SUGISAKA MASANORI

Journal of Advances in Artificial Life Robotics
Vol. 3(4); March (2023), pp. 250–253
ON LINE ISSN 2435-8061; ISSN-L 2435-8061
https://alife-robotics.org/jallr.html

Research Article

Proposal and prototype of an IoT self-tuning PI control device using Wi-Fi

Shinichi Imai
Graduate school, Tokyo Gakugei University, 4-1-1, Nukuikita-machi, Koganei, Tokyo, 184-8501, Japan

ARTICLE INFO

Article History

Received 14 October 2022
Accepted 30 July 2023

Keywords

Wi-Fi
IoT
Control
Self-tuning
Prototype

ABSTRACT

In this paper, development of IoT control device using Wi-Fi. In recent years, IoT has been attracting attention, and there are growing expectations in the industrial world for the utilization of data obtained from many sensors. These data are stored in databases in real time through communication between sensors and the cloud and communicating with the cloud. Meanwhile, digital controllers are widely used in the process industry as general-purpose controllers. However, it is difficult to incorporate AI, machine learning, and databases into general-purpose controllers due to data memory limitations. Therefore, in this paper, we develop an IoT self-tuning controller using Wi-Fi. As a result of experiments, the controller and computer were connected via Wi-Fi, self-tuning was performed on the computer side, and the calculated PID gains could be sent to the controller to achieve control.

1. Introduction

In recent years, the use of advanced technologies such as IoT and AI has been remarkable. In particular, IoT [1],[2],[3],[4],[5] is attracting attention, and there are growing expectations in industry for the use of data obtained from the many sensors installed in the system. These data are stored in a database in real time through communication between the sensors and the cloud. On the other hand, digital controllers are widely used in the process industry as general-purpose controls. In order to obtain the desired control performance, the control parameters must be appropriately calculated according to the characteristics of the control target, but most actual control targets have nonlinearities and fixed control. Therefore, it often happens that the parameters do not provide sufficient control performance. Therefore, self-tuning methods, in which control parameters are changed sequentially according to the control characteristics, have been proposed as data-driven control methods [6]. However, data-driven control is difficult to implement with the capacity of conventional controllers because it determines control parameters by accumulating a large amount of data in a database. In addition, ordinary controllers are very small, and it is also difficult to install a personal computer for calculation in a limited space such as a factory. Therefore, in this paper, we develop a Wi-Fi-based IoT self-tuning controller. Specifically, a microcontroller called ESP-WROOM-02 will be used instead of a conventional controller; ESP-WROOM-02 is very compact and can replace conventional controllers. It also has built-in Wi-Fi and Bluetooth. The ESP-WROOM-02 is connected to a personal computer via Wi-Fi, the personal computerP performs calculations to determine control parameters, and the calculated control parameters are sent to the ESP-WROOM-02 controller. This avoids the controller's data memory problem.

2. ESP-WROOM-02

Corresponding author's E-mail: shimai@u-gakugei.ac.jp URL: http://www.u-gakugei.ac.jp/

ESP-WROOM-02 incorporates Espressif ESP8266EX, which integrates a Tensilica 32-bit RISC(reduced instruction set computer) processor with ultra-low power consumption and reaches a maximum clock speed of 160MHz. A real-time operating system (RTOS) and Wi-Fi stack allow 80% of the processing power to be used for programming and development of user applications. The module also incorporates an antenna switch, RF balun, power amplifier, low-noise receiver amplifier, filter, and power management module at the SoC level, and its small size allows for easy integration into space-constrained devices. The external dimensions of the module are 18 x 20 mm. The type of flash used in this module is SPI flash with package size SOP8-150mil. The antenna applied to this module is a 3DBi PCB on-board antenna. Fig.1 shows ESP-WROOM-02. Table 1 shows the specifications of the ESP-WROOM-02.

3. IoT system

This IoT system consists of a "sensing system" that acquires numerical values with sensors and sends them to a computer, and an "adaptive system" that performs self-tuning based on the input and output data of the sensing system. The calculated parameters are sent to the control controller. Data is transmitted over Wi-Fi between the three systems. ESP-WROOM-02 is used for data transfer. Fig.2 shows a conceptual diagram of the IoT system.

Used by connecting to Arduino to communicate with ESP-WROOM-02. Fig.3 shows the circuit configuration. Arduino works with 5V. ESP-WROOM-02 cannot be directly connected to Arduino because it operates at 3.3V. Therefore, different signal levels are switched by attaching a level conversion IC. The current consumption of ESP-WROOM-02 is about 80mA. Arduino 3.3V terminal can only output 50mA and cannot be used. Therefore, it is necessary to prepare a 5V power supply and a 3.3V power supply in separate systems.

Use the Arduino input port to capture the inputs, outputs, and deviations of your experimental setup. It also sends PI parameters to the controller through the output port. The controller only updates PI parameters. Calculation of PI parameters is performed on a computer via Wi-Fi.

Table 1 Specifications of ESP-WROOM-02.

Supply voltage	3.0-3.6V
Current Consumption	Average 80mA
Supported WiFi Protocols	802.11b/g/n (2.4GHz)
Size	18mm×20mm×3mm
Wi-Fi mode	station softAP SoftAP+station
Security	WPA/WPA2
Encryption	WEP/TKIP/AES

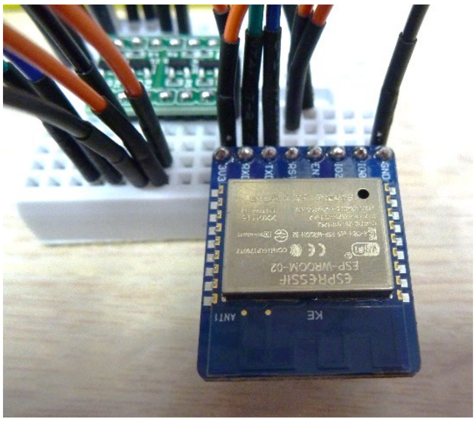

Fig.1 ESP-WROOM-02

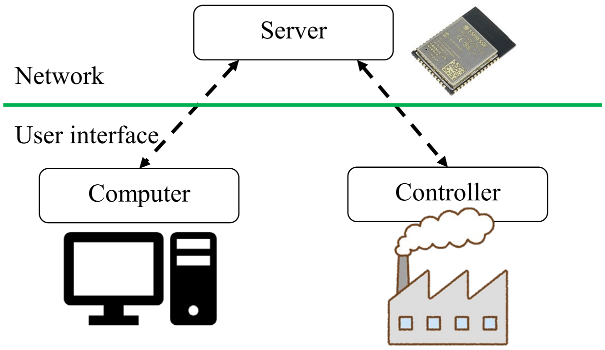

Fig.2 IoT IoT system conceptual diagram

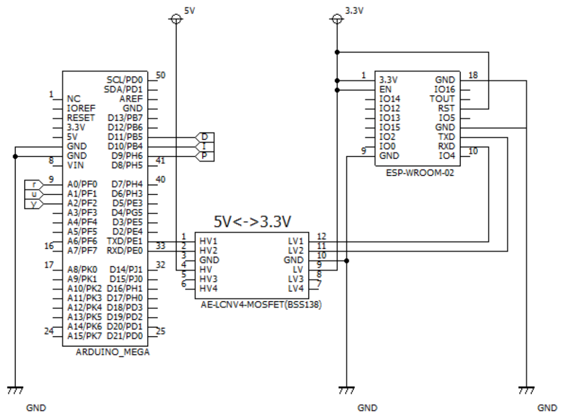

Fig.3 Circuit configuration

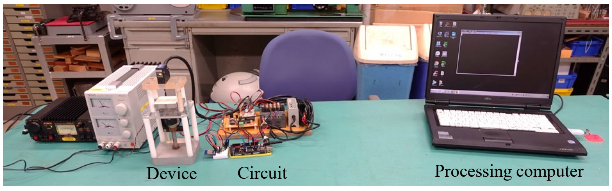

Fig.4 Outline of experimental apparatus

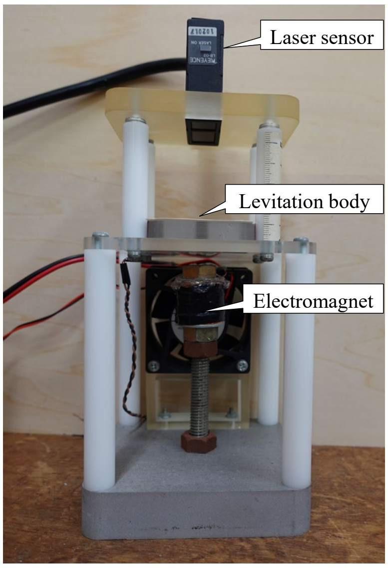

Fig.5 Experimental device

4. Experiment

A self-tuning [7] PID control is used for the experiment. An overall view of the experimental setup system is shown in Fig.4. In addition, a magnetic levitation device is used in the experimental device. Fig.5 shows the magnetic levitation device. A magnetic levitation device levitates a magnetic body by controlling the current

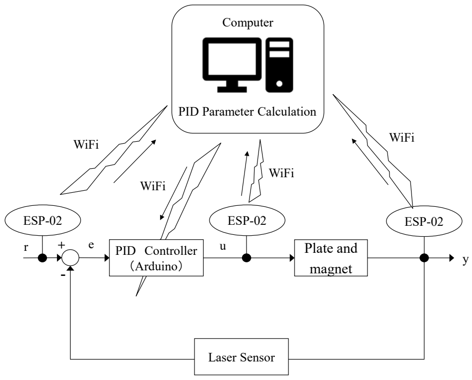

Fig.6 Block diagram

flowing through an electromagnet (coil) or the voltage across the coil. In the following, the magnetic body to be levitated is called the levitation body. This experimental device consists of a magnetic levitation device, an electromagnet amplifier, and a control device. Controller uses Arduino to send input/output data to another computer through ESP-WROOM-02. The server used a virtual server. The communication speed is 115200 bps. In addition, the displacement of the levitation body is measured using a laser displacement sensor. Fig.6 shows a block diagram of the magnetic levitation device. Control input u(t) is the voltage applied to the coil, and control output y(t) is the gap length (the distance between the sensor and the upper surface of the levitation body). In addition, the coil voltage is controlled by a PWM (Pulse Width Modulation) signal with a duty ratio corresponding to the control input. Therefore, the control input u(t) in this experiment is assumed to be the duty ratio (0 to 100%) of the PWM signal. Also, this experimental device can only start from u(0)=100 due to its specifications. In addition, the vibration of about 17.6m/s^2 is given to the levitation body to prevent the levitation body from being caught by the effect of friction. First, the target value r(t) is given as follows.

$$r(t) = \begin{cases} 11.5\ (0 \le t < 100) \\ 8.0\ (100 \le t < 200) \\ 10.0\ (200 \le t < 300) \\ 7.0\ (300 \le t < 400) \end{cases}$$

The parameters in the design polynomial and $P(z^{-1})$ re sigma=1, delta=0, and the sampling interval is Ts=0.1[sec].

At this time, $P(z^{-1})$ is obtained as the following equation.

$$P(z^{-1}) = 1 - 1.6375z^{-1} + 0.6703z^{-2}$$

Furthermore, let n_u =1 and k_m =0. The experimental results are shown in Fig.7. Fig. 8 shows the temporal change of the PI parameter. From the experimental results, the PI parameters change appropriately according to the characteristics of the system. This result shows that the PI parameters calculated by the personal computer are communicated through Wi-Fi.

5. Conclusion

In this study, an IoT self-tuning controller using Wi-Fi was developed. As a result, the controller and computer were connected by IoT technology, the PID tuning calculation was executed on the computer side, and the calculated PID gain was sent to the controller. In addition, the effectiveness of the system was verified through experiments. Future experiments will be conducted to evaluate the delay. We also plan to adapt the system to memory-intensive systems.

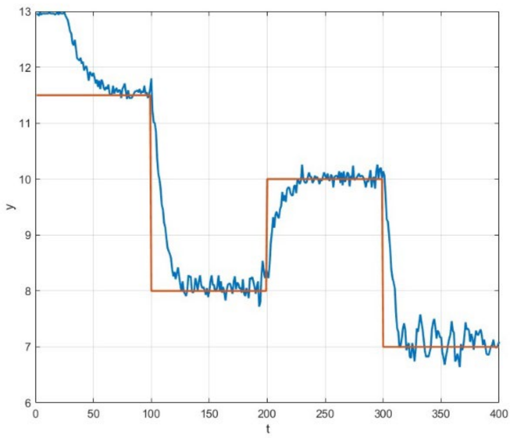

Fig.7 Experimental result

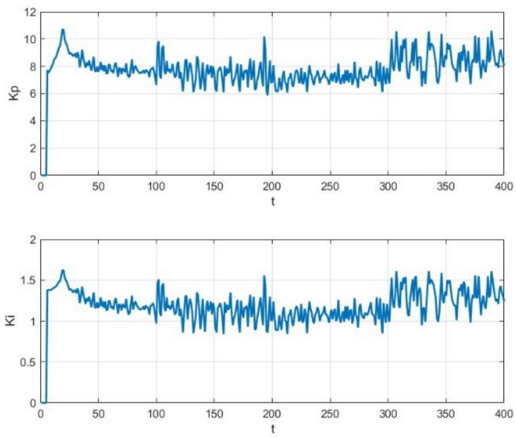

Fig.8 Changes in PI parameters

References

1. S. N. Swamy and S. R. Kota, "An Empirical Study on System Level Aspects of Internet of Things (IoT)," IEEE Access, pp188082-188134, October 2020.
2. T. Lan, J. Duan, B. Zhang, D. Shi, and Z. Wang, “AI-Based Autonomous Line Flow Control via Topology Adjustment for Maximizing Time-Series ATCs,” 2020 IEEE Power & Energy Society General Meeting (PESGM), August 2020.
3. A. K. Gupta and R. Johari, "IOT based Electrical Device Surveillance and Control System," 2019 4th International Conference on Internet of Things: Smart Innovation and Usages (IoT-SIU), April 2019.
4. Kuan-Chu Lu, I-Hsien Liu, Jia-Wei Liao, Shao-Chun Wu, Zong-Chao Liu, Jung-Shian Li, Chu-Fen Li, "Evaluation and Build to honeypot System about SCADA Security for Large-Scale IoT Devices", Journal of Robotics, Networking and Artificial Life, Vol.6, Issue.3 pp.157-161 (2019)
5. Seyed Mahmood Hashemi, Jingsha He, "LA-Based Approach for IoT Security", Journal of Robotics, Networking and Artificial Life, Vol.3 Issue.4, pp.240-248 (2013)
6. Y. Okubo, Y. Ashida, T. Kinoshita and T. Yamamoto, "Construction of a Data-Driven Control Platform using an Electronic Thermal Regulator", IEEJ, CT18026 (2018)(in Japanese)
7. S. Omatsu, T. Yamamoto, “Self-tuning control”, CORONA PUBLISHING (1996)

Authors Introduction

Dr. Shinichi Imai

He graduated doctor course at department of engineering in Hiroshima University. He works at department of education in Tokyo Gakugei University. His research area is about control system design, educational engineering.