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ROS-Based Humanoid Robot Pose Control System Design

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***Abstract*—This study utilized the Robot Operating System (ROS) to simulate various poses of humanoid robot. The distributed ROS architectures efficiently communicate with each other point to make sure the correct sequential procedures and execute full information exchange through the peer to peer topology. Humanoid robot software designed in Linux-based ROS environment to integrate the software and hardware system plant through ROS. The advanced Gazebo presents the cyber-physical behavior of humanoid robot in the reality experiments.**

***Keywords*—Robot Operating System, Humanoid Robot, Gazebo**

I. INTRODUCTION

In the humanoid robots research field, robot body imitates human behavior to literally fit with people's daily life. Recently, Humanoid robots have become the most interesting topic in the world. Researchers inspected locomotion model of animals to make an advanced Central Pattern Generator (CPG) for bipedal robot studies and applications. Righetti et. al. [1] and Morimoto applied a CPG method to develop a coupled oscillator model [2-3]. This model simulates a simple arc-sin trajectory for each motor. Due to the previous model by Morimoto, Ha [4] and Wong [5] offered a simplified coupled oscillators model. Coupled oscillators model can parameterize the direct relationship for fitting Humanoid robot's walking steps. Liu offered Humanoid robot's walking steps and controlled its waist locomotion in 3D space [6-7].

The ROS-based software is regarded as a friendly framework to rapidly reach the resources integrated purposes. The powerful ROS tools are developed to execute a consistent communication interface between internal procedures of Service, Topic, Action, …, etc. Highly modularized system structure obtains the more feasibility to enormously improve the resources handing ability and deployed its repeated utilization [8]. ROS offered the great shared ability in anywhere. ROS is known to be widely used in robot applications, such as PR2, Baxter, Fetch, Meka and UBR-1 machines. More and more ROS studies have been developed in the decades, EL-E type robot platform efficiently created a moveable arm of robot system by the great support of ROS [9]. Researches developed mobile robot system based on the availability of ROS [10]. ROS is performed to control multiple robots motions by the manipulated nodes of its architecture [11]. In robot virtualization platform, Gazebo contained with the powerful visualization in three dimensional (3D) working environment. This is known as the most famous 3D to be embedded in the ROS platform. Several studies completed the ROS robots system by the powerful 3D Gazebo software for reaching the robot module applications [12]. This is known as a very complex task to reproduce human action within the shorter time. ROS applied an efficient software platform to imitate various body motions [13]. ROS applies the fast responsibility to connect various sensors with humanoid robot in the applications of human pose and humanoid robot walking speed imitations [14-15]. Detail systems and ROS-based Gazebo simulations are clearly described in the next sections.

II. HUMANOID ROBOTS PLATFORM DESIGN

The humanoid robots platform design apparently mimics the human body and its related motion to support various tasks. Figure 1 actually shows reality humanoid robots in this study. Humanoid robots machines look like limbs and trunk of people. Bot's structure routing is made of the connection between sheet-metal parts and linking motors. Motor rotates joints to imitate human motion. Poses and pressure sensors are located at the Waist and under two feet bottoms, respectively. Sensors intuitively perceive the relational robot situations and outdoor information from various environments. A kernel control board works like human brain to gather the whole information, analyze an appropriated command to motor control board for driving the suited joints motion in robot applications.

Humanoid robots' movements are looking like the human being behavior to imitate and complete some our requests. Control objects of the humanoid robots are usually direct the full body into the right walking direction or moving leg and arm through the desired approaching positions. After realizing the designer's purpose, it is an important key point to analyze the structure of humanoid robots, and develop joints motions for their related functionalities.

Not similar to the industrial robot's design concept, Humanoid robots contains various structures and orientations to satisfy the respective tasks. An essential consideration is that Humanoid robots perform the legged motion control strategy, i.e. bipedal gait control rules. Humanoid robots stabilize center of gravity in order to self-control its approximate pose.

The ROSs is actually developed in robot applications.

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ROS is maintained by the Open Source Robotics Foundation. Not only design the robot hardware structure but also take care of the ROS software function, details are discussed in the following subsections.

Fig.1. Humanoid robot Real hardware View

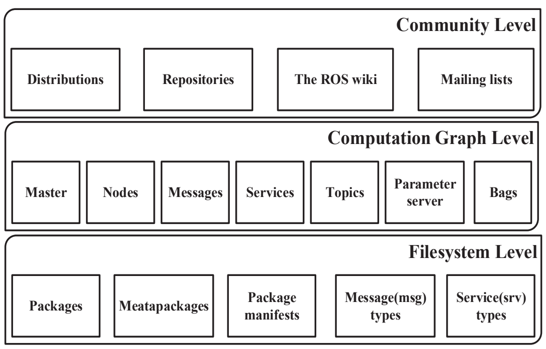


Fig.2. ROS packages Layout

ROS software contains many packages to reach different service applications. One package has various nodes to execute the required procedures. Nodes communicated each other through Topic or Services by Figure 3. Where Topic is a one-way communication to automatically publish message into the subscriber. Service is a two-ways communication way to send the request from the cilent and then give a response from the server nodes.

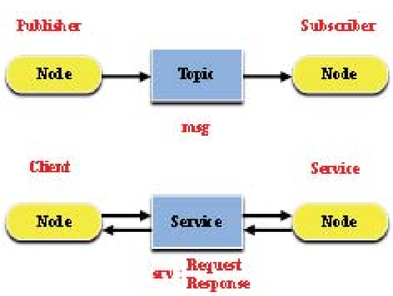


Fig.3. ROS communication methods

III. Humanoid Robot System Structure

The fundamental blocks of Humanoid robots for SoC FPGA internal kernel designs, these are divided into two parts: (1) Field Programmable Gate Array (FPGA) (2) Hard Processor System (HPS). Moreover, this data flow shared information through the hand shaking type Qsys tools.

FPGA is considered as a programing logical array gates to efficiently handle the computational tasks in parallel mode. This subsystem focuses on the real-time response and requires the higher accurate on the time planning work. For example, the sensory information feedback or motor control commands brocading at the same time.

HPS contains the universal CPU to conveniently conduct mathematic functions and flexibly regulate the parameters. HPS supports the human-machine interface, walking speed, gait planning, robotic kinematics and pose control strategy. The Robot Operating System is applied in this article to show Humanoid robot system architecture in Figure 4.

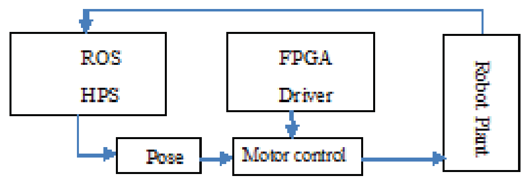


Fig.4. Humanoid robot system architecture

Data message deliveries through Topic and Service methodologies in ROS Cross–platform to support various robot applications. In Figure 5, three nodes in left side and three in the other right side can be regarded as different Humanoid robots. Each node (i.e. bot) communicates with each other through Topic and Service internal functions. A wireless computer is used to remotely control the Humanoid robot machine.

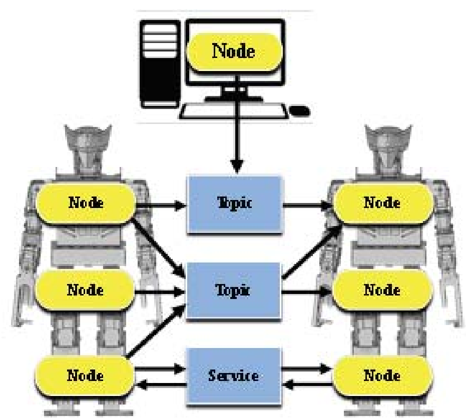


Fig.5. Block diagram of ROS-based Humanoid robot control system

In motor control design, HPS give command orders to FPGA module based on the body angle of Humanoid robots. An acknowledged (Ack) signal sends back response to HPS while an drivering module receives a motor control command. Henceforth, HPS carries out a computational result for the next command. These steps cycles are shown in Figure 6 to avoid the lost command situation. FPGA receives Ack signal and execute this command within a working period. HPS executes complex algorithms and mathematic computations at ROS platform. HPS will compute the next control command at the same period to reach multithreading purposes.

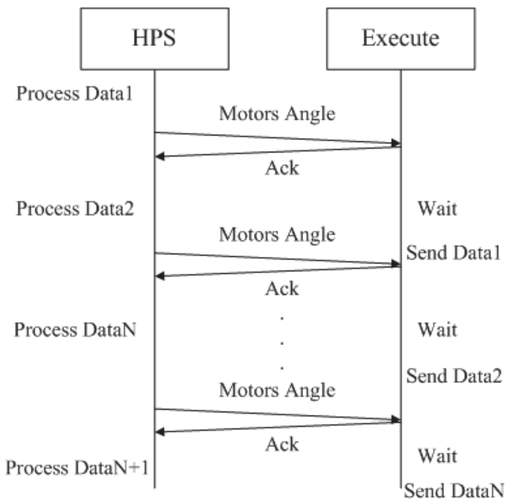


Fig.6. ROS communication methods

IV. ROS-BASED HUMANOID ROBOT GAZEBO SIMULATOR

This study uses Gazebo simulator with 3D graphic interface to clearly detect the motion change of humanoid robot. Due to the perfect reliability of Gazebo's elements analysis, the related mechanical motion is efficiently viewed by designers from any angle. Vision-based Gazebo simulation conveniently checks the conflict part in robot mechanism design. This way shorten modification hours and prevent the repaired time while in system design procedure. A Gazebo simulator applies concurrently to reach robot team works. Users remotely control the robot pose and execute a series of motion to test the predefined functions through a friendly interface. Gazebo really simulates physics characteristics, such as force friction, inertia and center of mass, to approach the practical robot condition.

A. 0bject Models Design

In object models design, Gazebo simulator directs Universal Robotic Description Format (URDF) to describe the relationships of different objects. This is a primary step to build the required environment in the world. Figure 7 shows an example of the simple mechanism sketch diagram. There are four sets links. URDF is deployed to shows theirs relations between joints and links at the robot machine. Therefore, link's position and direction are described by URDF and its block diagrams ae illustrated in Figure 8. This simulation shows that Gazebo uses URDF to efficiently design object models and powerfully construct the complex Humanoid robot motions. Total 23 main links with other connections elements are proposed to exactly construct the real Humanoid robot machine.

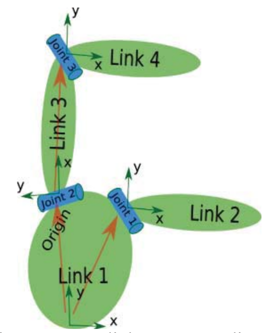


Fig. 7: Human links construct diagram

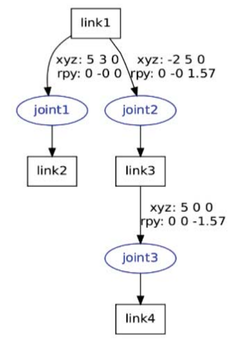


Fig. 8: Links relations and positions descriptions

Figure 9 shows a 3D-type Humanoid robot simulation with the support of previous URDF descriptions. Gazebo exactly builds the almost real model to match the approximated motion of robot machine.

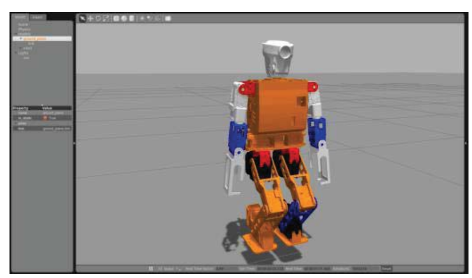


Fig. 9: Humanoid robot 3D Gazebo simulations

B. Gazebo Simulator Design

Gazebo simulator is worked as a software plant to send Topic data and communicate with each other nodes in ROS. In order to balance the control nodes, Kalman Filter and pose control nodes use dip angle and angle compensation topics to communicate with each other. This way coincides the newest sensory information with the dynamic environments. This study assigns Qsys as a service to centralize the whole motor information into Qsys and Gazebo. Qsys transmits control command of motor's rotating angle to FPGA. This state is for actually implementing the gait control of Humanoid robot to regulate the position. Gazebo mimics the motion of Humanoid robot by sending rotating control signal in the computer side. Software and hardware architectures of Humanoid robot are designed to achieve Cyber-Physical System (CPS) applications.

Kinematic equation of Humanoid robot is a very complicated work. Based on the linked structure and their relationships, the forward kinematic model is assigned in the Denavit-Hartenberg (D-H) coordinate matrix table for achieving the end-effector pose in Humanoid robot machine. The inverse kinematic of Humanoid robot is determined to calculate the angle of each joint based on the position and orientation of the end-effector. In this ratiocination, kinematic decoupling concept is offered to solve the inverse kinematic problem. Then, both inverse position and orientation kinematics are compared with the trigonometric functions to obtain the terminal angle of each joint. Therefore, the robot control machine drivers all motors connection into the desired positions by previous D-H tables. Humanoid robots collected the whole sensors information into controller through RS232 topology to build the required position commands. The integrated position analysis in cyber-physical system transfers control signal to regulate angles and speeds of motor with Qsys. Motor controller receives or sends signal through GPIO elements to handle all motions of robot. Detail block diagram for CPS system control mode is illustrated in Figure 10.

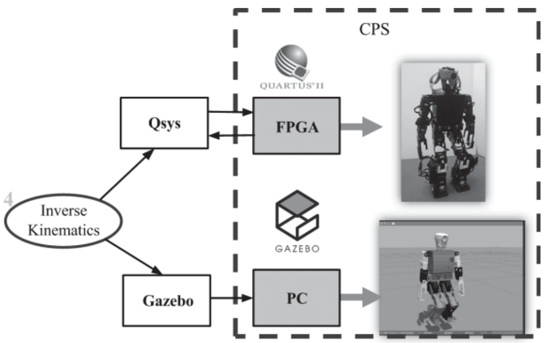
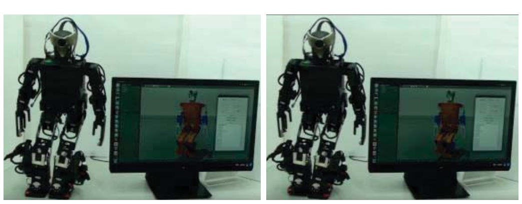


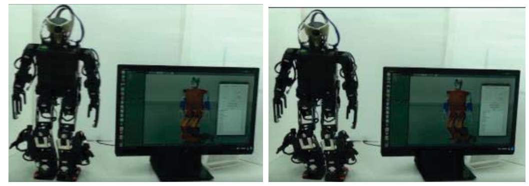
Fig. 10: CPS system control mode digram.

C. CPS System Test

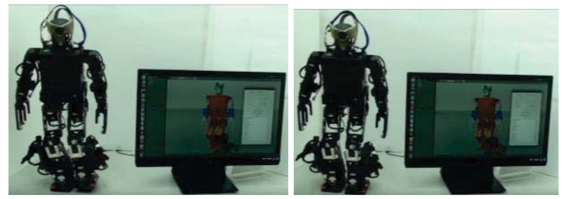
CPS system simulations with the Gazebo plant and its actual humanoid robot motions are plotted in Figure 11. A series of scenes show that ROS-Based Gazebo plant can flexibly approximate various humanoid robot poses. In this experiment, finished (a) the waist move to left side (b) lift up the right leg (c) waist move to middle position (d) waist move to right side (e) Lift up the left leg (f) waist move to middle position.



(a) Waist move to the left side (b) Lift up the right leg



(c) Waist move to middle position (d) Waist move to right side



(e) Lift up the left leg (f) Waist move to middle position

Fig. 11: Humanoid robot CPS system test.

V. CONCLUSION AND FUTURE WORKS

This paper uses the ROS-based system to simulate Humanoid robot motions and integrates real robot pose control to accomplish CPS system applications. Gazebo simulator creates Humanoid robot model and drive various motors to move links of reality robot connections for approaching the desired positon control purpose. Therefore, Humanoid robot walking control system designs through the pose controls technology will be implemented in the future work. Humanoid robot machine obtains the required sensory information to modify its pose. Gyroscope and accelerometer numerical value will be gathered from FPGA. The Kalman filter module evaluates previous information to create the accurate pose dip angle of upper body. Pose control module creates motor angle compensation for hip joints of biped. Therefore, humanoid robot real-time regulates body pose in the whole walking cycle will be achieved the goals in indoor environment.

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