A Study on The Implementation of Stable and High-speed Humanoid Robot (ICCAS 2004)

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Abstract: Most previous robots had used the wheels as means for movement. These structures were relatively simple and easy to control and this is why the method had been used until currently. However, there are many realistic problems to move from one place to another in human life, for instance, steps and edges. So we need to develop the two-legged walking humanoid robot. The 2-legged walking Robot system has been vigorously developed in so many corporations and academic circles of several countries. However, 2-legged walking Robot has been mostly studied in view of the static walk. We design a stable humanoid Robot which can walk in high-speed through the research of the dynamic walk in this paper. Especially, worldwide companies have been interested in developing humanoid robots for a long time to solve the before mentioned problems so that they can become more familiar with the human form. The most important thing, for the novel two-legged walk, is to create a stable and fast walking in two-legged robots. For realization of this movement, an optimal mechanical design of 12 DOFS, a distributed control and a parallel processing control are implemented in this paper. This paper proves that high speed and stable walking can be achieved, through experiments.

Keywords: high-speed waking, stable walking, two-legged robots, Humanoid Robot.

1. INTRODUCTION

Two-legged robots generally can be divided into two humanoid groups, one walking like a human and the other walking like a bird. The necessary minimum amount of joints must be 6 on each leg in order to walk like a human as [1] and [3]. Despite technical difficulties, walking robots have been studied vigorously in Japan because there are many advantages to this one. Honda successfully developed a 2-legged robot after previously creating a 4-legged design at an earlier time. The 4-legged model could easily walk more stably than the 2-legged robot. The first research periods of humanoid robots began in 1976 at Waseda University in Japan. The HONDA company began development of the E series in the 1980s. The original HONDA 2 legged robot took more than 5 seconds to move one step. However, the P2 and P3 of the present P series from ASIMO, which is a stably constructed system can walk fairly similar to a person without disturbance. It is a necessity for 2 legged walking robots to conquer realistic difficulties created by stairs or various levels of ground, where wheels cannot go and which can coexist with humans in an efficient manner.

We firstly develop the lower part of a humanoid system to embody walking of the high speed. The lower part of the body system is designed by 12 degree of freedoms. And each joints make use of 12 motors.

The big torque is required for high-speed walking. The geared motor is used for the bigger torque. But in case of using the geared motor that gear-ratio is high, its size will increase. This problem reduces a flexibility of robot design. In order to solve this design problem, it is necessary to separate a motor part and a gear part.

The gears are embarked in each joint, and it is connected with the motor, which is located in stable spot, by using the timing belt, and a power transmission is condoned. This system can take the higher torque through gear-ratio and belt itself. The motor for each joint is chosen in according to the dynamics and load of the joints. The biggest torque is required knee. The torque value for the others is decided as the order of ankle and thigh

Anyway, the goal of this paper is the development of a smart humanoid robot, which can execute walking with stability and high speed.

2. HUMANOID ROBOT IR-03

In this paper, a stable and high-speed 2-legged walking Robot is designed and implemented in a small size. IR-03 has 6 DOFS, which consist` of 2 DOFS (Yaw and Pitch) at the ankle, 1 DOF at the knee, and 3 (Yaw, Pitch and Roll) DOFS at the thigh. Therefore two legs have a total of 12 DOFS and the leg length is 21 cm. The actuator is a DC motor and its torque is 12.1 kg.

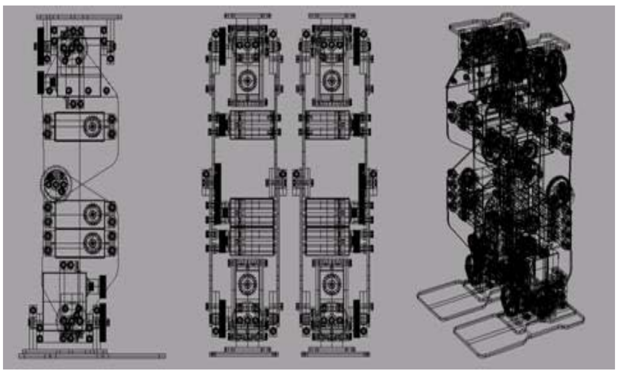

Fig. 1 Mechanical architecture

2.1 Control Architecture

This humanoid robot can generally be divided into the actuator department, main controller department and ATMEL AVR MEGA128 used by the main controller. The actuator makes use of small size independent DC servomotor module. The servomotor has a long life and an accurate potentiometer is built-in. Some of the H-bridges are mixed by a P channel and a N channel MOSFET internally. The gear ratio of the motor and last output is around 250:1, and the motor rotation speed can be around 60 degrees per 0.1 second. The way of control is to compare with the present location measure and target location measures of the potentiometer, which is located in the DC motor and is diminished by the gear until there are no differences. This way the MCU receives the present location measure by feedback in a small and fast motor cycle. The main MCU gives orders for the absolute position by using PWM of the servo motors. By relying on the length of "on times" the absolute position of the motor is changed. The MCU gives new PWM updated data to the motors at scheduled times after dividing the augment data, thus creating tiny unit increases.

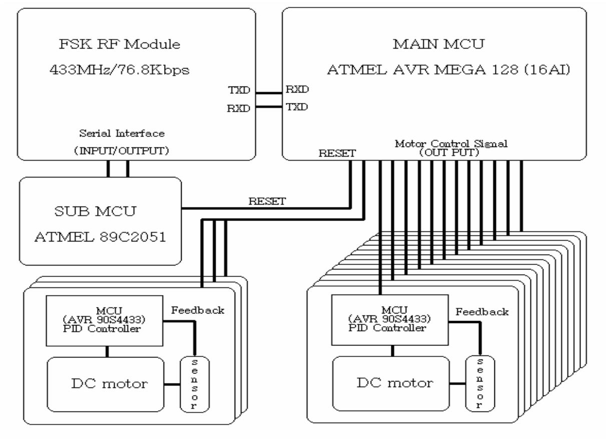

Fig. 2 Robot control architecture

The main MCU and the order of motors are interfaced through one line and all motors are linked on each port. Synchronization of the motor is important to execute one pattern of action. This way it up-dates the new location data during regular cycles that are divided into very small, variable pieces in the motor as signals. Synchronized data is inputted to the necessary motors for walking in the main MCU's memory and it executes walk pattern by drawing information needed from the main MCU after analysis of the RF signals that are supplied by a radio in the human interface controller with the role of calling data that is inputted.

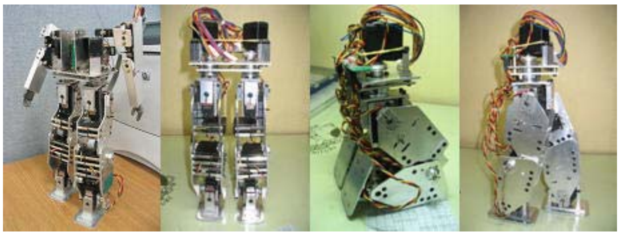

Fig. 3 The appearance

2.2 Human Interface Architecture

The human interface controller is greatly divided by the main MCU, potentiometer that detects position of key input levers and a RF wireless communication department, which can transfer data packages to the robot system via wireless platform. The user can control the robot with commands that have each lever and key input. The devices to receive the commands are the keypad and control levers that are fixed to the pattern action of the robot relying on the commands. According to movement of the control lever, the resistance of the potentiometer is changed, which is connected with variable portions of analog voltage. It is converted from analog to digital for processing in the MCU with a standard position. If it is higher than a standard position, the MCU recognizes that the control stick is in another position, then compares with a standard table and transmits the data of relevant commands to the robot by the RF module. In order to prevent errors, data is transmitted in a composed packet including a checksum to the robot. The packet includes the location of the lever and each command state of the keypad. If transmitting the packet to the robot's RF module, the robot decides whether this packet is in error or not, then picks the data up. After comparing and composing the packet data with its command, the robot executes the right action. This wireless reception data is updated 380 times per 1 second so the robot can react quickly. The distance of wireless communication is around 100m in an open space and 30m in a blocked space between the robot and a human interface controller.

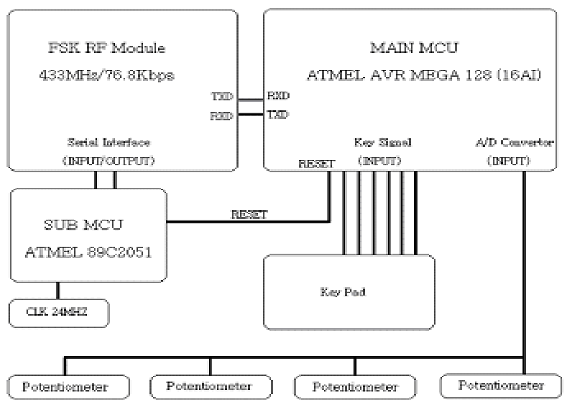

Fig. 4 Human interface architecture

3. EXPERIMENT & CONSIDERATION

This paper is not an analysis of two-legged robots but is suggesting implementation of a real model for stable and high speed walking. As the below table and figure show, we could increase the accuracy of realistic walking patterns by controlling each motor and the percentage of failures through several repeated experiments. We had experimented with the percentage of walking failures according to the number of walking times. Within two experiments there were no manipulator transfers creating changes to the center of gravity in the first and a change in the center gravity in the second. When there was no change of the center of gravity, there were no failures in 1000 walking tests, there also was 0% of failure during side walking on a flat floor. We had experimented with the walking speed of the robot, which was around 1.30 SPS as mentioned in table III Speed of walk. We had 3 kinds of experiments with the robot walking at 1.30 SPS (Second Per Step) involving change of the center of gravity.

Table 1 The number of failure at normal walk

Way of walk	Number of steps	Number of step failures	Percentage of step failures
Straight step	1000 times	0 time	0.00%
Side step	1000 times	0 time	0.00%

When the manipulator was slanted fore-end, center and back, there were no failures at center and back position in the 1000 tests cycles except for a one time failure in the fore-end position, which caused the center of gravity to change. There was no walk failure at a normal center of gravity at 1.3 SPS, thus, we could confirm there was stability with this experiment.

Table 2 The number of failure at center gravity change

Center gravity Change	Number of steps	Number of step Failures	Percentage of Failures
The front	1000 times	1 time	0.01%
The center	1000 times	0 time	0.00%
The back	1000 times	0 time	0.00%

Table 3 Speed of walk

Center Trans-fer	Raising Leg	Reach out the leg	Dropp-ing the leg	Total time Per 1 step	Second Per Step
0.45 sec	0.09 sec	0.09 sec	0.135 sec	0.765 sec	1/0.765 =1.30

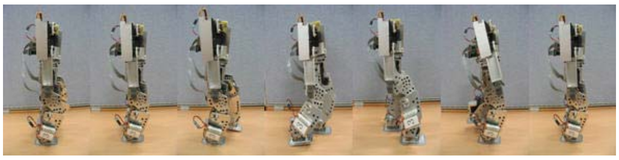

Fig. 5 Stable 2-steps straight walking

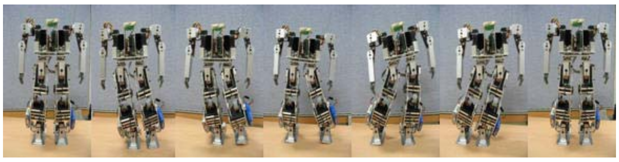

Fig. 6 Stable 2-steps side walking

As a result, we proved that optimal mechanical design, distributed control and parallel processing could affect stability and high speed walking through experimental data. We could get the appropriate data to enable the control of each section of motor speed and location.

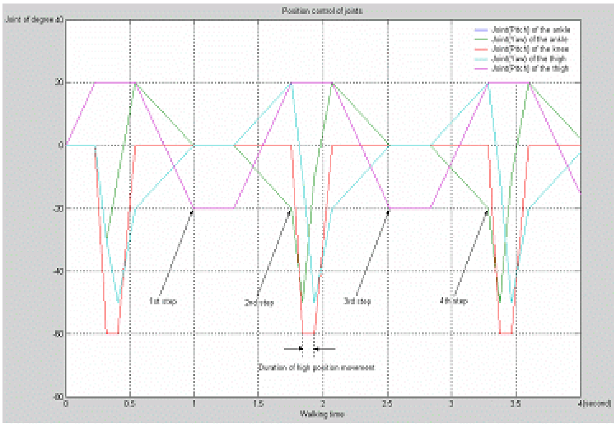

Fig. 7 Analysis of the controlled signal (Left leg)

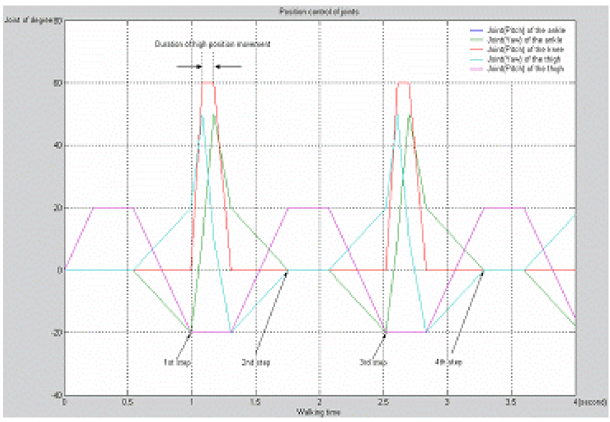

Fig. 8 Analysis of the controlled signal (Right leg)

4. CONCLUSIONS

The humanoid robot has a built-in control and human interface architecture, which were designed for optimal stability and high speed walking. For realization of stable walking, it used distributed control, which can minimize the inertia effect. Stable walking was proved. The synchronization of 12 motors was also an important point for high speed walking. In order to control the 12 motors, adjustable speed control and parallel processing control was relatively useful. It proved the walking speed was 1.30 SPS. This humanoid robot was a winner at the Asia Humanoid Fighting and the Korea Humanoid Fighting contests. A big-sized humanoid Robot, which can walk in stability and high-speed, is to be appeared in the end of 2004.

5. UNITS AND SYMBOLS

5.1 Units

SPS : Second Per Step.

5.2 Symbols

ZMP : Zero Movement Point.

ACKNOWLEDGMENTS

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