Theme Title	Research on FRIT (data-driven controller tuning method)
Name of Organization	Prof. Osamu Kaneko, Department of Mechanical and Intelligent Systems Engineering, School of Informatics and Engineering, The University of Electro-Communications
Technical Field	IT, manufacturing

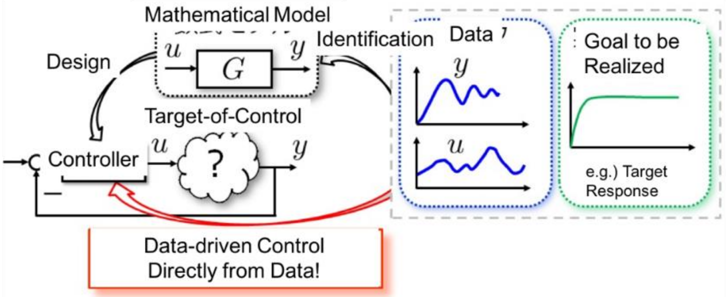
Overview

In order to perform advanced control, it is common for a person with high control know-how to design and manufacture an optimal controller based on a large set of input and output data. We have been studying FRIT, a control method that enables design of a highly precise controller using only one set of input and output data. FRIT can learn online which allows tuning in real time, for example, to a controller that matches the performance characteristics of a person. Therefore, it can be applied not only to general controller design but also to artificial muscles, rehabilitation equipment, wheelchairs, driving assistance, and so on. We welcome companies that are motivated in utilizing this technology.

Simplified Image

Research on FRIT (Data Driven Controller Tuning Method)

[FRIT]
Technology that constructs highly precise controllers from 1 set of input/output data



[Features]
・ The cost and labor for the construction of the control system can be greatly reduced.
・ A controller based on the character of a person who input the data can be modeled.
・ It can learn off-line and be re-tuned automatically, therefore evolves into a suitable controller as it is used. Highly tolerant to sudden breakdowns.

[Application]
It can be applied to a variety of control systems, for example, to control the movements of human-assist instruments , such as an assist suit using artificial muscles, rehabilitation equipment, and wheelchairs, in real time to suit the individual user.

Background

As represented by PID control, there are many situations where the structure of the controller has already been decided and the control parameters must be tuned appropriately. The need for controller tuning from the viewpoint of practical application is very high: for example, when control parameters of a controller in operation are re-tuned for maintenance and inspection, or when a controller must be tuned to match the characteristics of an altered material or product in a manufacturing process.

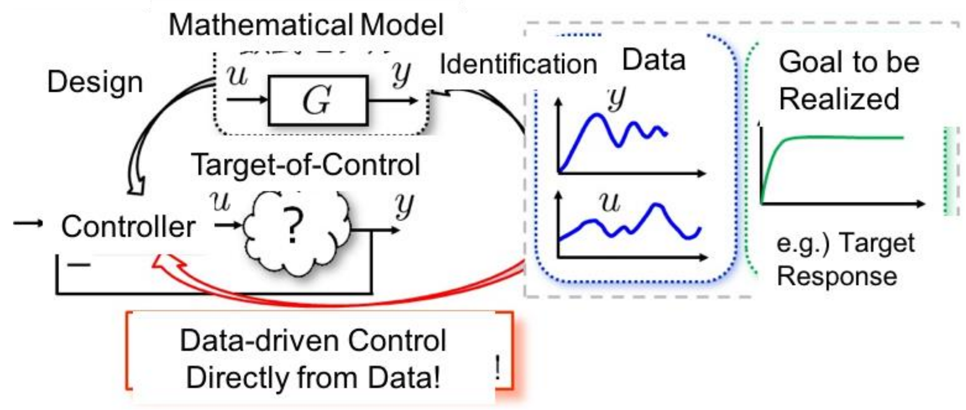
In order to design a control system that obtains such desired responses, a method that creates a mathematical model from the data information of the target-of-control to obtain the optimal controller parameters is generally used. This approach requires time and cost for experiments to obtain a mathematical model, and even if the control system is designed from the obtained model, significant time and money is necessary in order to tune the system to obtain the desired response. In addition, the work must be done by people who are familiar with the control system. This is not necessarily a desirable design method from the viewpoint of cost performance and delivery time, and a method that allows design of controllers in a short time with low cost is required.

Professor Kaneko has been studying FRIT (Fictitious Reference Iterative Tuning), a method to obtain a good-quality controller from a single experiment without directly using a mathematical model. This is one of the approaches of data-driven control (creating a controller directly from data) shown below, and FRIT can obtain a controller that achieves a desired response with only one set of data.

We welcome companies that are motivated in utilizing this technology.

Technology

The following figure shows one of the approaches of data-driven control (creating a controller directly from data), and FRIT is a method that can obtain a controller which achieves a desired response with only one set of data.



Basic Strategy of Data-driven Control

For example, if FRIT is used in a situation where only the data shown in Figure 1 is available,

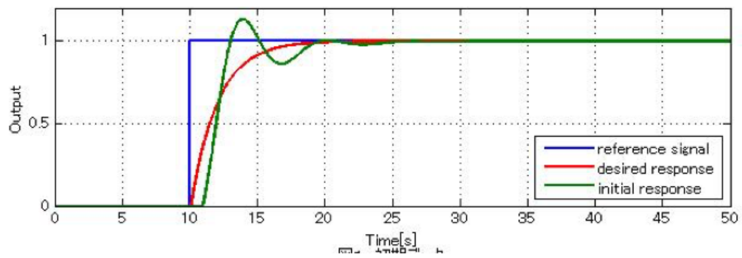


Figure 1 Primary Data

control parameters that achieve the desired dynamic properties shown in Fig. 2 can be acquired.

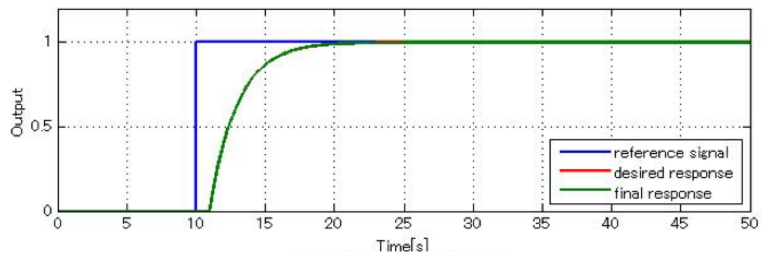
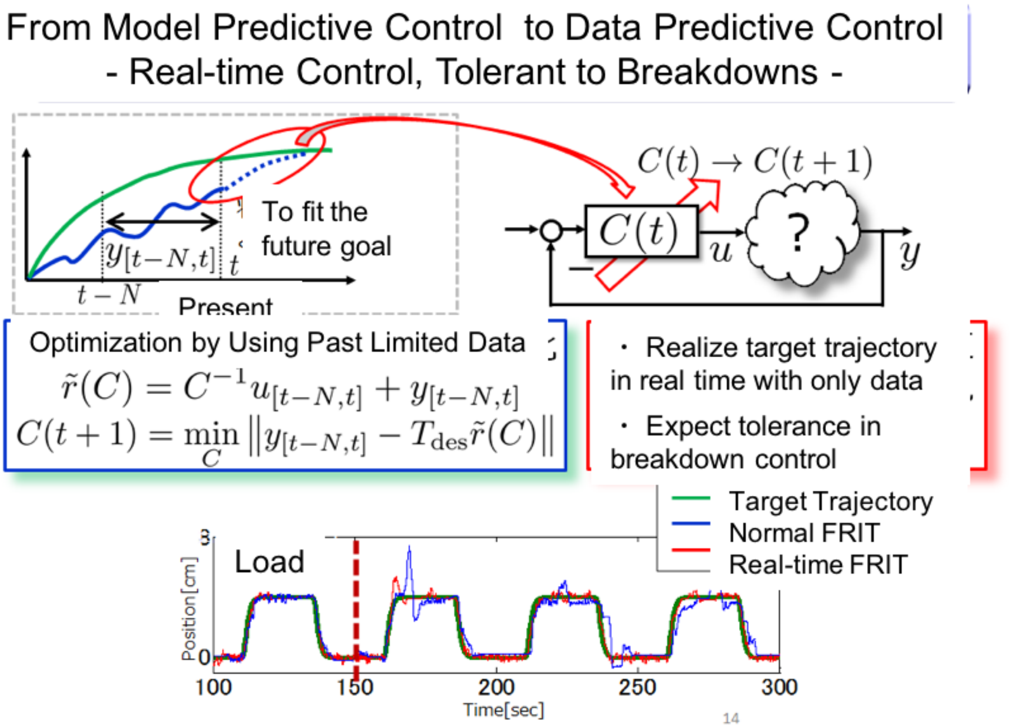
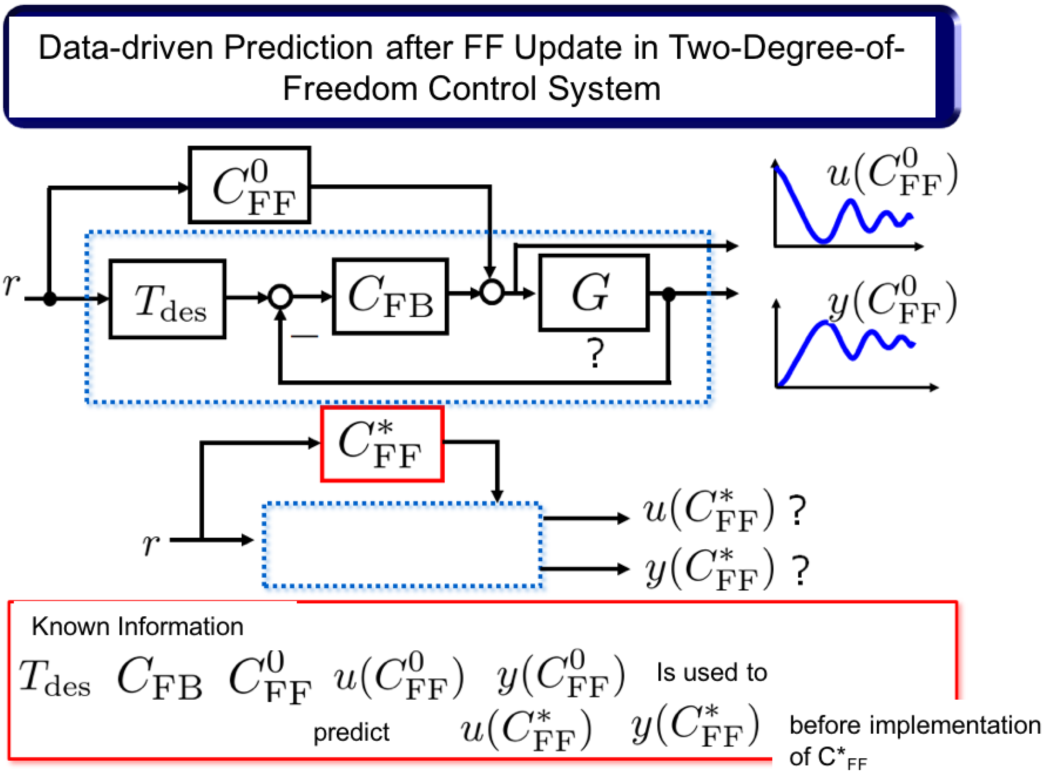


Figure 2 Tuning Result by FRIT

In addition, since learning is possible off-line, it is possible to perform appropriate control in real time for characteristic input data and changes in the behavior of input data. Moreover, it can respond to abnormal changes in input data in case of a sudden breakdown.



In a two-degree-of-freedom control system, the following figure shows an example of the prediction of an appropriate control system from known information.



Before Update

$$y(C_{\mathrm{FF}}) = \frac{G(C_{\mathrm{FB}}T_{\mathrm{des}} + C_{\mathrm{FF}}^0)}{1 + GC_{\mathrm{FB}}}r$$

After Update

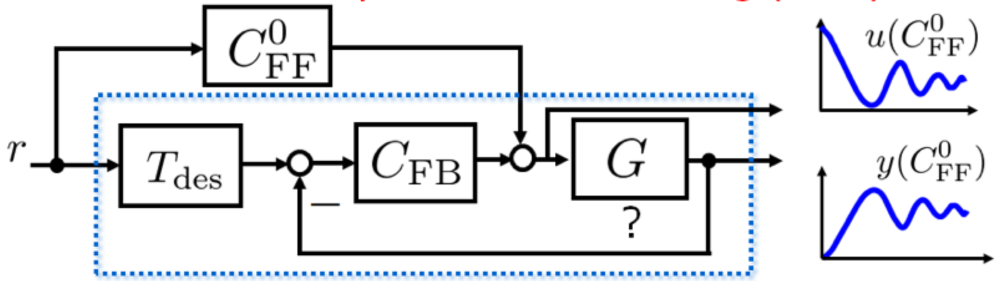
$$y(C_{\mathrm{FF}}^*) = \frac{G(C_{\mathrm{FB}}T_{\mathrm{des}} + C_{\mathrm{FF}}^*)}{1 + GC_{\mathrm{FB}}}r$$

$$y(C_{\mathrm{FF}}^*) = \frac{(C_{\mathrm{FB}}T_{\mathrm{des}} + C_{\mathrm{FF}}^*)}{(C_{\mathrm{FB}}T_{\mathrm{des}} + C_{\mathrm{FF}}^0)}y(C_{\mathrm{FF}}^0)$$

Predict y(C^*_{FF}) before implementation of C^*_{FF} without using model G

We are also investigating a control scheme (ERIT) that updates the predicted response in a two-degree-of-freedom system so that the predicted response comes closer to the target response.

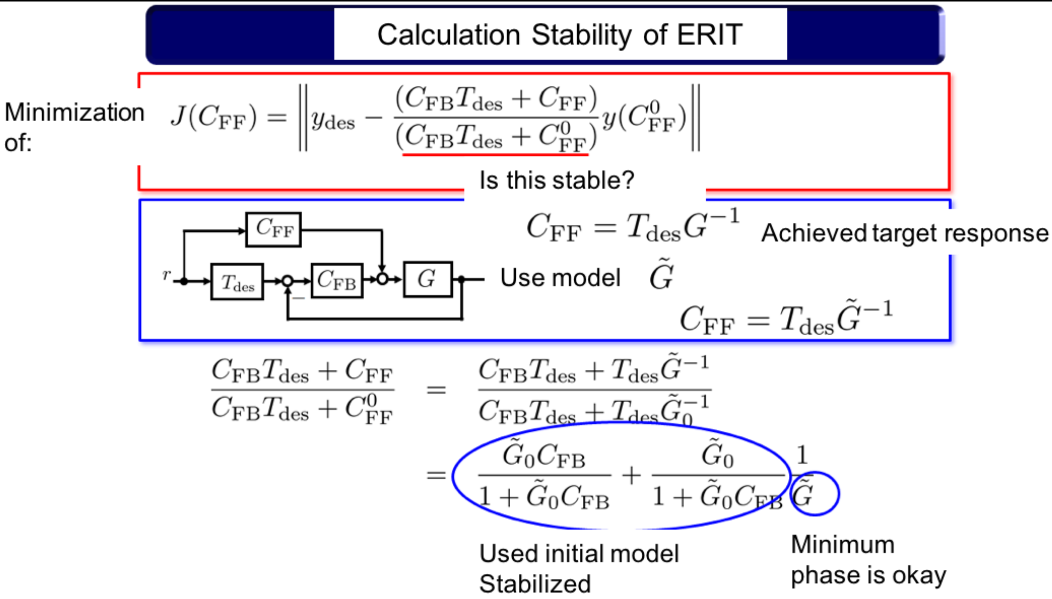
Estimated Response Iterative Tuning (ERIT)



Estimated Response $\quad y(C_{\mathrm{FF}}) = \frac{(C_{\mathrm{FB}}T_{\mathrm{des}} + C_{\mathrm{FF}})}{(C_{\mathrm{FB}}T_{\mathrm{des}} + C_{\mathrm{FF}}^0)}y(C_{\mathrm{FF}}^0)$: approximate to target response y_{des}

$$J(C_{\mathrm{FF}}) = \|y_{\mathrm{des}} - y(C_{\mathrm{FF}})\| = \left\| y_{\mathrm{des}} - \frac{(C_{\mathrm{FB}}T_{\mathrm{des}} + C_{\mathrm{FF}})}{(C_{\mathrm{FB}}T_{\mathrm{des}} + C_{\mathrm{FF}}^0)}y(C_{\mathrm{FF}}^0) \right\|$$

: minimization



The above figure shows an example of a two-degree-of-freedom system, but we are also studying a control scheme (VIMT) that can be applied to a one-degree-of-freedom system.

Strengths of the Technology and Know-How（Novelty, Superiority, Utility)

・The cost and time required to build a control system can be greatly reduced.

・Possible to model a controller based on the characteristics of the person who input the data.

・Possible to learn off-line and re-tune automatically, evolving into a more suitable controller as it is used.

It is also highly tolerant to sudden breakdowns.

Image of Collaborative Companies

We welcome companies with an interest in control theory.

For example, we may be able to work with the following companies.

1) Companies that design and develop control systems.

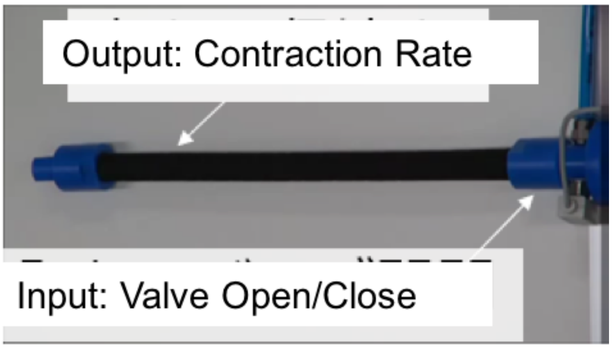
2) Companies that use control systems as an elemental technology in their products.

(3) Other companies that are motivated in utilizing this technology.

Utilization of Technologies and Know-How (Images)

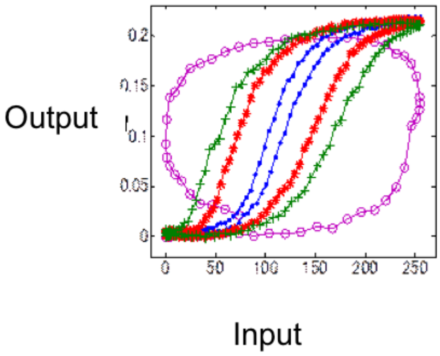
Although this technology is based on our own control theory, it can be applied to a variety of applications.

The following figure shows one example: it is a control that opens and closes a valve with an artificial muscle.



(Pneumatic Artificial Muscles)

In such control system, hysteresis generates, and the output changes significantly in response to the input as shown below.

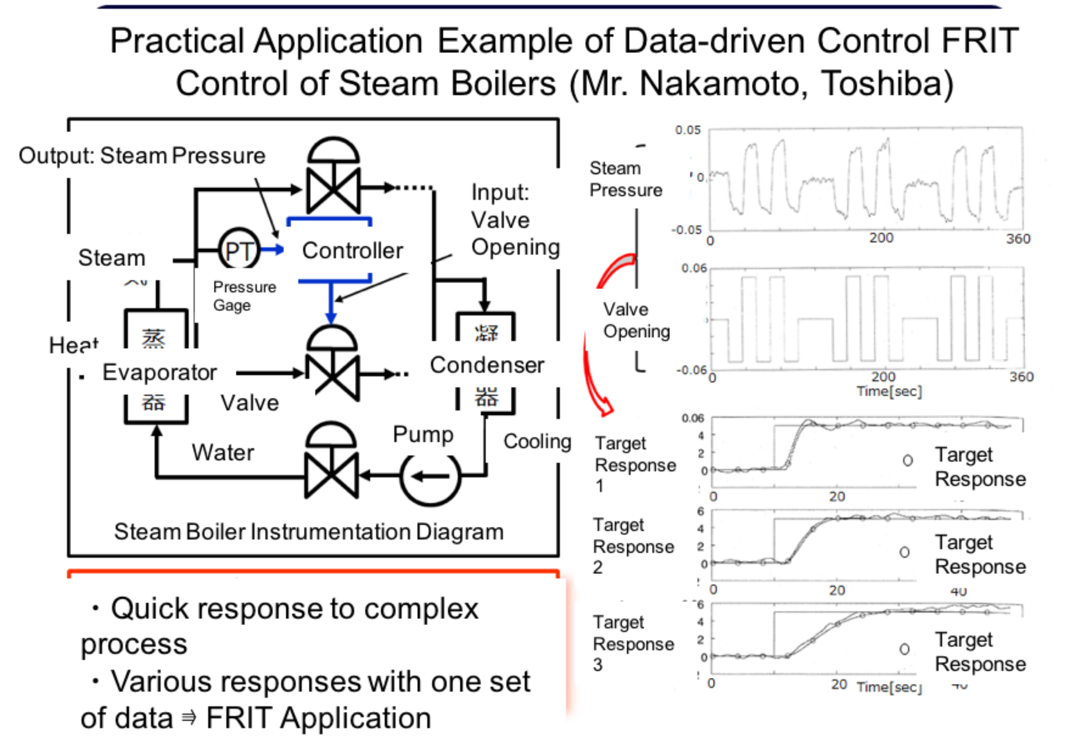


If the system learns off-line, the output signal, which was initially deviated from the target signal, improves as it is used to approximate the target signal, and it is even possible to model the control system to see what input generates the corresponding output.

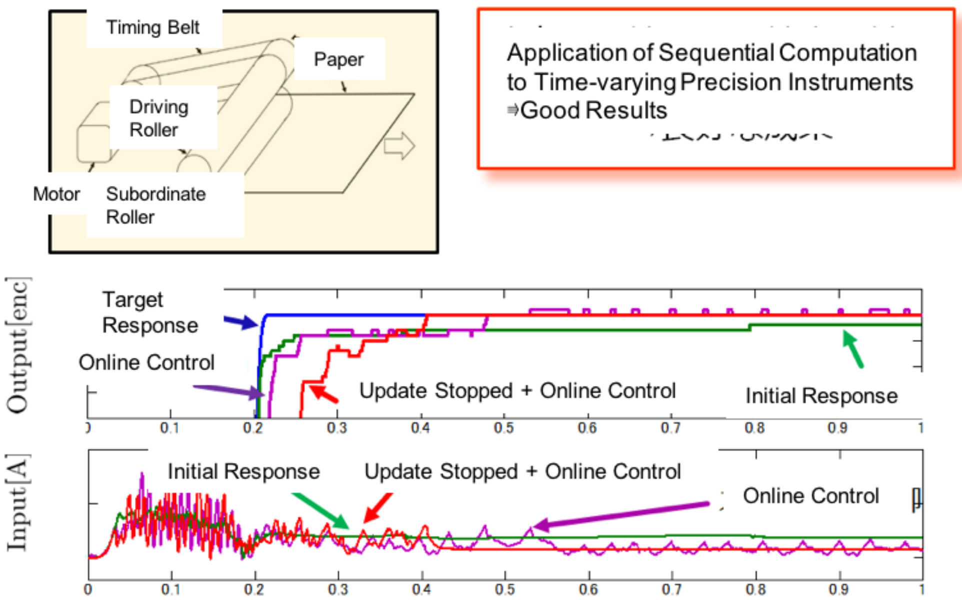
Artificial muscles are becoming more popular in power assist suits and other applications, but tuning to the unique movements of the operator is important to improve the ease of use, and our method is suitable for such applications.

Other examples of the applications include the following.

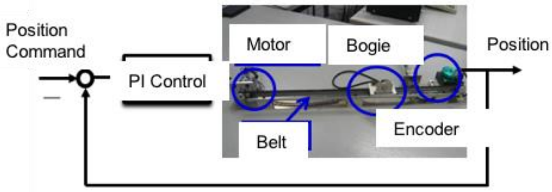
・Example of application to steam boilers



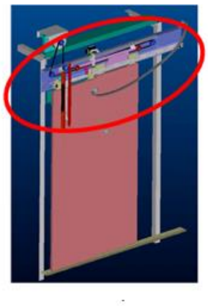
・Example of application to precision instruments



・Examples include the positioning of bogies, elevator doors, honing machines, and control valves for air conditioning.

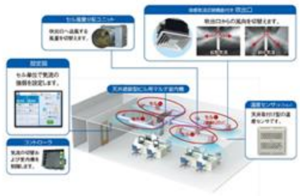


Positioning Control of Bogies



Elevator Door Control

Precision Improvement of Honing Machines



Control Valves for Air Conditioning

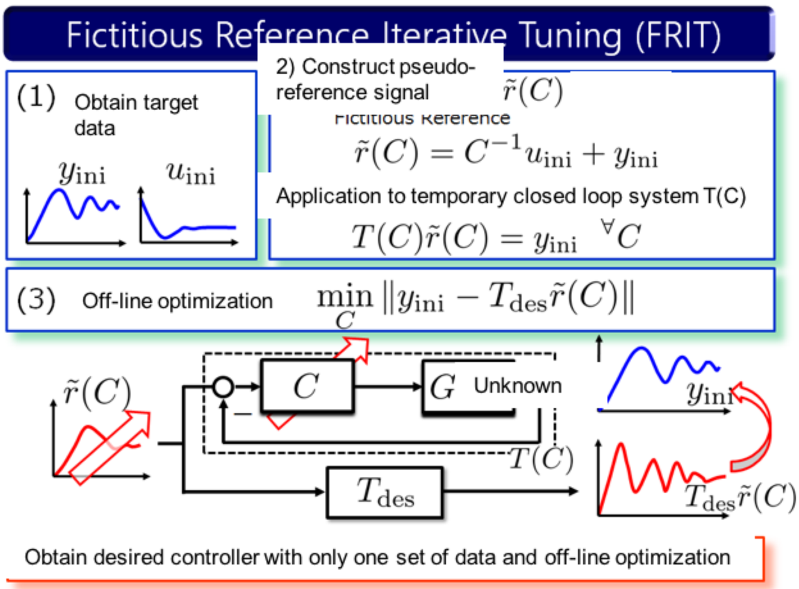
Flow of Technology and Know-How Application

After your contact, we will explain the details of this technology. Please feel free to contact us for more information.

Description of the Technical Terms

【FRIT】

The mathematical model is as follows. Please contact us for simple explanation. Its feature is that it can be tune with one set of data. For off-line optimization, not only the gradient method such as Gaussian-Newton's method but also multi-point search algorithms such as GA and particle swarm optimization can be applied.



【PID Control】

PID control is a type of feedback control in control engineering, in which the input value is controlled by three elements: the deviation between the output value and the target value, its integration, and the differential.

It has been systematized in the framework of classical control theory, which is one field of control theory, and has a long history. It is also the basis of feedback control, and even today, where various control methods are continuously developed and proposed, it is said to be the main control method in the industrial world for it is easy to make adjustments based on past results and the accumulation of experimental rules by engineers.

【Artificial Muscles】

Artificial muscle is a generic term for materials that are subjected to some external control to deform its shape and thereby perform their job. These include piezoelectric elements that shrink and expand when an electric field is applied, gels that deform due to differences in ion concentration, and polymers that swell and contract by light.

This artificial muscle contracts and expands by sending air pressure inside the rubber, and it is also called a "soft actuator" because it uses rubber that is soft and safe for humans.