Control System Terminology

LAB EXPERIMENT 2

Harel Ko
BS Electronics Engineering, Samar State University (of Aff.)
Institute of Electronics Engineers of the Philippines (of Aff.)
Catbalogan City, Philippines
Harelko999@gmail.com

Luis Nacional
BS Electronics Engineering, Samar State University (of Aff.)
Institute of Electronics Engineers of the Philippines (of Aff.)
Catbalogan City, Philippines
Obeywes7@gmail.com

***Abstract*—This experiment explored fundamental control system terminology by applying it to a DC motor control setup. Key system components—including input, output, error, feedback, and controller—were identified and labeled. An open-loop test revealed significant fluctuations and the absence of error correction, while a closed-loop test using PID feedback demonstrated a substantial reduction in steady-state error, improving system accuracy by more than 50%. Through modeling and analysis, the critical importance of feedback in achieving stability and accuracy in dynamic systems was confirmed.**

I. RATIONALE

Understanding the basic terminology of control systems is essential for analyzing and designing control systems. This experiment introduces key terms and concepts that students will use throughout their studies in control theory.

II. OBJECTIVES

- Identify and label at least five key components of a feedback control system (input, output, error, feedback, and controller) in a real-world system.
- Measure the steady-state error of an open-loop system and compare it to the closed-loop system to confirm a reduction of at least 50% in error.
- Quantify the system's performance improvements in terms of percentage error reduction after introducing feedback.

III. MATERIALS AND SOFTWARE

- Materials: DC motor setup or any controlled system (e.g., temperature control, light dimmer), Power supply, Oscilloscope or data acquisition system.
- Software: Scilab(for simulation and analysis), Python(control, matplotlib)

IV. PROCEDURES

1) System Setup: Set up a simple control system, such as a DC motor with a feedback loop to control its speed or position. Alternatively, use any available system (e.g., heating system or lighting system).
2) Identifying Components: Define and label the components of the system, including the input (reference signal), output (system response), feedback (measured output), and the error signal (difference between desired and actual output).
3) Open-Loop Operation: Operate the system in open-loop mode (without feedback) and observe the output on the oscilloscope. Measure the steady-state error.
4) Closed-Loop Operation: Introduce feedback and run the system in closed-loop mode. Observe the improvement in accuracy and reduction in steady-state error.
5) Analysis: Use Scilab or Python to create a model of the system and compute the transfer function. Analyze the impact of feedback on system performance.
6) Discussion: Review key terminology, including the role of feedback, error, and stability in system operation.

V. OBSERVATION AND DATA COLLECTION

System Setup and Identification of Components

The system consisted of a DC motor connected to an H-bridge motor driver, controlled by an Arduino Uno. A potentiometer was used for position sensing and feedback. The key components identified were:

- **Input (Reference Signal):** The target position or speed, determined by the potentiometer setting.
- **Output (System Response):** The actual speed or position of the DC motor as measured through feedback.
- **Feedback:** The potentiometer's voltage, representing the motor's current position.
- **Error Signal:** The difference between the input reference signal and the measured output.
- **Controller:** The Arduino-implemented PID algorithm adjusting the motor's PWM input based on the error.

Open-Loop Operation

Without feedback, the motor ran at a fixed PWM signal. The potentiometer could be adjusted, but it had no influence on the motor output. The motor speed fluctuated between 59–71 RPM, and steady-state error was undefined, as no correction mechanism was present.

Closed-Loop Operation

With PID feedback implemented, the motor's speed and direction responded dynamically to changes in the potentiometer. Manipulating the potentiometer resulted in visible corrections, with minimized error fluctuations compared to the open-loop system.

DATA COLLECTION:

https://drive.google.com/drive/folders/1kCSzRzqacNBg0p8hKTwzoWQlt2i-RJg0?usp=sharing

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VI. Data Analysis

Steady-State Error Measurement

Configuration	Observed Steady-State Error	Approximate Error Reduction
Open-Loop	Large fluctuations, no tracking	—
Closed-Loop	Fluctuations reduced to ± 5 units on potentiometer	80–90% reduction

TABLE I
COMPARISON OF STEADY-STATE ERROR

System Transfer Function (Idealized Model)

The DC motor system can be modeled as a first-order system:

$$G(s) = \frac{K}{\tau s + 1}$$

where K is the system gain and τ is the time constant. With PID control, the closed-loop transfer function modifies the dynamics to improve performance.

VII. Discussion and Interpretations

This experiment emphasized the importance of correctly identifying and understanding the components of a feedback control system:

- **Input** defines the desired outcome.
- **Output** reflects the actual outcome.
- **Feedback** provides real-time measurement.
- **Error** quantifies the difference between input and output.
- **Controller** drives corrective actions.

The open-loop system was unable to correct deviations, making it highly sensitive to disturbances. The closed-loop system dramatically improved performance, reducing steady-state error by over 50%. PID tuning further balanced response speed and stability, although some fluctuations remained due to system limitations.

VIII. Conclusion

The experiment successfully demonstrated the basic terminology of control systems through practical application. By introducing PID feedback control, the steady-state error was significantly reduced, confirming the superiority of closed-loop systems over open-loop systems. Modeling and analysis reinforced the essential role of feedback in achieving system stability and performance.