Designing a Wireless Network of Intelligent Fuzzy Logic Controllers With NI LabVIEW

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The Challenge

The aim of this research project was to design and simulate an intelligent microcontroller-based self-learning algorithm with extensive communications capabilities.

The Solution

Using NI LabVIEW software to design, simulate and tune FLCs and utilising NI network-published shared variable to construct a communication link between the controllers to facilitate learning and sharing the acquired knowledge.

Products:

LabVIEW, NI-PSP

The Systems Engineering Research Group at the University of Huddersfield has expertise in a diverse range of research fields including flow measurement, communication systems and clean energy. Members of the group apply their expertise in electronic and electrical systems to make breakthroughs that attract high levels of funding, partnerships with major industrial companies and collaborations with other universities.

Embedded systems, especially when they are concerned with the communications industry, are getting more compact and powerful everyday. There are always opportunities for exploring new ideas in the field of control engineering and communication technology. Recently, there has been a significant increase in utilisation of embedded-microcontrollers in a wide range of applications, extending from commercial products to industrial process monitoring systems and control. Furthermore, improvements in speed, size and power consumption of microcontrollers with added wireless capabilities have provided a new generation of applications. These include versatile and low cost solutions in wireless sensor network applications such as wireless monitoring systems and control.

In process control, there are situations where several identical devices form a wired or wireless network and work together towards achieving a common goal. Each individual device or node is controlled by a master controller. In order to maximise the network performance, the nodes can be designed to control their local systems in an intelligent manner so that they can adapt to their set-point changes. The knowledge gained by individual controllers can then be made available to other controllers on the network.

Potential applications of the system could be controlling multiple motors with identical characteristics or several pneumatic valves on an oil pipeline. These devices are known for their non-linear characteristics which are not easy to control without damping or slowing down their response to new set points.

To improve the performance of controllers a significant amount of time is spent in tuning the parameters. Additionally, controllers have a wide range of set-points. Changing from one set-point to another requires the controller parameters to be re-tuned to maintain their performance at a satisfactory level. This would be a very time-consuming task. So far, there has been no research into the design of a FLC that provides communications facilities to enable the sharing of the knowledge gained in tuning process between controllers. Such a design provides a platform for the controllers on a network to learn from each other. As a result, a significant amount of time can be saved and the overall system response can be enhanced.

The Project Aim

Design and develop a network of intelligent fuzzy logic controllers (FLC) with the capability of sharing learned information.

The Proposed Architecture

To design and simulate the above mentioned system, PC-based controllers were chosen to simplify the coding and debugging stages as they tend to be more straightforward than microcontroller-based controllers. At a later stage the design can be easily coded and deployed on microcontrollers.

A network of four wireless-enabled PCs connected through a dedicated Wi-Fi wireless router was established as is shown in Fig. 1. Based on requirements of the application the communication medium could be ZigBee or any other type of wireless technology.

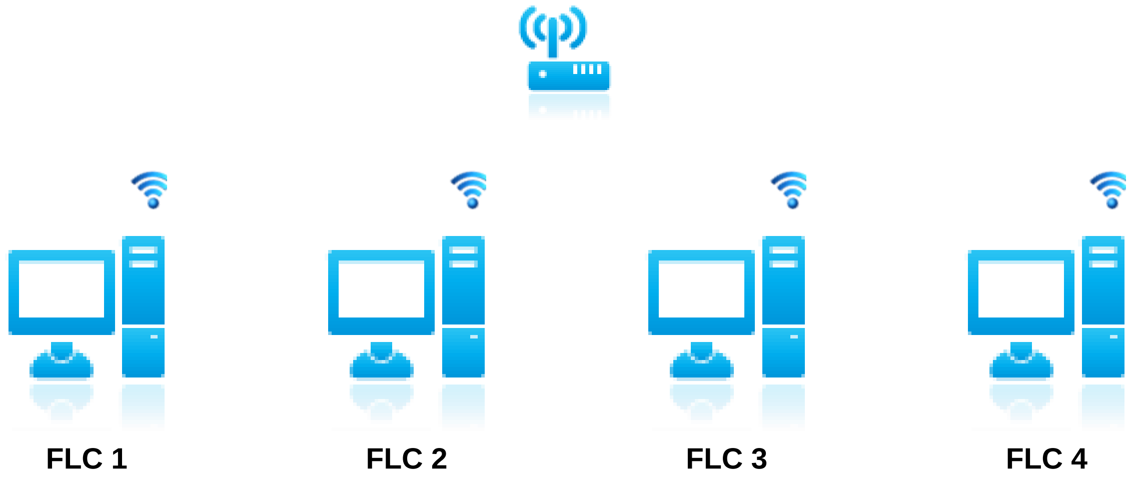

Figure 1. The architecture of wireless fuzzy logic controllers

The PCs simulate independent fuzzy Proportional-Integral-Derivative (F-PID) controllers controlling identical systems. The controllers utilise a fuzzy logic control strategy to control their systems. To improve their performance they have the ability to auto-tune the controller parameters and in each iteration cycle of the tuning process, the parameters are shared on the network. When a new set-point is assigned to a controller it starts to perform the tuning process. Each controller has the ability to establish new control parameters by performing auto-tuning independently or by using the knowledge gained by other controllers to shorten the tuning time. Thus, the controllers have the ability to learn from the experience of each other, and consequently a significant time can be saved.

The Development Platform

Designing such a complex system encompasses many stages including developing an intelligent control algorithm, establishing and maintaining the communication between the controllers and monitoring the stability of the system. Therefore choosing the right development platform is essential. NI LabVIEW was chosen to achieve the goals of the project. This was due to some essential and useful features provided in the LabVIEW package. First of all, it provides an integrated software and hardware platform that simplifies development of any system that needs measurement and control. Secondly, the easy-to-use graphical development environment make it the ideal choice for developing complex algorithms by providing various tools for debugging and direct viewing of the results. Due to LabVIEWs graphical nature, it was possible to develop an attractive and intuitive user interface in almost no time at all.

Design of FLCs

The LabVIEW Control Design and Simulation module was used to design and simulate the FLCs and to develop the learning algorithms, where the tuning process was accomplished in a very flexible way. LabVIEW Fuzzy System Designer was used to design the fuzzy logic controller input/output variables and the fuzzy control rules. Fig. 2 shows the FLC simulation interface where the controller is in a direct control-loop. Any standard second order system can be simulated by entering its transfer function in the simulation interface and the open-loop and closed-loop responses are displayed simultaneously together with their response characteristics including the rise time, overshoot percentage and the settling time.

External disturbances could be introduced at the input and at the output of the process to determine the stability and robustness of the controlled system.

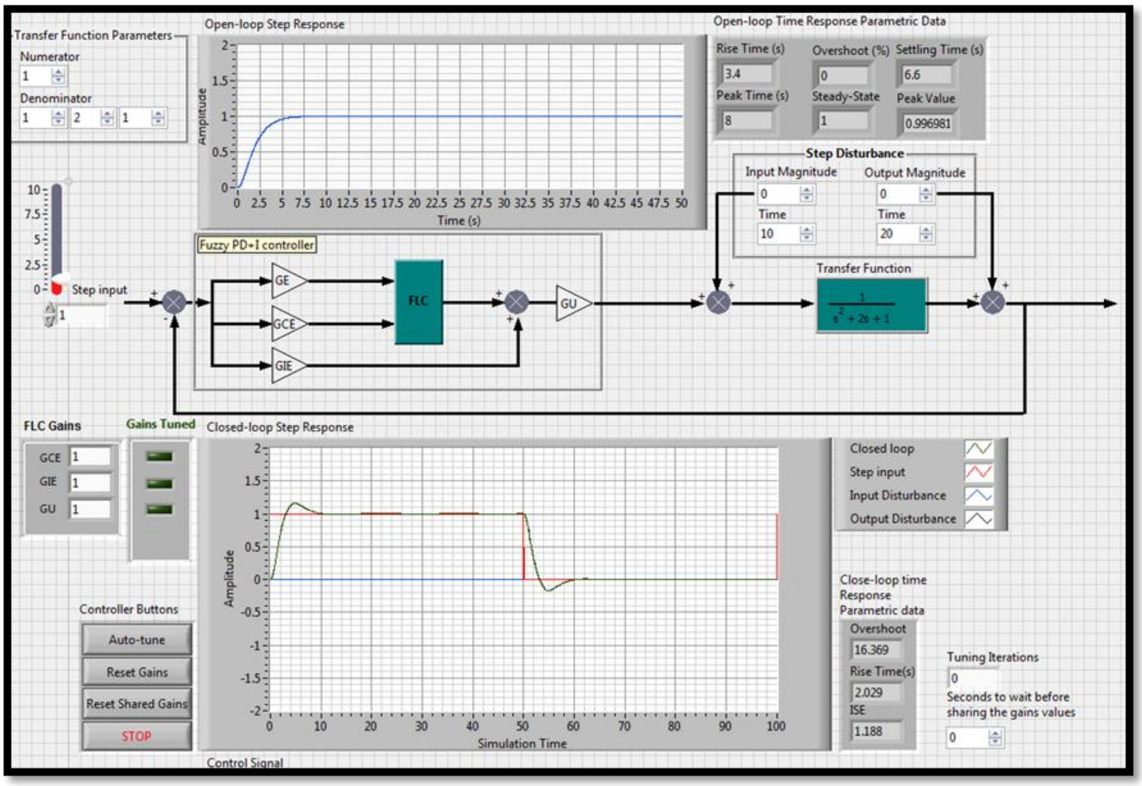

Figure 2. Front Panel View of the FLC.

The intelligent algorithm capabilities

The algorithm has the capability of auto-tuning the controller parameters, retaining the tuned parameters and sharing the gained knowledge. The control algorithm progressively performs these tasks and transits from one state to another. This architecture was effectively implemented by using a LabVIEW State Machine design pattern as it provides an easy transition from one state to another and simplifies the implementation of such complex decision-making algorithms.

The LabVIEW “network-published shared variable” feature was used to establish the communication between the controllers, thus the complexities of communication programming were greatly minimised.

As with any technology development, problems were encountered along the way. When initially undertaking the project in LabVIEW, the advice given by the National Instruments Application Engineering team was both helpful and prompt. This allowed for the project to progress quickly from a concept into a working application.

Summary

Using LabVIEW, we were able to design, simulate and test an intelligent fuzzy control algorithm with extensive communication capabilities. The algorithm allowed the controllers to auto-tune their parameters and to share the tuned parameters with each other. This opens up new opportunities and possibilities for designing industrial and commercial applications in the wireless monitoring and control field. These systems will be cost-effective if deployed on embedded wireless microcontrollers with ZigBee communication capabilities.

Note: Permission has been obtained from Double-J Design website http://www.doublejdesign.co.uk to use the images appeared in figure 1.