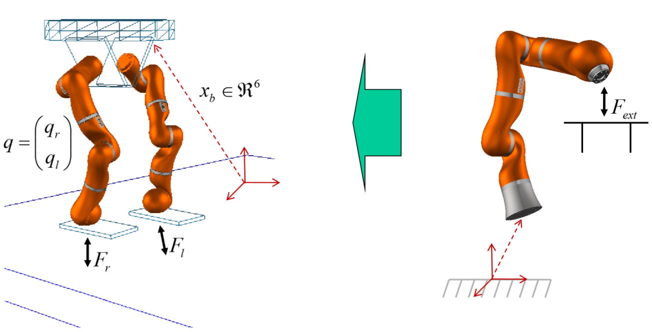
HRP2

Joint			(a) Standard Human	(b) HRP-2
Head		R	-50 deg. to 50 deg.	no existence.
		P	-50 deg. to 60 deg.	-30 deg. to 45 deg.
		Y	-70 deg. to 70 deg.	-45 deg. to 45 deg.
Right Arm	Shoul -der	R	-90 deg. to 0 deg.	-95 deg. to 10 deg.
		P	-180 deg. to 50 deg.	-180 deg. to 60 deg.
		Y	-90 deg. to 90 deg.	-90 deg. to 90 deg.
	Elbow	P	-145 deg. to 0 deg.	-135 deg. to 0 deg.
		Y	-90 deg. to 90 deg.	-90 deg. to 90 deg.
	Wrist	R	-55 deg. to 25 deg.	no existence
		P	-70 deg. to 90 deg.	-90 deg. to 90 deg.
Right	Hand	P	0 deg. to 90 deg.	-16 deg. to 60 deg.
Waist		R	-50 deg. to 50 deg.	no existence
		P	-30 deg. to 45 deg.	-5 deg. to 60 deg.
		Y	-40 deg. to 40 deg.	-45 deg. to 45 deg.
Right Leg	Hip	R	-45 deg. to 20 deg.	-35 deg. to 20 deg.
		P	-125 deg. to 15 deg.	-125 deg. to 42 deg.
		Y	-45 deg. to 45 deg.	-45 deg. to 30 deg.
	Knee	P	-0 deg. to 130 deg.	-0 deg. to 150 deg.
	Ankle	R	-20 deg. to 30 deg.	-20 deg. to 35 deg.
		P	-20 deg. to 45 deg.	-75 deg. to 42 deg.

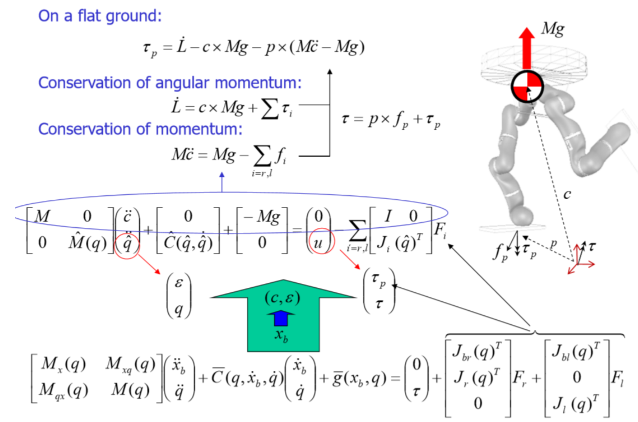
The study of articulated robot is based in rigid body, static and dynamic. Some theory of kinematic and dynamic are required.

C. Modelling

The robot motion can be modelled using dynamic equation of set of rigid bodies . Where for humanoid robot for gait and stability control, 2 sets of joints must be used. one for each leg. (For arms, torso and head D.O.F don't will be part of this topic).



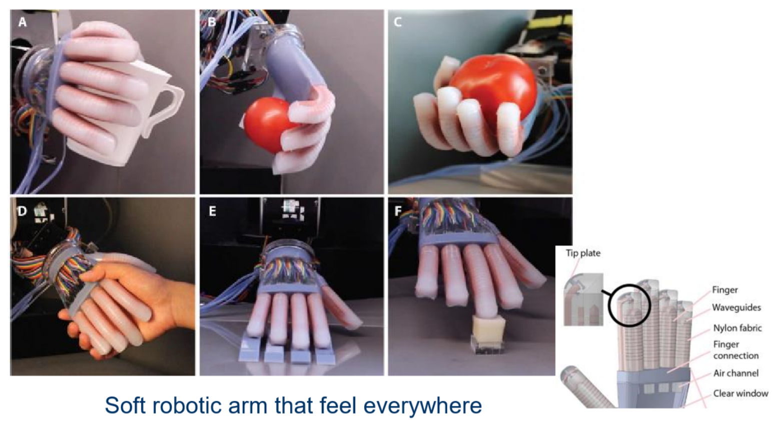
Dybamic equation is based on lagrange formulation. This 2nd order diferential equation depend on mass matrix, colioris and gravity matrix.



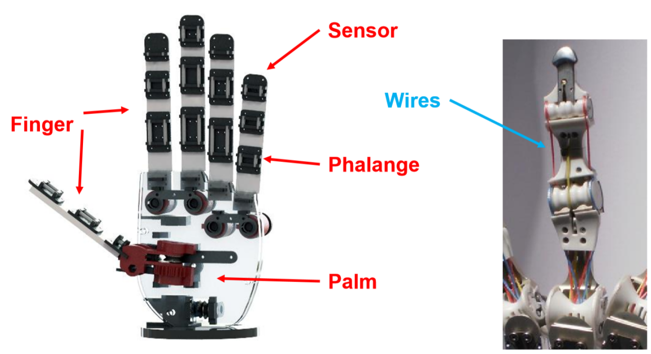
The solution for stability in steady state for dynamic robot ensure that robot won't fall out.
There are some approaches for stability control and will be talk in the following topics.

D. Grasping

Grasping is the action to grab objects. Mostly humanoid robot uses hand with 5 finger (but also there are exceptions) like human hand:



Soft robotic arm that feel everywhere



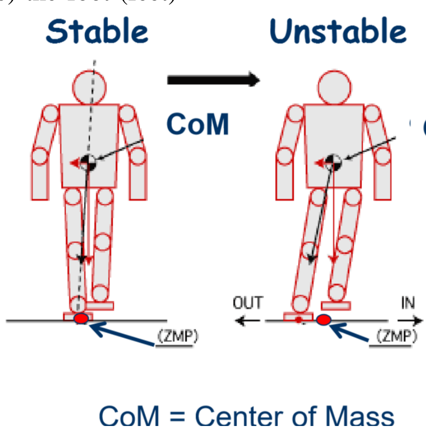
the motion planning, control feedback and coordination are recurrent in many application for grasping.
For grasping control take in mind that is required force and torque control, because the object could be made of any material.
Motion planning to generated the trajectory of action grasping

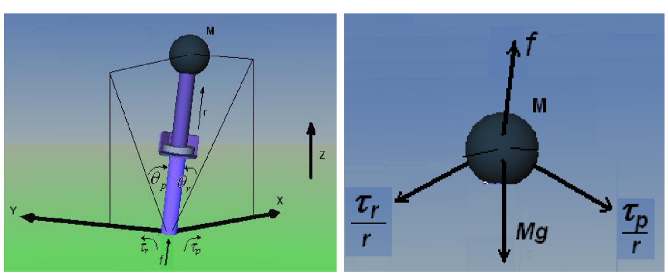
is considered as well. In many cases both need computer vision system to solve it.

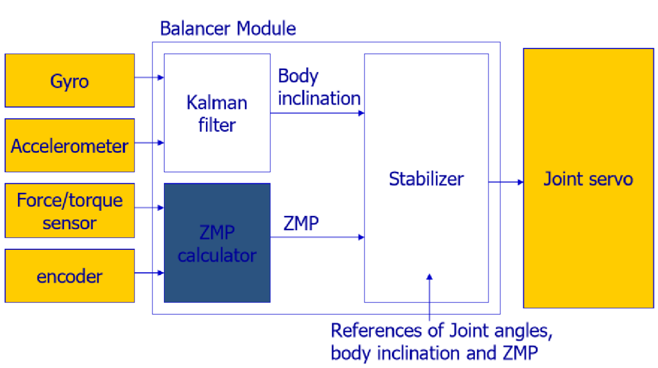
E. Stability

In this topic i will mention some of the techniques used for stability human robot:

ZMP.- is the point with respect to which dynamic reaction force at the contact of the foot with ground does not produce any moment, i.e. total reaction forces equals to zero [Vukobratovic, 1968].
CoP .- The Center of Pressure, in short CoP, is the point on the SP (Support Polygon) of the biped where the total sum of the contact forces FR acts, causing a force but no moment. When standing, the part(s) of the body exerted by contact forces is (are) the foot (feet)

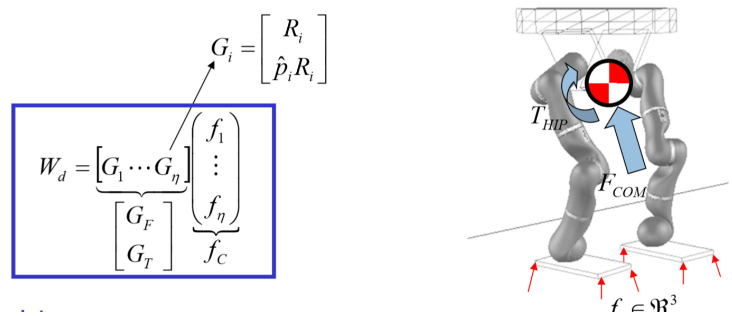




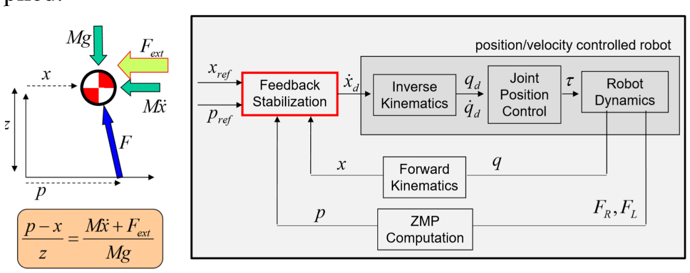


F. Balancing Control

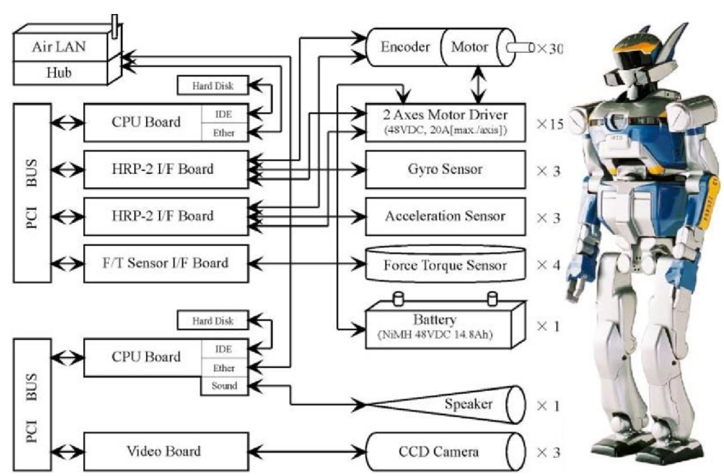
In control theory the feedback is used to improved the control system, making it more robust and optimal. There are many control strategies to take into account when we want to design a control system. For Instance: Is the robot model is a linear system, approaches like: PID controller, feedforward+feedback control, state state feedback, or based in the root's place could be considerated.
If we have no linear behaviour, the stability for non-linear system can be solved by: lyapunov function, backsteeping control, Hinf, predictive control, etc.



So far, with the model for stability the block diagram for balancing control is designed. Feedback stability control based on optimization or cost function with restriction is applied.

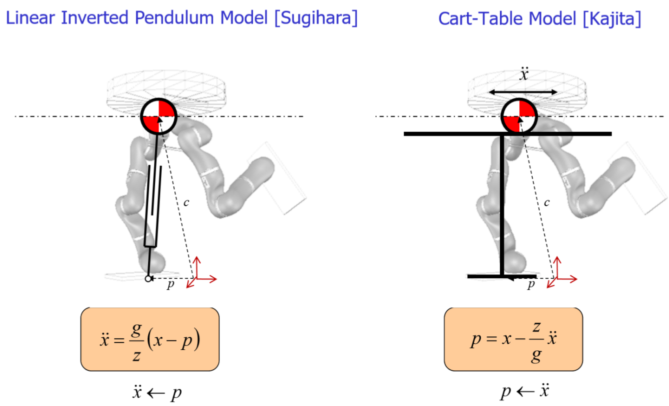


Finally, the architecture of human robot for balancing or stability control looks like this:

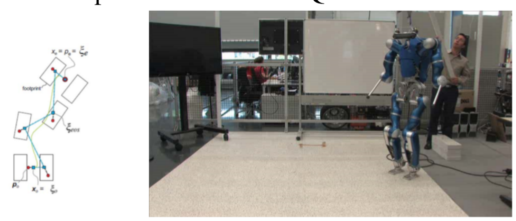


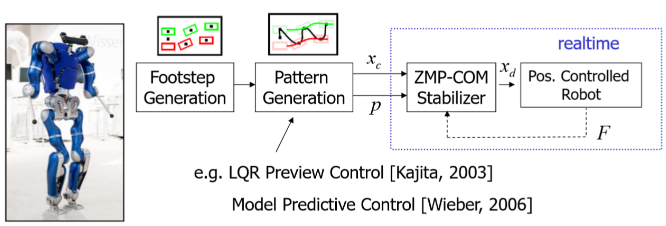
G. Walking Control

Two approaches could be considered here for this article:
LIPM.- Linear Inverted Pendulum Model. As you know, the stability of inverted pendulum is a classic example of stability control. Also we have Cart-Table Model.

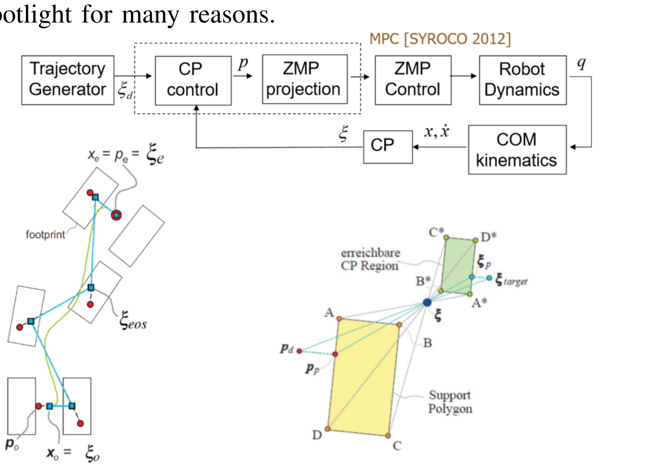


The walking control for humanoid is tedious. Two controller have to designed. First one is the feedback control, for walking is a predictive controller DMC (Dynamic Matrix Control). Also for motion planner based on LQR Preview Control.





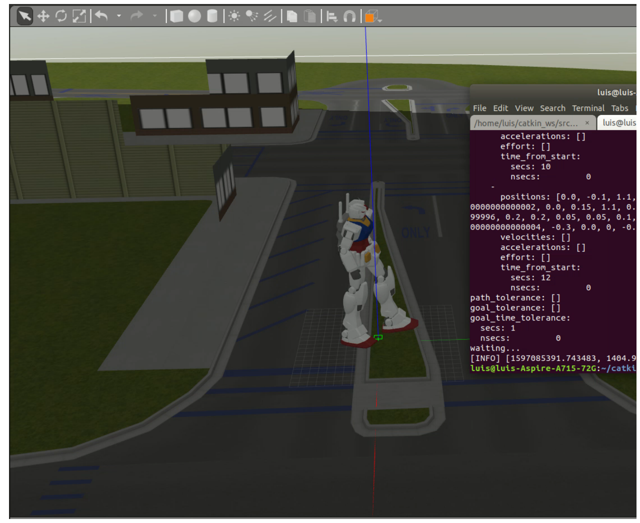
Finally the walking control is based on cascade control, because there perturbation and no linearities of the system. Predictive control for no linear model with restriction is spotlight for many reasons.



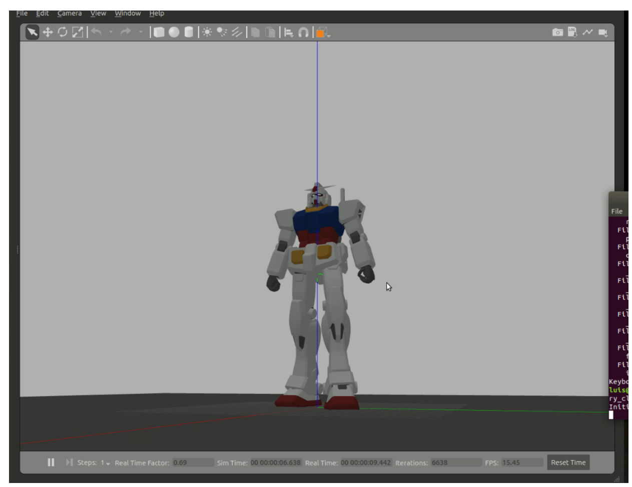
H. Simulation and Result

In this point. I'm going to take advantage of 3d simulator called Gazebo to show you one example of humanoid robot. Perhaps everybody know Gundam robot. Yeah the biggest robot made in Japan

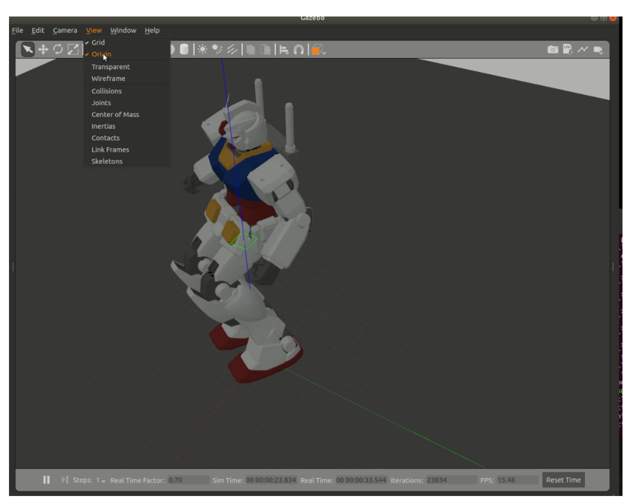
Fortunately I found this package for gazebo to emulate humanoid robot as this big robot.

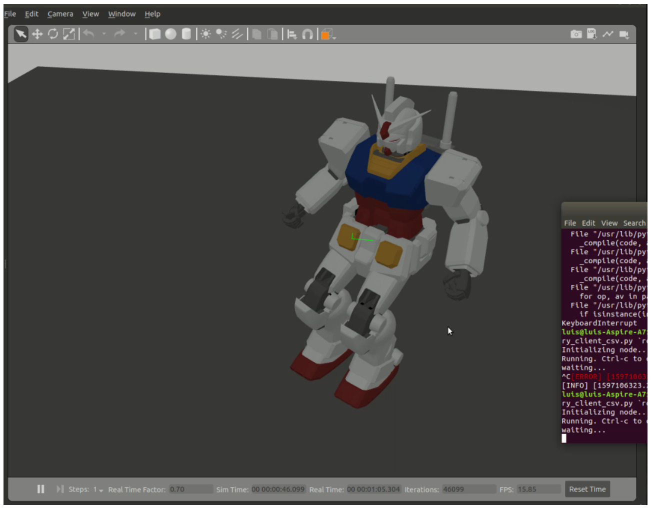


1) Gazebo: The motion of the robot, take into account the stability and gait control is show in this sequence of screen shots.

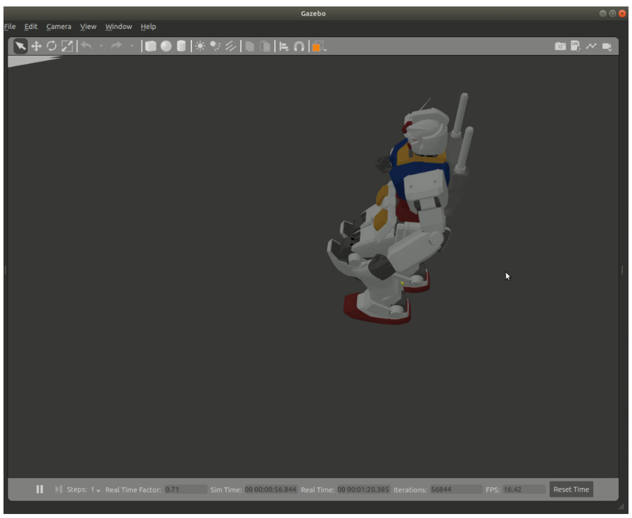


This is the link for video (https://www.youtube.com/watch?v=tYirnOIzEa4).





Finally. This simulation shows us the walking a balancing control of humanoid robot.



II. Conclusion

The short article introduces some ideas for humanoid robot concepts. The statibity and gait control was demonstrated using ROS and gazebo to simulate a real humanoid robot. The gundam robot is the biggest robot created nowadays. The structure of this robot was simulated in gazebo.

References

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