Control of Bionic Robot Leg Performance with Proportional Integral and Derivative Controller

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***Abstract*— False limbs are aids for people with disabilities who have not been able to make users move freely like normal people. In this study, the concept of PID control prosthetic limbs was developed with a robot function that resembles the function of the knee ankle joints. By using PID control that the motion of the robot leg can be controlled accurately. The PID parameters obtained for the knee are kp = 2, ki = 18 and kd = 0.5, while for the ankle that is kp = 1, ki = 1.5 and kd = 0.5. The performance of motion bionic robot leg is obtained with small overshoot signal, small error signal and quickly to achieve stable response are 3,432%, 3.69% and 0.877s respectively.**

***Index Terms*—PID control, bionic robot leg, electromyography, dc motor, performance**

I. INTRODUCTION

Indonesia country is still unable to produce artificial robot legs themselves, due to inadequate domestic industrial technology to produce the materials needed. However, from interviews with disable people that they want to have robotic bionic leg because manual prosthetic limbs cannot be moved freely. To overcome this, this research includes developing the concept of robotics on artificial legs called bionic legs or robotic limbs [1] [2]. The robot function applied in this study was made to resemble the knee function and ankle function. Skeletal legs are shaped like human feet. This robot uses a dc motor commonly used on car wiper motors. This dc motor movement will be controlled by an Arduino Mega 2560 which is synchronized with the Myoware sensor. This sensor will be connected to the leg muscle where the signal from the electrical potential will be forwarded to the microcontroller [3]. This study uses the concept of a prosthetic leg. We have developed it into the inventor software and then simulate it with the MATLAB/Simulink program [4].

Prototype Bionic Leg has adapted the low technology robot system because it only uses an electric motor. The price is cheap and easy to control, besides each prototype only has 2 elbow movements and a cycle time of under 10 seconds [5]. The bionic robot foot was developed using Proportional Integral Derivative (PID) control system. The advantage of using this control system is that it is easier to make adjustments through the measured variables obtained [6]. According Hualong Xie, the bionic robot leg with PID controller control system provides natural human motions using trial and error methods[7].

In this study the auto PID control system on MATLAB / Simulink-based is designed to get an optimal, accurate, and fast response to the prototype bionic foot by reducing the error signal, maximum overshoot, and completion time [8].

II. METHOD OF RESEARCH

A. Description of Research

The research method has used a simulation and experimental method. We make modeling visualizations and test causal hypotheses through the manipulation of independent variables. Fig. 1 shows the visualization of 3D bionic leg modeling is using the inventor program and PID control system testing using MATLAB/Simulink software.

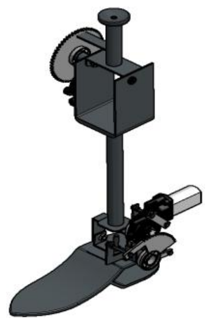

Figure 1. 3D modelling of a bionic foot prototype

Voltage is the input reference as the independent variable and the dependent variable is the output in the form of the actual motion of the prototype. The data obtained are in the form of bionic transient response graphs. The discussion is made from the results of testing the data so that conclusions can be obtained about the design and implementation of the PID control system on prototype of bionic robot leg.

The making of the prototype robot leg follows the example of the 3D drawing design that has been drawn. The size can be made to adjust the user's feet later, but currently, the author makes it in accordance with the size of the 3D image reference. The author works on making the framework itself using available technical equipment such as grinding, drilling, welding tools, some tools to

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help measure and refine the materials that are in the Laboratory of Mechanical Engineering, Udayana University.

Fig. 2 shows a prototype bionic foot containing several electrical and mechanical components such as the Arduino Mega 2560, DC motor, motor drive (L298N), EMG sensor and potentiometer. The DC motor used in this study is a dc wiper motor car. DC motor as an actuator is connected to the motor drive, Arduino Mega 2560 and battery. Arduino microcontroller is used to adjust the rotation of the DC motor. Myoware is a muscle sensor as a reference input of muscle movement. The potentiometer is used as a feedback input. An angular position robot is actual output.

In the MATLAB program, there is a Tuning controller function to determine the parameters of the PID controller with the aim that the closed-loop system meets the desired performance criteria following the plant and the DC Motor actuator used.

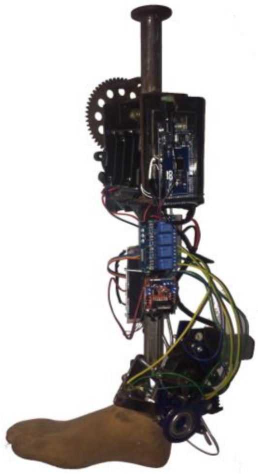

Figure 2. The real prototype bionic robot leg

B. *Testing of Research*

Fig. 3 shows about the initial testing of the bionic robot leg. In the first of experiment we have interfacing with Matlab / Simulink on the prototype applying a simple control system, and combination of various PID control at 10s, 90 ° for the knee joint rotation and in Fig. 4 shows the ankle joint rotation can move from 0 ° to 50 °. From the testing motion of prototype is computed the performance of the error signal parameters and maximum oscillation small than 5% and time stability control quickly.

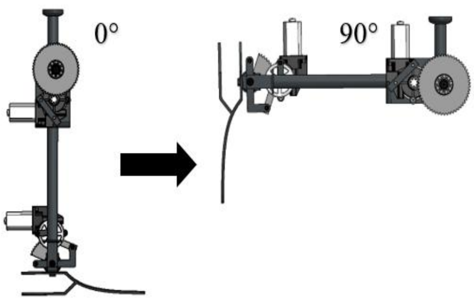

Figure 3. Knee section prototype reference angle modeling

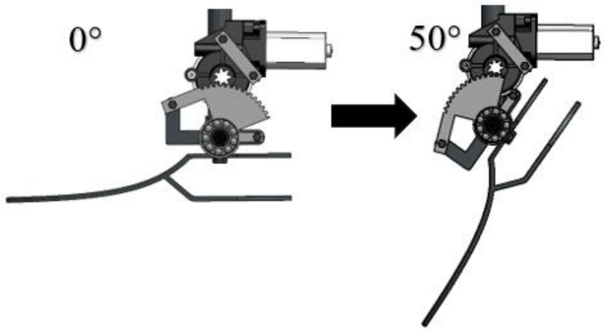

Figure 4. Modeling the prototype reference angle of the ankle section

C. *Strategy Control*

In this study, the prototype of the bionic foot will focus on the knee and ankle joints because the center of the load of the motor will be in that part. The movement of the prototype was adapted from the human walking phase to get the reference angle used as a benchmark in this study [9].

The block of PID controller is shown in Fig. 5. PID controller parameter tuning is always based on a review of the regulated characteristics (plant). There are two methods of experimental approach including the Ziegler-Nichols method and the Quarter decay method.

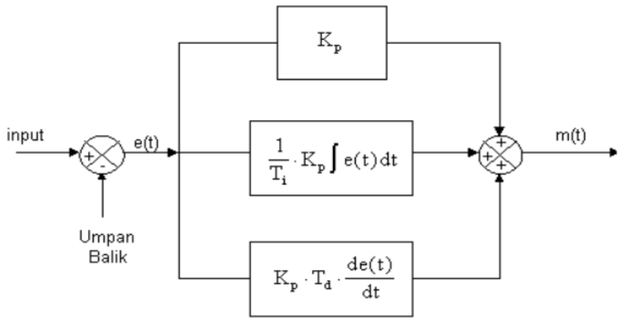

Figure 5. Block diagram of a PID controller

The characteristics of a PID controller are strongly influenced by the large contribution of the three parameters P, I and D [10]. The setting the constants, and will result in the protrusion of the properties of each element. One or two of the three constants can be adjusted more prominently than the others. The prominent constants are influenced on the overall system response.

III. Result and Discussion

By performing an interface between the bionic foot prototype and the MATLAB program, the test results are in the form of a graph of the actual response of the bionic foot movement. The following is presented a comparison of the results of testing the motion of the robot leg with a control system without PID and with PID.

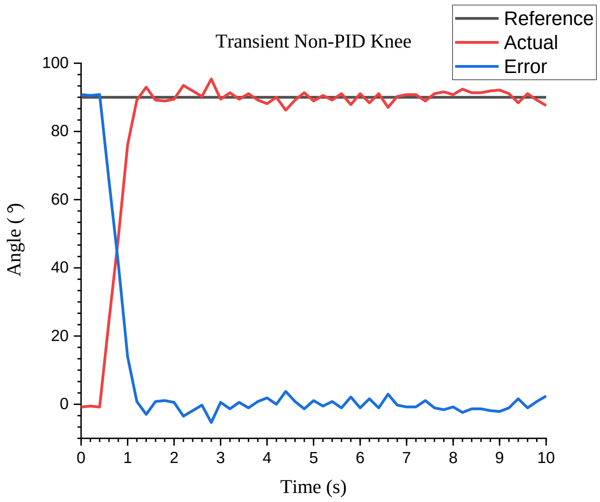

Figure 6. Transient responses in knee without PID control

Fig. 6 shows gray line is the reference angle, the red line is the actual movement and the blue line is the error signal. From the test of a simple control system shows the oscillating DC motor movement and tends to be unstable. The unstable movement is caused by the absence of a motor movement regulator. The time needed to reach the reference angle is 1.714s. Maximum overshoot is achieved at an angle of 98.04 degrees or 17.31%. The test results show that the maximum oscillation signal outstrips the predetermined value. The driving error signal from the dc motor rotation is 7.25%. So the magnitude of the error value generated by the simple control system prototype exceeds the specified limit (above 5%). Prototype performance is still not good and produces movements that are not optimal and accurate.

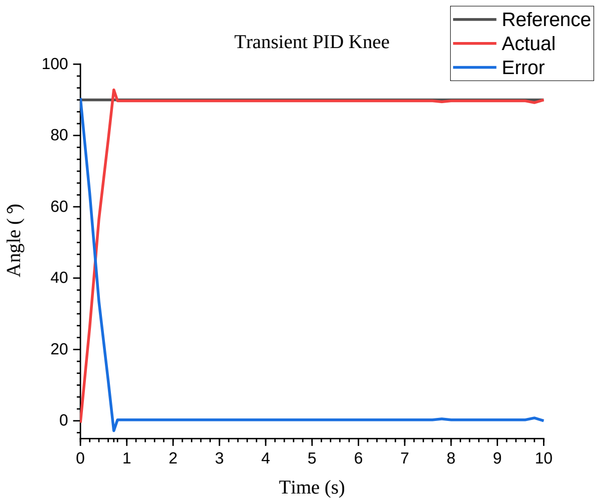

Figure 7. Transient responses in knee with PID control

Fig. 7 shows the gray line is the reference angle, the red line is the actual movement and the blue line is the error signal. By using the PID control system, the movement of the dc motor rotation is more accurate than that of the simple DC motor control system. The time needed to achieve the reference angle is 0.7 seconds and reaches stability at 0.9 seconds with an angle of 89.73 degrees. The maximum overshoot is at 92.81 degree, which is 3,432%. The maximum overshoot value obtained does not exceed a predetermined value (below 5%). The error signal is 3.341% and the maximum error value obtained is at 90.54 degree so that the percentage of error signal is 3.69%. The error signal produced by the prototype with the PID control system does not surpass the specified limits and produces more accurate movements than using a simple control system.

The Table I shows the comparison performance of actual motion dc motor using PID and without PID control system.

TABLE I. TESTING OF MOTION DC MOTOR AT ANKLE WITHOUT AND WITH PID CONTROL

No	Performance	Without-PID	PID
1	Max-Overshoot (%)	17.31	3.432
2	Error (%)	7.25	3.69
3	Settling time (s)	1.714	0.877

IV. CONCLUSION

The parameters obtained from the design of the PID control system on the prototype bionic foot are Kp=2, Ki = 18 and Kd = 0.5 on the knee; While Kp = 1, Ki = 1.5 and Kd = 0.5 on the ankle. The prototype motion with the PID control system has a maximum overshoot value, error percentage, and settle time at the knee valued at 3,432%, 3.69%, and 0.877s respectively; Whereas the ankles are 0.688%, 0.739%, and 2.2s respectively. The prototype motion with a PID control system is better than a simple control system because.

CONFLICT INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Conceptualization, W.W. and C.G.I.P.; methodology, W.W, I.G.N.N.S., I.N.G.A.; software, W.W., and I.C.I.P.; validation, W.W., I.G.N.N.S. and I.N.G.A.; formal analysis, W.W.; investigation, W.W. and I.N.G.A.; resources, W.W.; data accurate, W.W.; writing—original draft preparation, W.W.; writing—review and editing, W.W. and I.G.N.N.S.; visualization, W.W.; supervision, W.W.; project administration, C.G.I.P.; funding acquisition, W.W.

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