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# IMPLEMENTATION FOR A BIPED ROBOT AND DETECTION OF HIP, KNEE AND ANKLE ANGLES IN WALKING STEP OF HUMAN USING A VIDEO CAMERA

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## ABSTRACT

In this study, the motion functions providing how to move in a coordination of 12 joints of biped robot were measured by a video camera, and implement in the software of biped robot. Each joint hereby was ensured to move in harmony with each other. Every engineers interested in mechatronic wants to make a biped walking robot, because the harmony in normal human walking derived from rhythmic movements is spectacular. It is very difficult to budge in a harmony all joints of biped robot composed of minimum 12 joints. Therefore it must be known how to move in a step of each joint.

## INTRODUCTION

The development and modelling of walking movement on two legs of humanoid first human-like robot were performed by Prof Vukobratovic in 1969. The most functional humanoid is ASIMO, who was developed by Honda company, nowadays[1]. However, advances on humanoid have been rapidly continuing, and each new study on robots adds additional humanoid characters to them. The most important feature of humanoid is that they are biped. At least one foot of the robot must be on ground, while the robot is walking in the balance as biped. As the feet of robot are not connected to the ground, there are at least six degrees of freedom (DOF: Degrees of Freedom); two in hip, one in knee and two in ankle, directly uncontrolled between ground and the feet of robot . Therefore, a walking humanoid must have at least six degrees of freedom (DOF) for its each leg.

The orbits of joint angles are needed to program a biped walking robot. Moreover the movements of these joints are associated with each other. Therefore it is necessary to determine a method to be used finding joint orbits of robot before programming a biped robot.

In general, six methods are used to determine orbits of joint angles:

1. Analytical (Constraint Based Design, Oscillatory Gait Trajectory (Sinusoidal Gait Generation, Coupled Oscillator Pattern Generator), Interpolation Based Design),
2. COG Based (Modeling as an Inverted Pendulum),
3. Measured Human Walking Data Based,
4. Stability Based,
5. Optimality Based, and
6. Computational Intelligence Based [2].

The aim of present study was to form orbits of the hip, knee and ankle angles of a biped robot detecting by a video camera joint angles of the sagittal plane view of participant, using a model “Measured Human Walking Data Based”.

## RESULTS AND DISCUSSION

### Human walking

It is a series of rhythmic movement using two feet for a human motion from one place to another. In this process, at least one foot must be on the ground. Meanwhile all the joints move to form a harmony. Therefore, the harmony in normal human walking derived from rhythmic movements is spectacular [3].

### Gait cycle

Identification of the gait cycle was firstly done by the German Weber brothers in 1836. Walking is found as a cycle due to the constant repetition of joint movement on legs in human walking process. Gait cycle starts with replacing the heel of foot. Cycle is 0% when foot touches on the ground and in the ongoing process, cycle becomes 100% when the same foot is on the ground. Gait cycle consists of two phases. These phases are the stance and swing phases [4]. Although some authors report that stance and swing phases rates are 60% and 40%, respectively, others state that stance and swing phases rates are 62% and 38%, respectively. It was determined that there is a rate about 1,618 between stance and swing phases in 2013. This rate corresponds the golden ratio of every detail in universe [5]. According to the terminology developed by Jacqueline Perry, "Rancho Los Amigos (RLA)", stance and swing phases were divided into 8 sections: Initial contact, Loading response, Midstance, Terminal stance, Preswing, Initial swing, Midswing, Terminal swing [4]. ]. In Figure 1. an example of human gait cycle model is given.

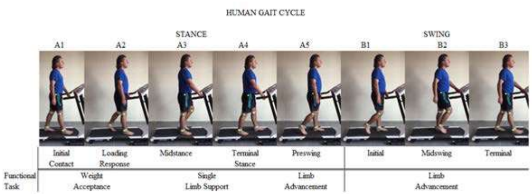


Fig. 1. Gait Cycle

### Gait Analysis

Gait analysis was firstly performed by Garrison (1923). Then this analysis was developed by Bresler & Frankel (1950) and Steindler (1953), and perfected by Sutherland (2001, 2002, 2005) [6].

As human eye can not see smaller motions than 83 ms, a more detailed observation is needed.

So the following analysis techniques are used in order to evaluate human walking:

• Video cameras with a software system overlay
• Chronophotography (strobe lighting to identify areas)
• Passive Markers (reflective markers placed on the body)
• Active Markers (markers that react to infrared and return a signal)
• Force platforms (floor mounted systems to read the force that areas of the feet apply during motion)
• Electromyograms (EMG – sensors attached to the body to identify individual muscle activity) [7].

Although walking gait analysis is also used to diagnosis of disease in the medical field, in this study, it is used to determine the required joint orbits for programming in the construction of walking robot [6].

Figure 2. is Gait Analysis Method Of Participant, developed by us. This is the first Mobile Phone Camera-based Gait Analysis, which successfully realized in sport center.

Fig. 2. Gait Analysis Method Of Participant.

### Participant

The joint angles of a healthy male subjected of the sagittal plane, who is 1.70 m and 43 year old, were used to determine the required joint angles for programming of robot in this study.

### Video Recorder

A camera of Iphone 6 plus mobile phone, which has 60 shooting features per second, was used to obtain the images of joint angles.

Participant was run on a marching band in speed 2 km/h and his video recording was made of the side view.

### Motion Analysis Software Program

Video records, which are required for the walking analysis, were examined with the Tracker program, and values of hip, knee and ankle angles per 60 fps were used to draw a excel chart.

In Figure 3. Tracker is easy and free Motion Analysis Software Program.

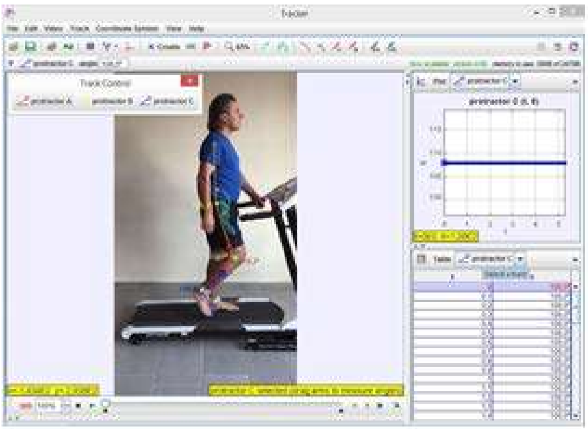

Fig. 3. Determination of angles with Tracker.

### Servo Motors

Smart servo motor was used for providing the two-legged robot joint motion. The Dynamixel MX-64T servo actuator(Figure 4.)is developed by a Korean manufacturer ROBOTIS. Improved economic and compact intelligent servo motors intended for use in robotics and automation systems. Equipped with an ARM Cortex M3 features a PID control algorithm and provides feedback information such as speed, temperature, position and load. Over a simple TTL interface you can command, configure, and access information from several daisy-chained(Figure 5.) servos[8].


Fig. 4. MX-64T Servo Motor.

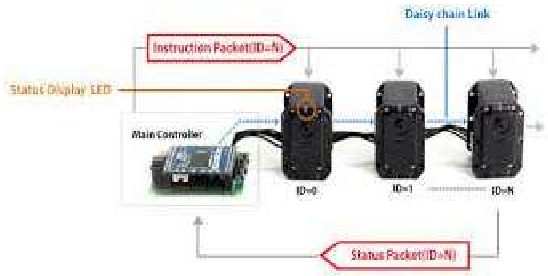


Fig. 5. Several Daisy-Chained Servos.

### Main Control Board

In order to check a total of 12 servo engines in the biped robot, we used a OpenCM.9.04 control board(Figure 6.), which allows the open source programming. Just as An Arduino IDE, In Figure 6., Open CM.9.04 Control Board also is available for C/C++ programming.

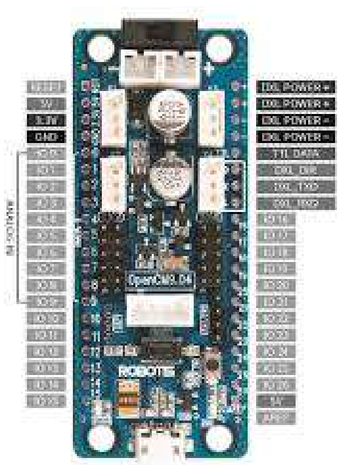


Fig. 6. Open CM.9.04 Control Board.

### Results

In this paper, hip, knee and ankle angles(Figure 9,10,11.) were obtained from the participant by a video camera using gait analysis (Figure 7.). After these angles were linearized (Figure 12,13,14.),they applied to the biped robot software(Figure 8.). The measurement results of hip, knee and ankle angles from the biped robot were found with the Tracker software using a video camera, and then these results were compared to previous studies. Although the linearized angle values were implement to the biped robot, it was observed that harmony in walking steps of the biped robot was spectacular.

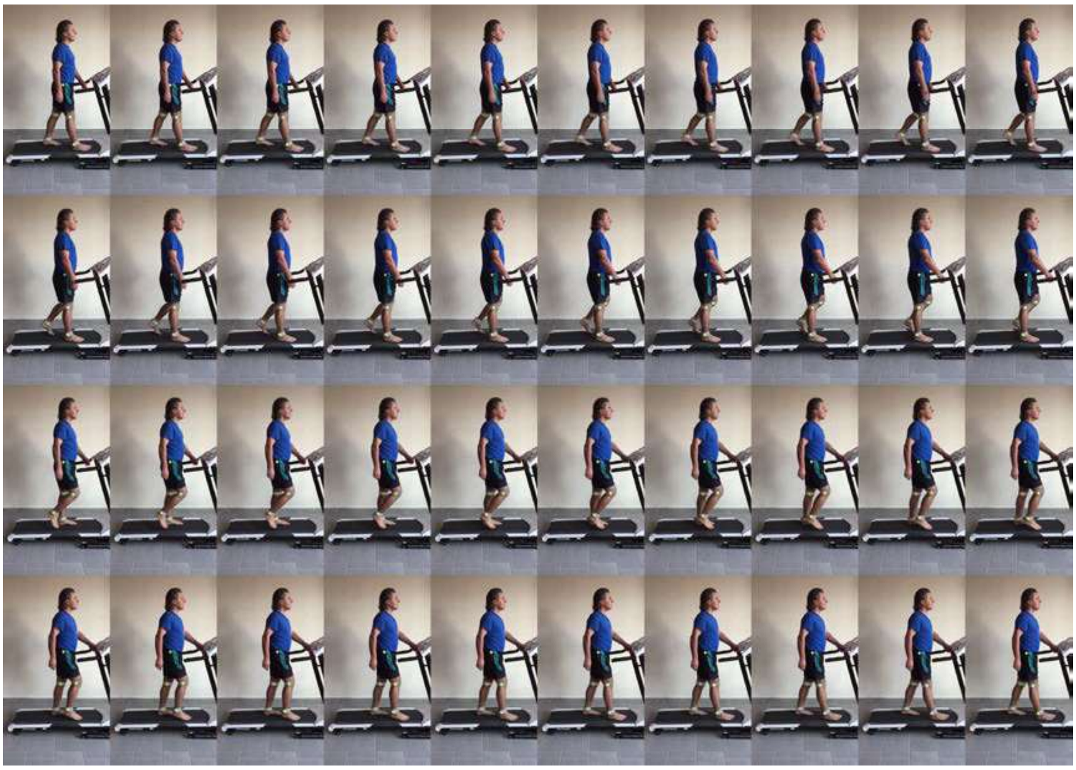

Fig. 7. Motion Recorder Result Of Participant.

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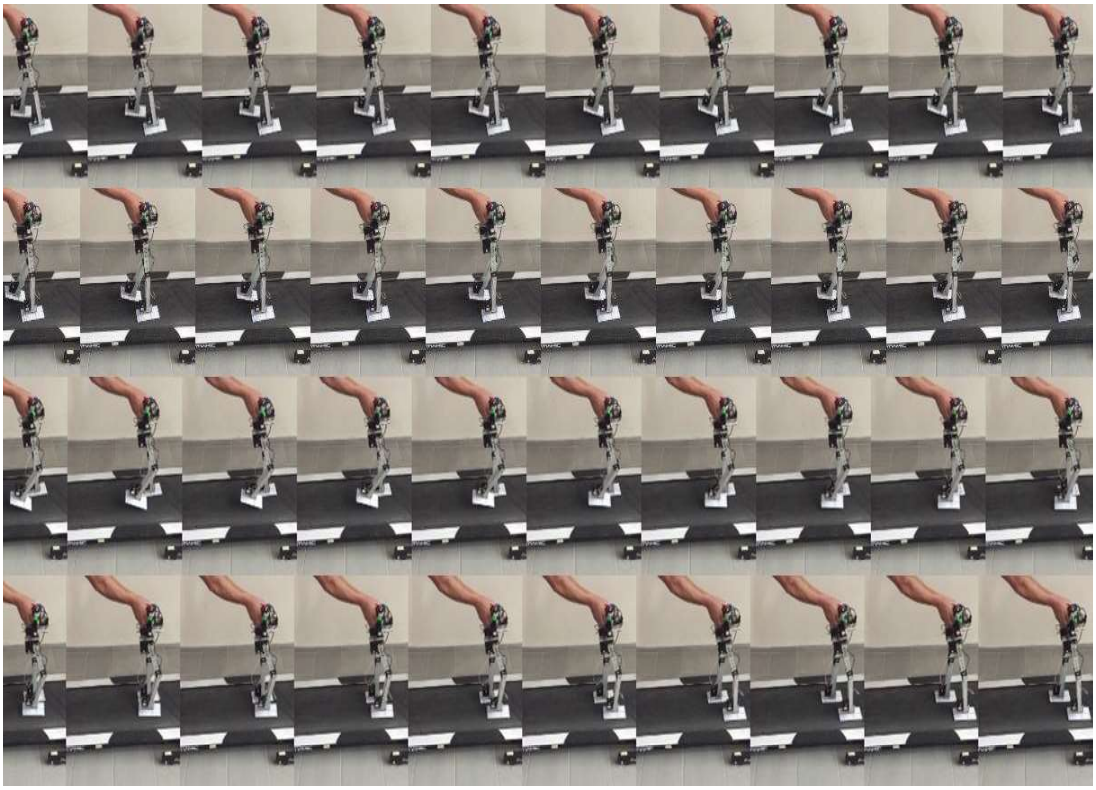

Fig. 8. Motion Recorder Result Of Biped Robot.

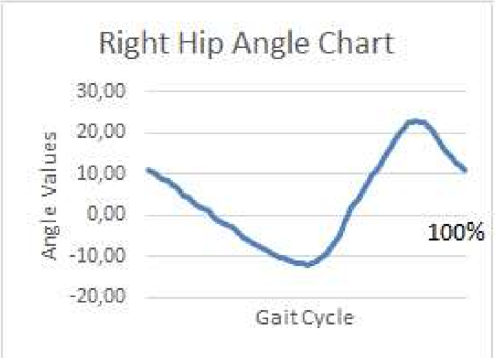


Fig. 9. Right Hip Angles Result Of Participant.

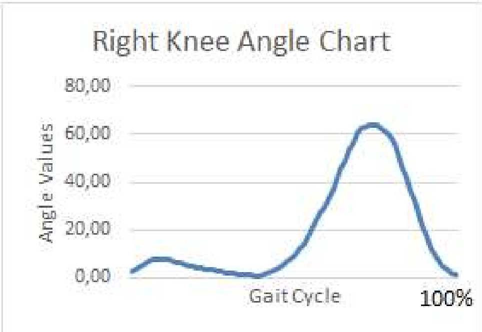


Fig. 10. Right Knee Angles Result Of Participant.

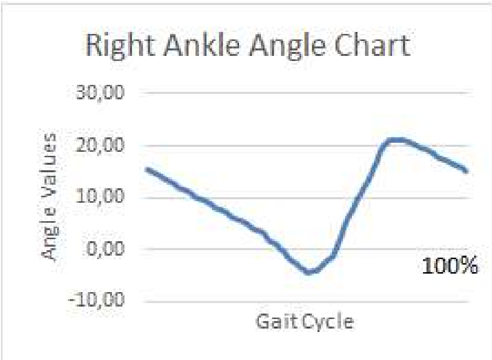


Fig. 11. Right Ankle Angles Result Of Participant.

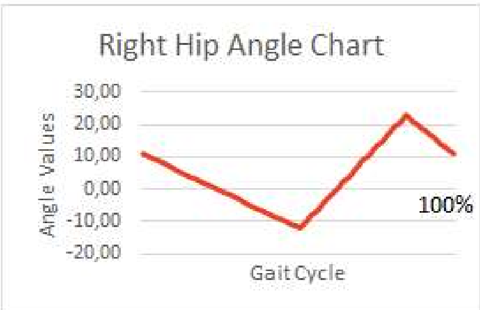


Fig. 12. Right Hip Angles Result Of Biped Robot.

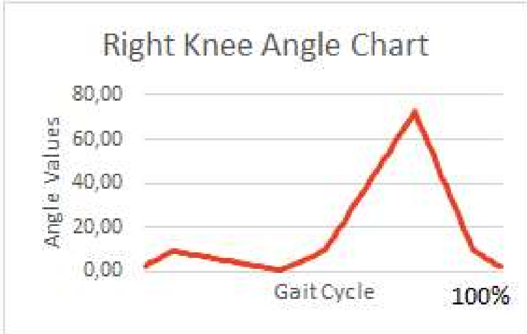


Fig. 13. Right Knee Angles Result Of Biped Robot.

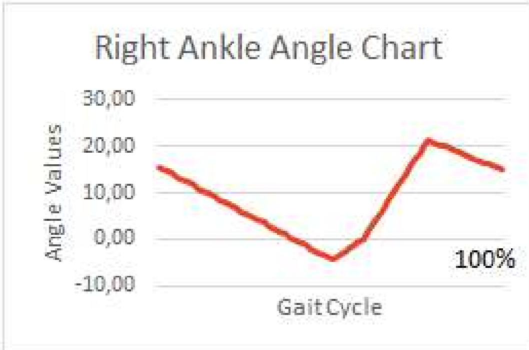


Fig. 14. Right Ankle Angles Result Of Biped Robot.

## CONCLUSION

In the future studies the target participants hip, knee and ankle graphics without linearization, determining real curve functions and installing to the biped robot's software is intended. Thus, it is concluded that the hip, knee and ankle angles of the curve in the graph of the harmony in the biped robot's gait cycle would be enriched. Additionally, if the movements of other animal robots such as cat dog and horse analyzed real walking robots like these can be made soon.

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