

Fuzzy Control of Inverted Pendulum Using LABVIEW

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ABSTRACT: Generally the inverted pendulum is unstable, because the pendulum will fall downward due to the gravitational force acting on mass of the pendulum. Keeping the pendulum at vertically inverted position, the position of DC motor shaft needs to be controlled using closed loop analysis. For closed loop analysis, feedback or input device such as encoder is used. To control and set the pendulum at desired inverted position in LABVIEW, fuzzy control logic was selected. Fuzzy control logic provides the stabilization of pendulum at vertical position without using mathematical approach such as conventional approach. Fuzzy logic control system (FLC) was selected as the control technique due to its ability to deal with nonlinear systems such as inverted pendulum. Special feature of fuzzy logic control is that it controls the physical system.

KEYWORDS: inverted pendulum, fuzzy logic control and LABVIEW.

I. INTRODUCTION

Modern day control engineering is a relatively new field of study that gained a significant attention during 20th century with the advancement in technology. Control theory is a field rich in opportunities and new directions dealing with disciplines and methods that leads to an automatic decision process in order to improve the performance of a control system. The evolution of control theory is related to research advanced on technology, theoretical controller design methods and their real-time implementation. It is important to note that evolution of control theory is also closely related to education and the next generations of students studying control system must receive the scientific and pedagogical supports required to verify conventional techniques, develop new tools and techniques and verify their realization.

Fuzzy Logic Control system (FLC) was chosen as the control technique because of its ability to deal with nonlinear systems, as well as its intuitive nature. Fuzzy logic is gaining increasing interest in the controls community. It is one of several control schemes, that include neural network and genetic algorithm based controllers, which are considered unconventional. One special feature of fuzzy logic control is that it utilizes the expertise of humans to control the physical system, so that complex system can be controlled without precise knowledge of the plant. The designer can build up the controller based on general idea of what it must accomplish. It is for this reason that fuzzy logic is particularly useful in instances where a human operator is being replaced, or where a human has an implicit model in mind of the input-output behavior of the system. Another reason for the recent interest in fuzzy logic controllers is their inherent robustness property because of the fuzzy nature of the controller, variation in system parameters are handled with ease. However, all evidence of robustness is either from simulations or experiments as no mathematical proofs of robustness can be constructed. For an example, there are clearly some situations where fuzzy logic will not work well because fuzzy controllers rely on sample rates that are high relative to the system dynamics as well as a common sense control situation. For fast systems with a complex input-output relationship, other control schemes may be more appropriate.

Thus, the modeling and analysis for this controller is done in LABVIEW. Therefore, the best control approach needs to be discovered in order to give the best performance for the inverted pendulum system.

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Section II provides the mathematical model of inverted pendulum system, description of fuzzy control logic and energy calculation of inverted pendulum system. Section III gives the conclusion and future scope of the project.

II. INVERTED PENDULUM SYSTEM

This section briefly discusses the overall project design including the workflow of activities, controller design and model inverted pendulum design. Figure 3.1 shows the flow chart of this project activity. Basically, the process of developing a fuzzy logic control for inverted pendulum can be divided into three (3) phases: first phase is inverted pendulum design, second phase is fuzzy logic controller and last phase is interfacing the system design with hardware. Before designing the inverted pendulum system, their mathematical model needs to be obtained in the first place. From the mathematical model, the transfer function of the system can be derived. Then LabVIEW VI is used to generate the output response.

A. Inverted Pendulum Design

The first phase of this project involves the inverted pendulum design. The previous section has discussed about the theory and previous researches on inverted pendulum system. In this section, the first step is to derive the mathematical model for the inverted pendulum (IP) system. After that, the IP system can be designed based on the mathematical model calculation by using LabVIEW. The inverted pendulum is a highly nonlinear and open-loop unstable system. This means that standard linear techniques cannot model the nonlinear dynamics of the system. When the system is simulated the pendulum falls over quickly. So, the project requirement is to be fulfilled based on the objective and scopes.

B. Fuzzy Systems

A fuzzy system is a system of variables that are associated using fuzzy logic. A fuzzy controller uses defined rules to control a fuzzy system based on the current values of input variables. Fuzzy System Designer and the Fuzzy Logic VIs can be used to design and control the fuzzy systems. Designing a Fuzzy System with the Fuzzy System Designer, for information about the Fuzzy System Designer. Modifying a Fuzzy System with the Fuzzy Logic VIs, for information about the Fuzzy Logic VIs. Fuzzy systems consist of three main parts: linguistic variables, membership functions, and rules.

Linguistic Variables

Linguistic variables represent, in words, the input variables and output variables of the system you want to control. For a heater, you might have two input linguistic variables, current temperature and desired temperature, and one output linguistic variable, heater setting. Each linguistic variable has a range of expected values.

Linguistic Terms and Membership Functions

Linguistic terms represent, in words, categories for the values of a linguistic variable. The linguistic variables current temperature and desired temperature each might include the linguistic terms cold, moderate, and hot. The linguistic variable heater setting might include the linguistic terms off, low, and high. Membership functions are numerical functions corresponding to linguistic terms. A membership function represents the degree of membership of linguistic variables within their linguistic terms. The degree of membership is continuous between 0 and 1, where 0 is equal to 0% membership and 1 is equal to 100% membership.

Rules in Fuzzy Logic

Rules describe, in words, the relationships between input and output linguistic variables based on their linguistic terms. For example, you might define the following rule: IF current temperature is cold AND desired temperature is moderate, THEN heater setting is low. The clauses "current temperature is cold" and "desired temperature is moderate" are the antecedents of this rule. The AND connective specifies how the fuzzy logic controller relates the two antecedents to determine the truth value for the aggregated rule antecedent. The clause "heater setting is low" is the consequent of this rule. A rule base is the set of rules for a fuzzy system. The rule base is equivalent to the control strategy of the controller.

Fuzzy Controllers

Fuzzy controllers can be used to control fuzzy systems. Most traditional control algorithms require a mathematical model of the system we want to control. However, if we can describe a control strategy qualitatively, we

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can use fuzzy logic to create a fuzzy controller that emulates a heuristic rule-of-thumb strategy. Figure.1 illustrates the process of a fuzzy controller.

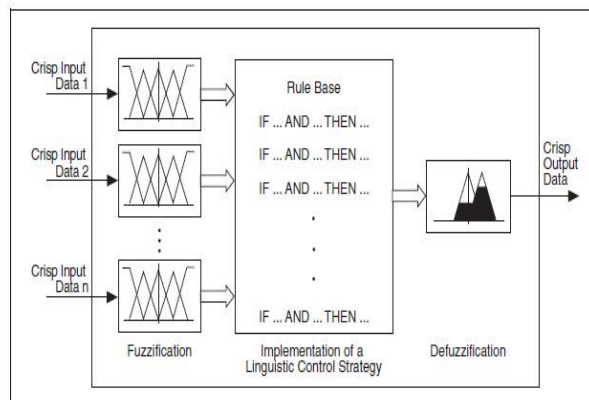


Figure.1 Process of a Fuzzy Controller

Fuzzification

Fuzzification is the process of associating crisp, or numerical, input values with the linguistic terms of the corresponding input linguistic variables. For example, a fuzzy controller might associate the temperature reading from a thermometer with the linguistic terms cold, moderate, and hot for the current temperature linguistic variable. Depending on the membership functions for the linguistic terms, the temperature value might correspond to one or more of the linguistic terms.

C. Energy calculation in a Pendulum

In a simple pendulum with no friction, mechanical energy is conserved. Total mechanical energy is a combination of kinetic energy and gravitational potential energy. As the pendulum swings back and forth, there is a constant exchange between kinetic energy and gravitational potential energy.

Potential Energy

$$E_p = M_p * g * L_p (1 - \cos \alpha) \quad (1)$$

Where, E_p is potential energy, M_p is the mass of the pendulum, $g=9.81$, L_p is the length of the pendulum.

Kinetic Energy

$$E_k = 1/2 * J_p * (\dot{\alpha})^2 \quad (2)$$

Where, E_k is kinetic energy, J_p is moment of inertia.

Total Energy

$$E = E_p + E_k \quad (3)$$

$$E = M_p * g * L_p (1 - \cos \alpha) + 1/2 * J_p * (\dot{\alpha})^2 \quad (4)$$

$$\dot{E} = M_p * u * L_p * \dot{\alpha} * \cos(\alpha) \quad (5)$$

$$u = (\dot{E} - E) * \dot{\alpha} * \cos(\alpha) \quad (6)$$

III. RESULTS AND DISCUSSION

This section provides the simulation results of inverted pendulum system using the LabVIEW software by implementing fuzzy control technique.

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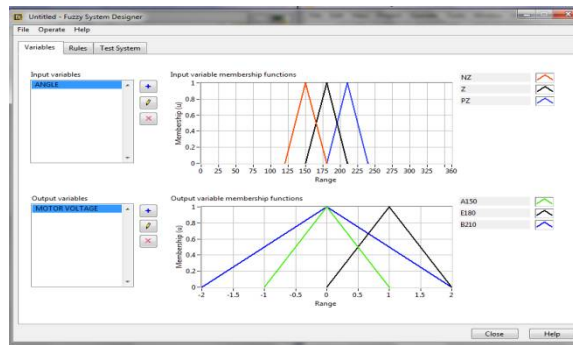


Figure.2 Creation of Fuzzy Linguistic Variables

The above figure.2 shows that the creation of linguistic variables. Fuzzy control logic consists of angle as an input variables and motor voltage as an output variable.

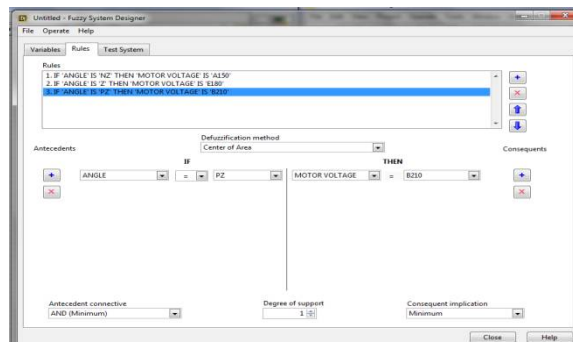


Figure.3 Creation of Fuzzy Rules

The above figure.3 shows that the creation of rules in fuzzy logic for given input and output variables.



Figure.4 Experimental Setup of Inverted Pendulum System

The above figure.4 shows that the experimental setup of inverted pendulum system using fuzzy logic control.

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Figure.5 Output of Fuzzy Control of Inverted Pendulum System

The above figure.5 shows that output of fuzz control of inverted pendulum system using LABVIEW while balancing of pendulum at inverted position.

IV. CONCLUSION AND FUTURE WORK

Finally, the inverted pendulum will be designed using fuzzy logic in LABVIEW. The singing of pendulum can be controlled by calculating energy of the pendulum by controlling angle and position of DC motor shaft. The balancing of pendulum at inverted position can be done using fuzzy logic control technique. Moreover simulation with LabVIEW software saves project development time as the motor position and generation of proper motor control signal can be easily adjusted. LabVIEW debugging tool is self-adaptive and easy to implement which saves considerable amount of time than other simulation software's like MATLAB. This can be applied to rocket or missile guidance, where the center of gravity is located behind the center of drag causing aerodynamic instability.

Future work of the project can be done by using the concept of single inverted pendulum we can design the inverted pendulum by controlling the pendulum with the help of cart and also we can design the double inverted pendulum using LABVIEW.

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