A demo platform to teach and learn the behaviour of a PI controller

Carlos Felgueiras
Polytenic of Porto School of Engeneering
ISEP
Porto, Portugal
mcf@isep.ipp.pt

Kevin Serradeiro
Polytenic of Porto School of Engeneering
ISEP
Porto, Portugal
1150844@isep.ipp.pt

Andre Fidalgo
Polytenic of Porto School of Engeneering
ISEP
Porto, Portugal
anf@isep.ipp.pt

Ricardo Costa
Polytenic of Porto School of Engeneering
ISEP
Porto, Portugal
rjc@isep.ipp.pt

Abstract **– Nowadays new demands are posed to engineering education. Students are becoming more autonomous and curious, which requires the use of new educational platforms to complement theory with practice. A well-designed engineering course should include ways to demonstrate evidence of specific theories, in order to involve students and to dissipate any mistrust that they may have when specific theories are presented. On the other hand, it is important to create sustainable solutions, i.e., low cost solutions that do not produce much waste to the environment. While traditional and/or remote labs can be considered for many situations, there are others where a simple demonstrative platform is enough. It was precisely based on this condition, that a simple PI controller platform was idealized and implemented. This allows a teacher to show the behaviour of a PI controller according to the definition of a set of parameters that will enable the displacement of a pointer with accurate and responsive corrections.**

Keywords- Education, Engineering education, Close loop control, PI controller.

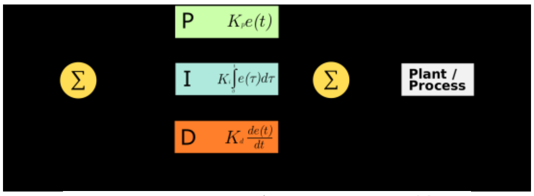
I. Introduction

The new educational paradigm introduced by the Bologna process led to a substantial reduction on the contents of scientific courses. The plan of these courses is currently more concentrated, which means there is less time to include all the necessary contents that would contribute to achieving the required educational outcomes. This is particularly relevant in engineering courses, where teaching the scientific basis is always a requirement to then understand the new and recent innovations, whose inclusion is a necessity in the curricula of those courses. Summing these two aspects (less time and more teaching requirements) alerted the educational community that new teaching and learning solutions are welcome [1,2]. Additionally, it is evident that it is fundamental to provide the people with education in order to integrate them in the current society. From young to old people, all should have the possibility to learn, which means the number of students tends to increase as time passes. This growth of students indicates that more infrastructures are required, such as rooms, equipment, staff, etc. Taking into consideration the enumerated issues, namely: a) new curriculum requirements to include in less hours; b) the trend to increase the number of students and; c) the necessity to have more infrastructure (rooms, technical equipment, etc.), it becomes evident that new teaching and learning methodologies are required in every educational program. Therefore, the old and traditional educational methodologies focused on the teacher are no longer adequate. While some courses can be supported by remotely providing theoretical educational contents, for example, using virtual learning environments such as the Moodle platform, for engineering courses it is necessary to provide practical evidence of theories. This means that the experimental activity is a requirement in every well-designed engineering course. More laboratories are required to enable students' access to real equipment. If the traditional method is adopted, more facilities and personnel would be required. In many situations, providing a remote access to the laboratory through remote laboratories, such as VISIR [3] or other, is a solution to consider, but in terms of sustainability, this solution can be inefficient, since it always means higher costs and more material requirements. According to Gro Harlem Bruntland "a sustainable development is the one that satisfies current necessities without compromising future generations" [4]. This means that, in some situations, it is not necessary to provide a laboratory (be it remotely or not) to students. In fact, it depends on the learning outcomes of a specific topic. If the main issue is providing evidence of a specific theoretical area, a simple practical demonstration in a theoretical class should be enough. This solution will not compromise the sustainability motivation, since it will not increase the costs and the waste of equipment that would affect the environment, especially if a common laboratory or a remote laboratory was designed. In some situations, it is important that a teacher may validate the presented theories using a simple demonstrative infrastructure, in order to dissipate any mistrust students may have on those theories. Through a traditional theoretical class, a teacher may present specific theories, invite students to validate them with calculations and, at the end, it would be interesting to enable the test of those theories using real equipment.

Taking into consideration a compromise of current and future educational needs, and the requirement for creating sustainable solutions in education, a demonstrative platform to verify the behaviour of a PI controller (Proportional and Integral controller) was idealized and implemented. It is intended to be a support platform to verify the behaviour a specific PI controller in a traditional class. This allows students to compare theoretical results with the real behaviour of a PI controller. The steady state error of a typical PI controller can be visualized by observing the displacement of a simple pointer and controlled by changing a set of knobs.

II. PID Controller

The main purpose of using a controller in engineering is to guarantee that a specific definition on a target system is correctly made without, or having the minimum amount of, error. For that purpose, it is very common the utilization of closed-loop system that allows the measuring of the result of a specific definition (set point) on a target system, establishing comparisons to handle possible errors that may exist, and applying accurate and responsive corrections. In engineering, this control is made using the denominated Proportional–Integral–Derivative controller (PID controller). This is a control loop mechanism that employs feedback that is widely used in industrial control systems and in a variety of other applications requiring continuously modulated control. A PID controller continuously calculates an error value e(t) as the difference between a desired set point (SP) and a measured process variable (PV). Based on that difference, it applies a correction in the target system (plant, process, etc.) based on proportional, integral, and derivative terms (denoted by P, I, and D respectively). Figure 1 shows the block diagram of a PID controller and the equation that describes the mathematical influence of each correction (Ki. Integral, Kp-proportional and Kd-derivative) in the behaviour of a given system.



$$u(t) = K_\text{p} e(t) + K_\text{i} \int_0^t e(t')\, dt' + K_\text{d} \frac{de(t)}{dt},$$

Figure 1: Typical diagram and the equation of a PID controller.

Therefore, to demonstrate the behaviour of a controller, an analogue system of a simple PI controller was implemented. As illustrated in figure 2, the project has a reference pointer and a target pointer controlled by a motor able to rotate between 0 to 180 degrees. The user is able to define the reference pointer to a specific position and, according to the definition of two knobs, the controller parameters Kd and Ki are defined, in order to promote the correction on the target pointer that should go to the same position defined for the reference pointer.

The block diagram and the main circuits used to define the PI parameters of the implemented system are represented in figure 3. The set point (R) is defined by a potentiometer that indicates the reference pointer position. The closed-loop has a potentiometer and a signal conditioning system that measures the current position of a motor, and, therefore, of the target pointer, in order to obtain, through a subtraction, the error (e) that will be handled by the PI parameters. These parameters are defined using two typical AmpOp based circuits, namely an inverter summing circuit and an integrated circuit. The Kp and Ki parameters are defined by the selection of a specific resistor through the indicated knobs.

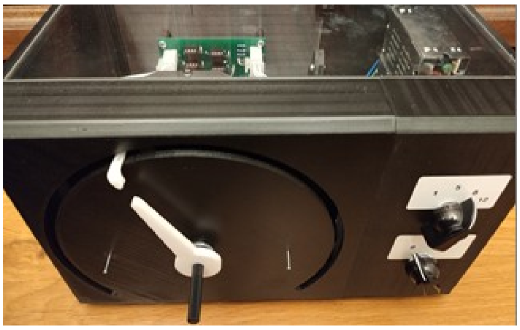


Figure 2: Implemented infrastructure.

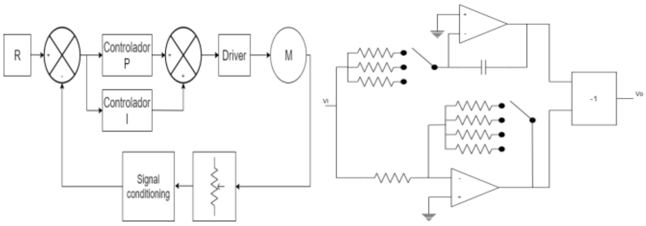


Figure 3: Block diagram of the implemented circuit and the circuits based on AmpOp to define the Ki and Kp parameters.

III. Conclusion and Future Work

Students of this new generation are becoming more demanding towards and questioning any theory that can be presented. This requires that teaching a specific subject should be complemented, whenever possible, by showing practical evidence of specific theories in order captivate students' attention.

Seeking to create a sustainable solution (with a low cost and with little waste of resources), the work presented in this paper described a demo platform of a PI controller. Using a closed-loop control system and a PI controller, it enables a teacher or student to change the position of a specific pointer based on a reference pointer with the minimum error possible. In the future, an improved solution can be developed, namely a solution able to be accessed remotely, always taking into consideration sustainability.

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