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A Simulation System with Simplified Dynamics Model of Biped Robot

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Abstract: This research proposed a physical-based simulation system that used a three-mass linear inverted pendulum model (3MLIPM) to represented the biped robot. The simplified dynamics model is the important factor in developing the real-time walking control system for the biped robot. The proposed simulation system was implemented in Python. The experiment was performed to validate that the simulation system can successfully represented the actual robot system especially when the stability of robot is concerned.

Keywords: humanoid robot, physical-based simulation, sim-plified dynamics model

1. Introduction

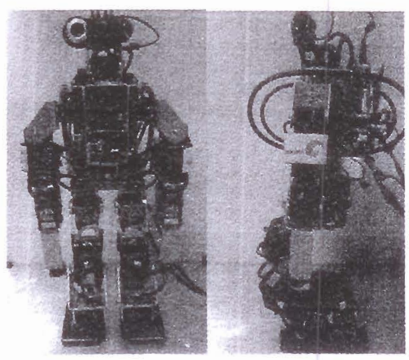

Fig. 1 KM-Series Humanoid Robot

In recent years, many researchers have studied the humanoid robot especially biped humanoid robot in order to replicate human action such as walking and running. However, the process of designing the walking control algorithm on the real robot is quite difficult because the robot can be easily damaged when it falls down before the stable walk can be achieved. Therefore the robot motion simulation software becomes an important tool for testing the robot system. However, the problem of the difference between the dynamics model of the real robot and the robot in the simulation software could prevent simulation software to be used effectively. Moreover, the full body dynamics model of the robot in a numerical simulation framework requires too large computation time to be used in a real-time control application. For this reason many studies in dynamics and control of the humanoid robot have employed the simplified dynamics model idea to the simulation software. Takenaka and Matsumoto [1] have proposed method to minimize the dynamics error using dynamics error compensation using ZMP trajectories compensation on an simple inverted pendulum and flywheel model. This approach would not be accurately enough for replicating the real dynamics of the robot to the simulation model. Aiman Musa and Omer [2] have developed a walking support system based on dynamics simulation. By using the Waseda Bipedal Humanoid Robot WABIAN-2R, the simulation software can simulate human motion in order to help the handicapped or disabilities people. However in this work, they do not mention about the conformity between the real robot and the simulated robot in dynamics model perspective. In order to develop an effective tool for supporting the development of control software is the 'software in the loop' (SIL) concept which uses the simulation robot under real environment condition. M. Friedmann [3] have proposed simulation of multi-robot with flexible level of detail including the consideration of kinematic and dynamic model which called MuRoSimF. In this research, a novel simulation framework is developed. This framework contains with the internal sensor simulation, camera simulation and motion simulation.

In this paper, dynamics simulation software was designed for the 12-DOF of the biped humanoid robot. The simulation software was developed under the simplified dynamics model concept so that it can be used later on in realtime control application. By using the three mass linear inverted pendulum models (3MLIPM) and the consideration of dynamics parameters such as center of mass, torque and force, the experiment was performed to show that the simulation software can replicate the dynamic behavior of the real robot.

2. Humanoid Robot System

A. Mechanical Structure

The FIBO Kid Size Humanoid Robot (KM-Series) has 20 degree-of-freedom (DOF), 6-DOFs on each leg, 3-DOFs on each arm and 2-DOFs on the head. The total weight of the robot is 3.3 kg including the main processor, the controller and batteries. The robot's height is 53 cm. The robot uses a commercial servo motor (Robotis) as an actuator (i.e. 18 of RX-28 and 2 of RX-64). The power consumption of the robot is 0.5A at no load condition and 1.0A while the robot is standing. The KM robot is shown in Fig. 1.

B. Hardware Architechture

On the robot, the PICO-iTX which is an Intel® Atom cpu@1.6 GHz is used as a main processor in order to do the image processing and decision making. The motion generation is generated from the ARM-7 controller which controls 18 DOFs of the body through RS-485 bus. Another 2-DOFs (pan-tilt) is controlled directly from the main processor. The diagram of the robot controller is shown in Fig 2.

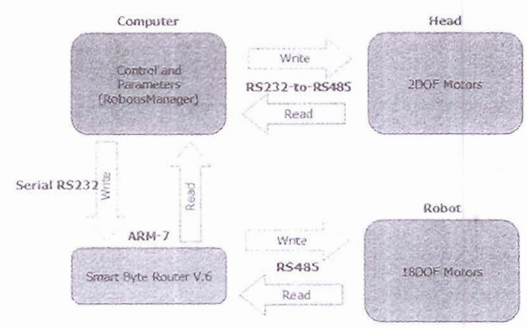

Fig. 2 Robot System Diagram

3. Simulation System

C. Physical based Simulation

In order to simulate a real world in the simulation world, the real world environment such as gravity force and torque must be implemented into the simulation. Several existing dynamics simulation packages provide the numerical integration, collision detection and handling. In this research, we use the Open Dynamics Engine (ODE) [4] packages which is an open-source project to handle the physic behavior of rigid bodies. Because the simulation system is developed in Python, the ODE package is wrapped by PyODE [5] library. In this simulation, vPython [6] library is used to visualize the simulation world.

The robot is constructed by simple shapes such as box, sphere and cylinder. By these simple shapes, the complex object can be created. For example, the motor is constructed by three boxes shape with different size and two cylinders as shown in Fig. 4. The mass property is added to this virtual servo motor. The connection between each motor is called "virtual Hinge Joint" which can be able to compute dynamics parameters such as force and torque. The other components in the simulation also construct from box shape. However, in order to apply 3MLIPM simplified dynamics, these virtual parts are considered as mass-less.

The captured screen of this humanoid simulation software is shown in Fig. 5. In this simulation software, we focus only in the lower body part of the robot because this part affects the robot's stability more than the upper body part.

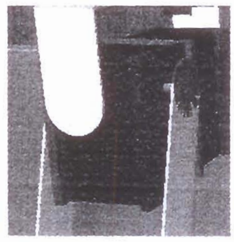

Fig. 3 An Example of a Visual Object

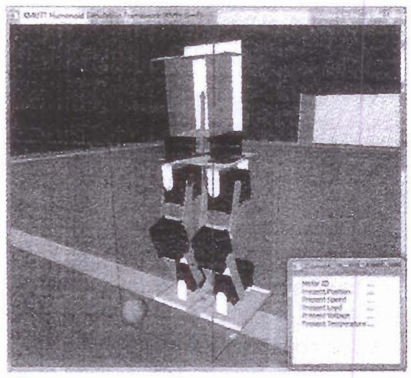

Fig. 4 Lower body robot simulation (KMUTT Humanoid Simulation Framework)

D. A simplify dynamics model: Three mass linear inverted pendulum model

This model is proposed by Shuai Feng and Zenqi Sun [7]. The 3MLIPM is the model that considers the dynamics of the leg rather than only the hip mass like in linear inverted pendulum model (LIPM). Therefore, the complexity level of 3MLIPM is more than the LIPM. The illustration of 3MLIPM is shown in Fig. 6. The derivation of moment equation about supporting ankle is:

$$\tau_z = \sum_{i=1}^{3} m_i(\ddot{x}_i + g)y_i - \sum_{i=1}^{3} m_i \ddot{y}_i x_i \quad (1)$$

$$\tau_y = \sum_{i=1}^{3} m_i \ddot{z}_i x_i - \sum_{i=1}^{3} m_i(\ddot{x}_i + g)z_i \quad (2)$$

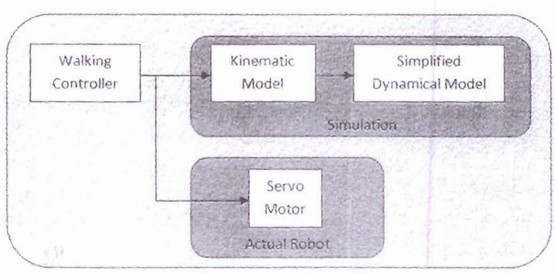

Fig. 5 Control Diagram

E. Communication with real robot

The communication between the simulation program and the actual robot uses a standard RS 485 with robotis dynamixel protocol. The high level module, called robotismanager, was developed to handle the read and write robotis protocol. This module is developed in Python and also provide cross platform usage.

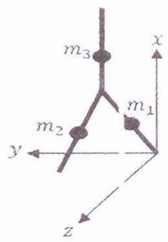

Fig. 6 The illustration of 3MLIPM

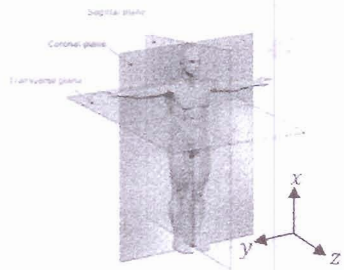

Fig. 7 Reference plane [8]

4. Experiment And Result

Some assumptions must be introduced before continuing to discuss about the testing results as follow:

- The ground is flat
- The foot position always in the same point
- No slip on the ground
- The robot body is rigid
- There is a constant voltage input from the switching power supply

F. Sagittal Plane

In Sagittal plane, shown in Fig. 7, a set of motors which takes into account is both ankles, both knees and hip is rotated around Y-axis. According to the 3MLIPM, the actual model of the robot is simplified to three mass on both knees and hip. The other component is mass-less. With this model, the replication of the real robot to the simulation is easier than the full body modeling. The center of mass of the real robot is measured by using a flat and mass-less plate in order to know the reference point of the CoM of the robot. From the testing result, the position of the left leg m_1 , the right leg m_2 and the hip m_3 in centimeters, which were measured from the origin of the virtual frame, are (15.23, 4.17, 8.81), (15.23, -3.92, 8.81) and (38.8, -1.2, -4.7) respectively. The actual humanoid robot information is shown in Table I.

Actual Biped Robot Parameters

Parameters				
Shin Length	*Thigh Length*	*Mass of Left Leg (m_1)*	*Mass of Right Leg (m_2)*	*Mass of Hip (m_3)*
10.0 cm	10.0 cm	0.740 kg	0.738 kg	2.02 kg

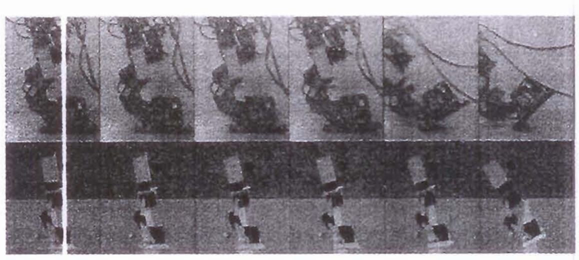

Fig. 8 The real robot and the simulated robot when fall forward.

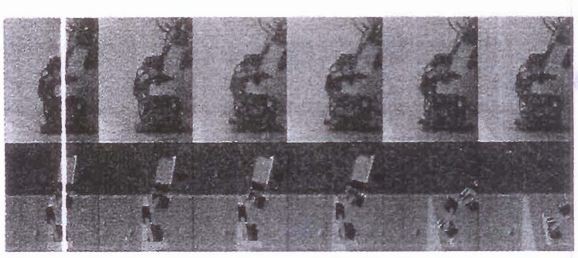

Fig. 9 The real robot and the simulated robot when fall backward.

The model verification was done by leaning robot forward and backward in the Sagittal plane (ten trials). The testing scenario which is shown in Fig.8 and Fig.9 represented falling forward testing and falling backward testing respectively. With the following assumption, if the simulation model can replicate the real robot, when the real robot falls down the simulation robot must be fallen down in both forward and backward leaning. The result of this testing is the real robot would fall down when the robot's leaning angle exceeded 9° for forward direction and 16° for backward direction. In the simulation robot, when the virtual robot leaning angle exceeded 9° for forward direction and 16.8° for backward direction, the virtual robot was also fall down. The error of 0.8° in the backward falling case might be caused by the backlash in mechanical design. Furthermore, the joint torque in both ankle and both knee were considered which are shown in Fig. 10 and Fig. 11. The joint torque were read from the robot during the testing sequence which were center to forward, forward to backward and backward to center. The visualized graph can be divided into two sections, leaning section and stabilizing section. The stable section is read in order to verify that the read torque is valid to use. According to the limitation of RS485 bus and our controller firmware, the communication between motors in the robot and the main controller cannot send and receive data simultaneously. Therefore, the sampling rate in the real world motor is much smaller compare to the virtual motors in the simulation. The sampling ratio between the real robot and the simulated robot is approximately 1:20.

The graphs of joint torque in Fig.10 and 11 show that the change in joint torque for both knee and ankle of the real robot and the simulated robot have similar trend even though the simulated one has exhibited a higher frequency component due to the higher bandwidth of the simulation loop.

5. Conclusion

In this paper, we proposed an application of 3MLIPM to be use in the humanoid simulation software and to adjust the CoM factor in order to match the dynamic behavior between the real and the simulated robot. The forward and backward leaning tests were done to verify the similarity between the real robot and the simulation. By adjusting the virtual CoM on each mass linear pendulum model, the virtual model can change the dynamics behavior which can make it matches the actual robot. For example, if the real robot is changed some parts or components, the simulation model will be easily adjusted to behave like the real robot. The future work is how to make this adaptation mechanism automated

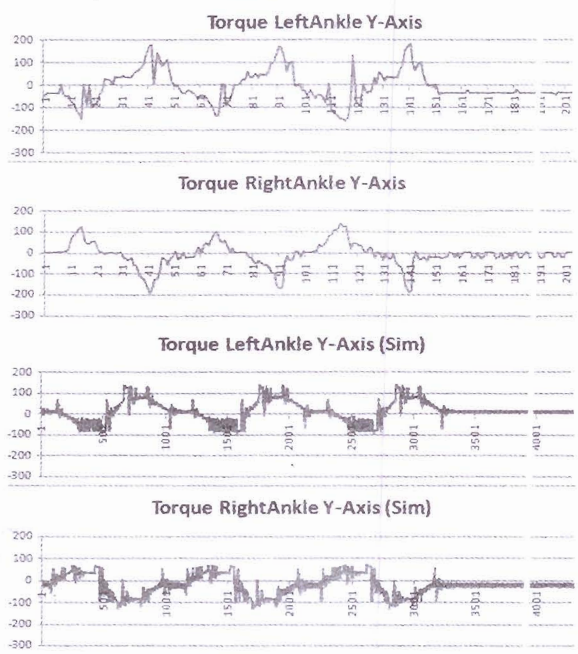

Fig. 10 Torque at the ankle in actual robot and virtual torque from simulation (Ncm.)

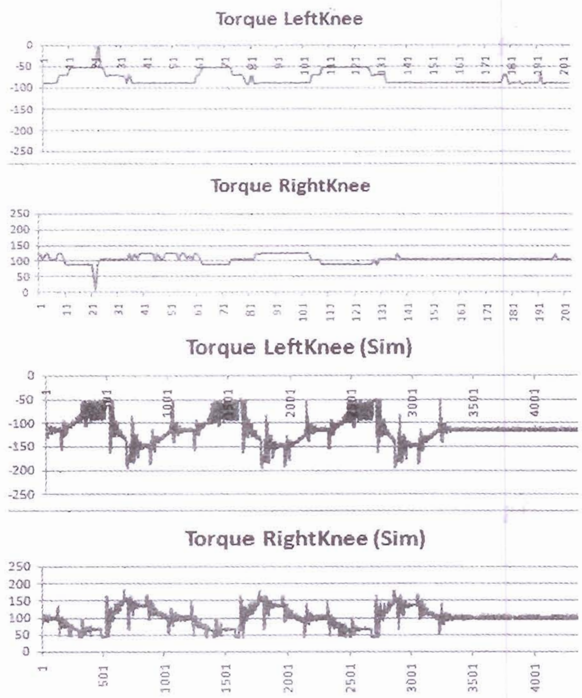

Fig. 11 Tc rque at the knee in actual robot and virtual torque from simulation (Ncm.)

6. Ac :nowledgment

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7. Re erences

[1] T. T kenaka, T. Matsun oto, and T. Yoshiike, "Real time motion generation and control for biped robot -3rd report: Dyn mics error compen :ation," in *Intelligent Robots and Systems, 2009. IROS 2009. IEEE/RSJ International Con; rence on*, 2009, pr. 1594-1600.

[2] A. N M. Omer, H. Kon lo, L. Hun-ok, and A. Takanishi, "Development of walking support system based on dyna nic simulation," in *Robotics and Biomimetics, 2008. ROBIO 2008. IEEE International Conference on*, 2009, pp. 137- 42.

[3] S. C: pin, I. Noda, E. Pa gello, M. Reggiani, O. von Stryk, M. Friedmann, and K. Petersen, "Simulation of Multi-Robc : Teams with Flexi le Level of Detail," in *Simulation, Modeling, and Programming for Autonomous Robots*. vol. . 325: Springer Berl n / Heidelberg, 2008, pp. 29-40.

[4] R. S ith, "ODE - Open Dynamics Engine", www.ode.org, 2007.

[5] A. D mitrache, "PyODE", http://pyode.sourceforge.net/, 2010.

[6] D. S erer, "vPython", http://vpython.org/, 2000.

[7] C. X ng, H. Liu, Y. Hu ng, Y. Xiong, S. Feng, and Z. Sun, "Biped Robot Walking Using Three-Mass Linear Inve: ed Pendulum Mod l," in *Intelligent Robotics and Applications*. vol. 5314: Springer Berlin / Heidelberg, 2008, pp. 3 1-380.

[8] Wiki edia, "Sagittal plar e", http://en.wikipedia.org/wiki/Sagittal_plane , 2010.

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