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Digital Control Systems Functions and Applications

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ABSTRACT

This paper is an evaluation of Digital Control Systems and aims to introduce the past and current developments about these kinds of systems. The focus of this research is in the field of electronics and communications engineering. Digital Control Systems are becoming the standard in most control systems being developed. This research will provide an in-depth view of the development of digital control systems.

Key words: Digital Control Systems, Quantization Techniques, Information Systems, Digital Controllers.

1. INTRODUCTION

The term digital control system is used when a certain system wherein the controller utilizes a digital system or design. A digital system, on the other hand, is a system that has an output or an input that is digital.

Nowadays, digital control systems are being developed and incorporated in everyday devices to help in improving the quality of life. Analog control systems were the staple for systems before the development and transition to digital control systems. However, digital control systems present improvements that are important to further improve the current technology.

Some of the advantages of digital control systems over analog control systems are the accuracy of the output of the system, also digital systems can be reused by programming to perform a different task and be used for another application. The most notable advantage of digital control systems is that these kinds of systems require less power to operate, less expensive, and less area [1].

Digital control systems operate by converting the different parameters and measurements into a code that is accurate depending on the resolution or the bit level of the data. However, some 'physical' variables may still require some intervention with analog devices which means that some systems are not fully digital [2].

An example of early development for digital control systems is the radar that was used for fire control of weapons. It utilized pulsed-data transfer functions. Most of the developments for digital control systems started during world war 2 when the engineers were trying to find new ways to improve the war effort and be one step ahead of the opposition.

2. LITERATURE REVIEW

In the paper entitled "Accuracy Analysis of Digital Control Systems with Two-Time-Scale Motions", the use of two-time scale motions on closed-loop systems was discussed. Two-time scale motions are often used in designing digital control systems without some of the information needed in the design. The paper concludes that it is possible to create a design of a digital control system using this technique given that the control accuracy and the output transients are known [3].

The paper "Recent Advances in the Field of Sampled-data and Digital Control Systems" by Jury mentioned that the recent control systems that are being developed are becoming more and more fully digital. This is because of the advances that are improving the accuracy and flexibility of the devices that are being used in the system. However, some of these systems are still not reviewed in detail but the different theories such time-varying, linear, and nonlinear can be utilized in future control systems based on the observations and assumptions that are done in this paper [4].

The paper "Analysis and Design of Two Types of Digital Repetitive Control Systems" by Chang discusses the design of the control system to reduce the error from harmonic and non-harmonic components. This design utilized the use of digital repetitive control systems. Two designs were tested and proved to be effective. The first design used an algorithm that uses the relative error transfer function. The data from the experiment shows that the design successfully reduces the error significantly in both the harmonic and non-harmonic components [5].

A paper entitled "Structures within the Quantization Noise: Micro-Chaos in Digitally Controlled Systems" by Gyerbrozski discusses the error that arises from the unwanted oscillations from the system. The error or noise that can be produced from the system may vary depending on the component. This means that the significance of the disturbance also depends on the component. Some issues may have to be addressed since it may cause problems for the system. In the paper, the researchers used an inverted pendulum model to test this hypothesis. Figure 1 shows the Inverted pendulum.

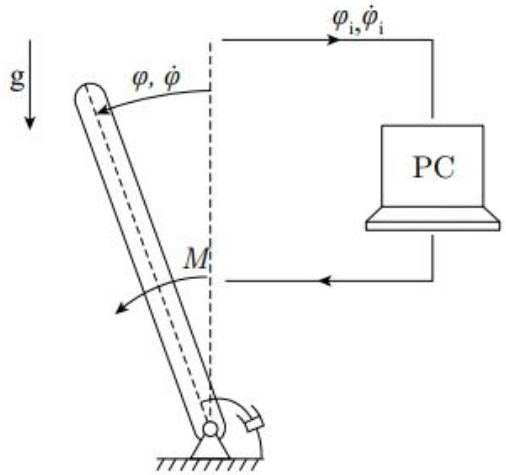

Figure 1: Inverted pendulum

The quantization is shown by the figure 2 below.

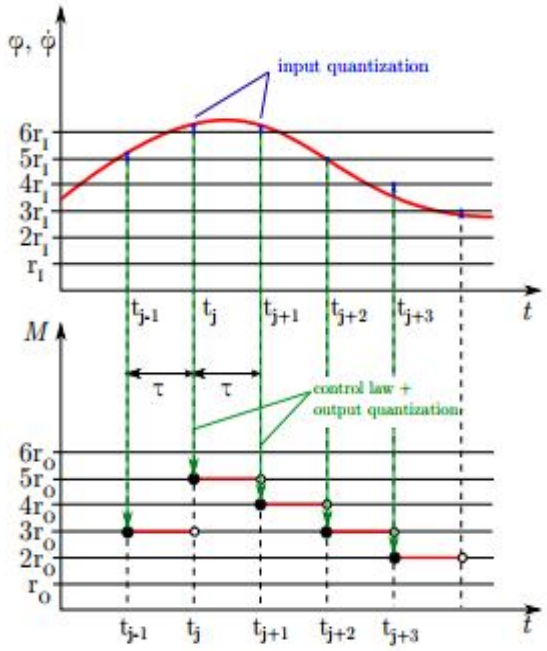

Figure 2: Quantization

The figure 3 shows that the model introduces a quantization error that may be easily resolved. In this case, the model has an easily solvable problem. However, in more complicated and sensitive systems, these small errors may prove to be significant for the output of the system and alter the results [6].

The next research to be discussed is from the paper "Implementation of Digital Temperature Control System on the Photovoltaic cell model: An Experimental Analysis" by Samal. The paper implemented a digital control system that is able to increase the efficiency of the solar panel and increase the translation of power. The block diagram for the system is shown below.

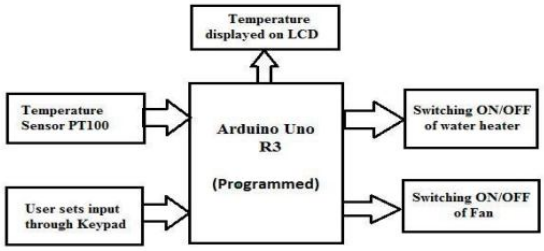

Figure 3: Block diagram for the system

The designed system was able to perform its function and thus was able to increase the efficiency of the solar panel. This paper shows the effectiveness of digital control systems to improve the technology that is already under development [7].

The paper "Project controls for electrical, instrumentation and control systems: Enabling role of digital system information modeling" by Love discusses the implementation of a system that will incorporate the different information and data into one system. This will include human interaction and machines at the same time. According to the researchers, the system is a success and the managers and workers were able to monitor and handle the different works and data that are being handled [8].

3. THEORETICAL CONSIDERATIONS

The development of digital control systems introduced a whole new world of possibilities when it comes to improving the technology that we have around us. However, there are still some parameters that are impossible to obtain without using analog devices. In an analog control system, there are two types of input, reference and disturbance signals. Reference signals are often controlled inputs and are the parameters that are used to adjust the output. On the other hand, the disturbance signal is a kind of signal that represents the intractable signals that are always present in analog control systems (figure 4).

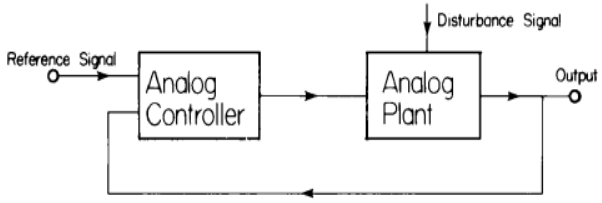

Figure 4: Analog Control System

In digital control systems,(figure 5) there are no disturbance signals that will enter the system. This is because digital signals have fixed values, unlike the analog signals which have infinite values. Digital control systems are much easier to control and to improve compared to analog control systems.

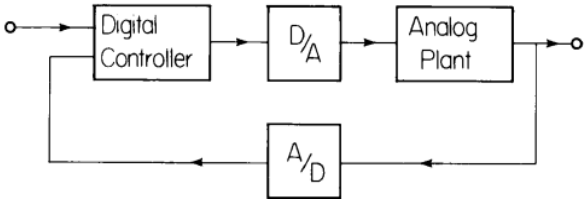

Figure 5: Digital Control System

Digital control systems design has different procedures that can be used to create and improve a design. Some of these are Finite settling time and the Multirate Sampled data. It depends simply on the kind of digital control system being developed [9].

A study in Russia was made which utilized control systems to aid the commuters for them to have the best experience in riding public transportation. The system was used to identify the registration of routes, route planning, and informing the commuters of the situation in the tracks and traffic. Shown below (figure 6) is the image for the information system under conceptualization.

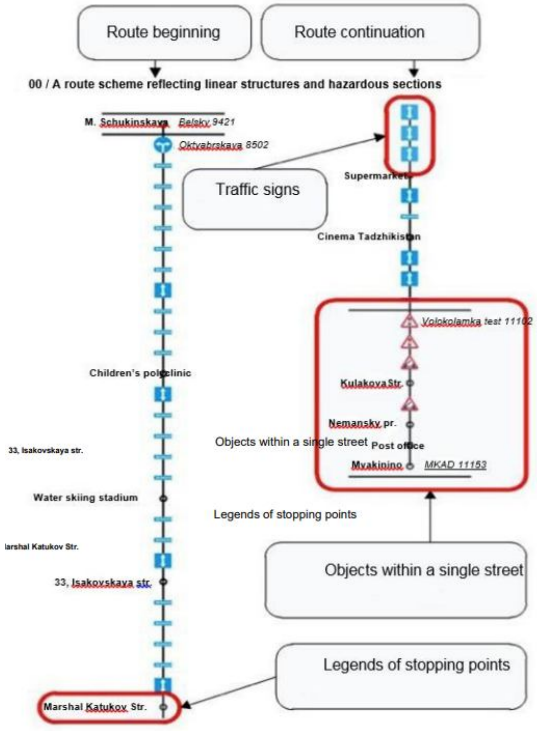

Figure 6: Information System [10]

In the paper entitled "Methodology for analyzing the dependencies between human operators in digital control systems" by Li, the researchers develop a method wherein the system can analyze the dependency of the operators in control systems. A fuzzy logic system was developed to perform this test and the resulting system (figure 7) is shown below.

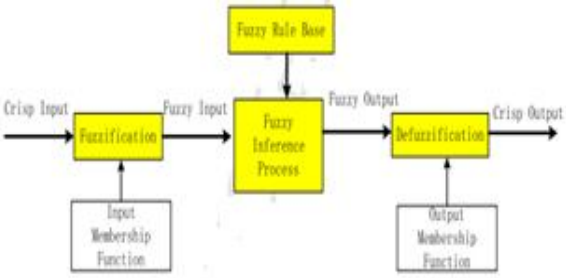

Figure 7: Structure for system

The researchers were able to conclude that the developed system is effective and it was successful in analyzing the actions of operators in the digital control systems [11].

4. DESIGN CONSIDERATIONS

The paper "Practical Aspects of Digital Control Systems Design" by Dohnal and Rerucha discussed the aspects that are important in designing a digital control system. In designing a system, it is important to keep in mind that:

(1) Which techniques are to be used in handling systems with discrete and continuous-time devices to determine certain parameters.
(2) The period T that will be ideal for the system. Since a high sampling system will increase the load.
(3) The effects of the different digital components being used on the system. The changes of the behavior of the system depending on the devices being used in the system.

These are some of the things that an engineer must keep in mind when designing a digital control system [12].

Digital control systems are often studied with the assumption that both the input and the output are synchronous and are operating on a constant rate. However, this is not the case in real-life applications. This is where multi-rate control systems come into the picture. In this kind of control system, the input and the output of the system are being measured by their own individual rates. This design is best when there is a device in the system that requires some time before it is able to provide the necessary data for the system. This would mean that the control and the measurements in the system will be done in different sampling rates. Another reason to use this type of design is when the sensors or the input devices that are being used in the system are small in quantity but are tasked to measure a large amount of data. This is because the device will not only the data to be transmitted at the same time which means that the data will have to be transferred one at a time or by batch depending on the capabilities of the devices that are being used.

The use of multi-rate design is shown to significantly boost the performance of the system. Improvements in sensitivity and rejection were among some of the performance enhancements that were seen in the design [13,14,15].

5. CONCLUSION

Digital control systems have been in development since the second world war. The digital age has helped us improve the quality of life and the devices that we are currently using. These advancements have opened the door to more possibilities. Digital control systems are still in development and can be further improved. Every year, new innovations are being discovered and incorporated into digital control systems. Fewer errors and less power consumption are among the many improvements in the technology. Devices are getting smaller, and processors that control the system are getting more and more powerful. Analog sensors that utilized the resistance are getting more and more accurate. While some are being digitally developed. There are designs that will lessen the amount of error and improve the performance of the system. One of which is the multirate design that is discussed in this paper. When programming this digital system, the studies of [16,17,18] can be used as a pattern. When creating the database, it can be patterned in the studies of [19].

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