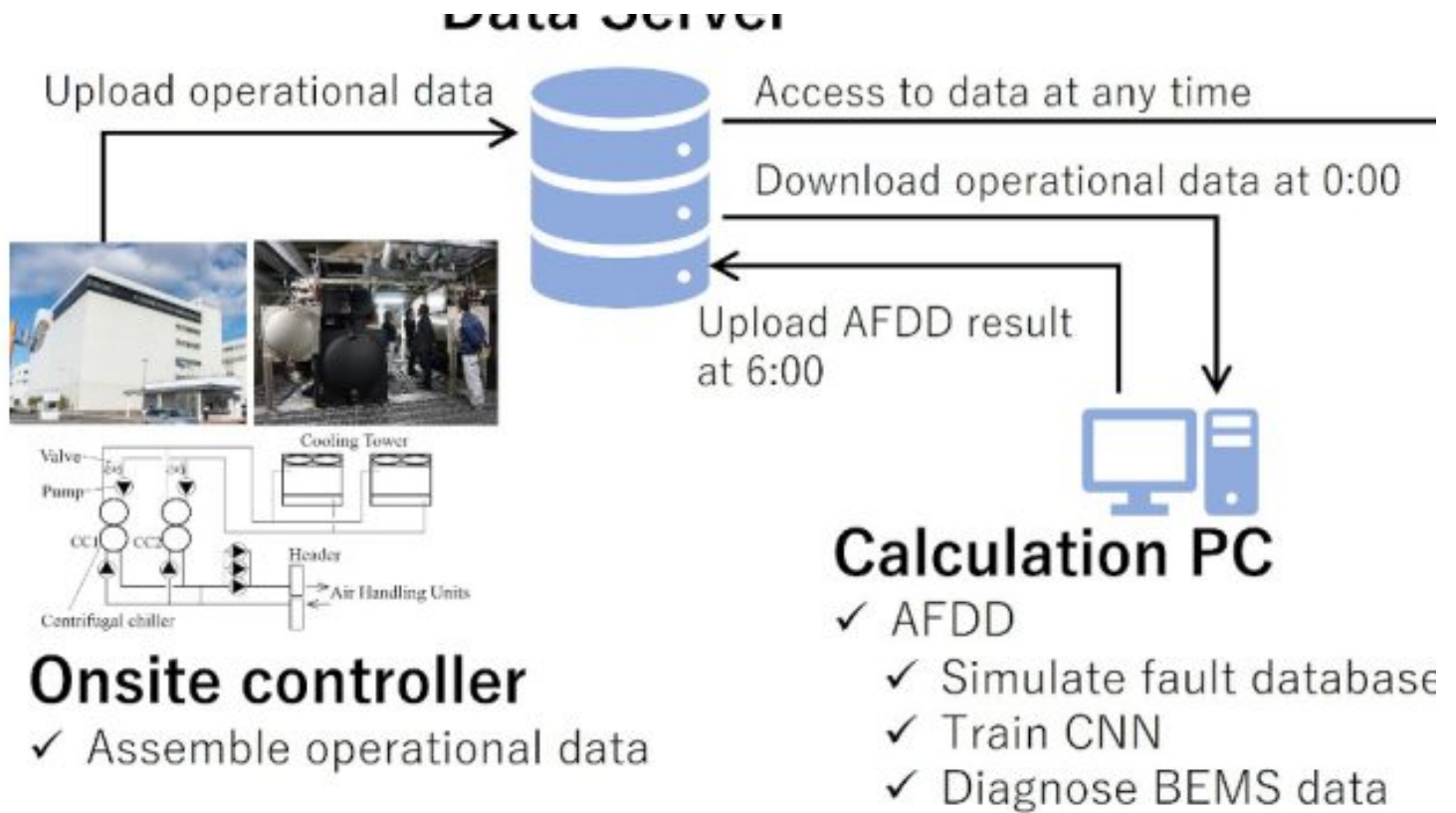


# COOLING PLANT IN A FACTORY



Method from: Miyata, S., Lim, J., Akashi, Y., Kuwahara, Y., & Tanaka, K. (2020). Fault detection and diagnosis for heat source system using convolutional neural network with imaged faulty behavior data. *Science and Technology for the Built Environment*, 26(1), 52-60.

The target system is a cooling plant for air-conditioning in a factory building, which demands high cooling load throughout the year. The onsite operators have a lot of works except for the energy savings, therefore, automated fault detection and diagnosis (AFDD) methodology was developed and demonstrated it in real time. Operational data is diagnosed every day and each morning it is possible to confirm the AFDD result of the day before.

## PROJECT INFORMATION

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Location	Sendai, Miyagi, Japan
Building Typology	Industrial Building
Technology Installed/Proposed	Automated fault detection and diagnosis (AFDD) using convolutional neural network (CNN).
Data Availability	Information such as system configuration, equipment specifications and equipment performance curves, as well as operating data at 15-minute intervals, such as flow rate, temperature, power and frequency (pumps), can be shared within IEA-EBC Annex 81 members only.
Status	Operational - Results Available

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## PROJECT AIM

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Although the current rule-based AFDD is useful for abnormal detection, there are still difficulties to locate root causes of the faults as it requires expert knowledge to define thresholds for faults that should be varied from a system to another. Therefore, we proposed a novel AFDD method using simulated faulty data and CNN to diagnose real data. Firstly, to achieve high diagnosis performance, an original simulation program was developed to obtain faulty behaviour data with high quality. Then, CNN was trained based on the faulty data. Finally, the trained CNN diagnosed the real operational data. The aim of this case study is to demonstrate the effectiveness of the proposed AFDD method in the real world.

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## STAKEHOLDERS

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Key Stakeholders

Information Providers

The key stakeholders were:

- a. Client
- b. Designers
- c. Consultants
- d. Monitoring and reporting
- e. Commissioning providers

Prof. Akashi's group at University of Tokyo led this consultancy project.

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## BUSINESS PROPOSITION / MODEL

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This project has not studied the business model yet. However, it could be offered as software as a service (SaaS) or as a service tied to energy services.

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## VALUE PROPOSITION

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In this case study, a 3% annual improvement in energy efficiency was achieved through a simple change in setpoints. Since the proposed AFDD method makes it easy to identify the root causes of faults, we were able to smoothly change the setpoints by showing the energy-saving effects of the simulation to the onsite operators.

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## IMPACTS

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It is generally impossible to estimate the effect of AFDD because the state of a system can only be observed when it is diagnosed. Therefore, AFDD is not effective for systems without faults, but in this case, a simple change in the setpoint resulted in a 3% improvement in operation. Scalability/transferability are follow-up tasks for the demonstrated AFDD method, especially coding the system simulation for faulty data generation.

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## LESSONS LEARNED

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### Modelling and simulation:

Coding system simulation requires very high cost; however, it is not easy to pay it back only by AFDD. Therefore, the developed simulation should be utilised not only for AFDD, but also for other technologies such as optimal operation and optimal design for the renovation.

### Model transferability/ Data specification:

We tried to apply this AFDD system to other systems which have less measured data. However, it was difficult due to the low resolution of the data. Therefore, data requirements should be discussed from the design phase of the system, and we need to appeal the effectiveness of the AFDD system to the building owners.

### Industry acceptance:

In this case study, we explained the result of AFDD and expected improvement using the simulation result. The onsite operators welcomed the result and were cooperative in fixing the faults.

### Computational requirements and complexity:

Automatic data acquisition from the onsite controller required some cost. The most difficult challenge is the stable operation of the AFDD system. The target system sometimes stops operation for maintenance; therefore, it is necessary to connect information from the field to the AFDD system. In addition, the calculation server was set in the university, where power outages for inspections occur, so it is necessary to devise ways to ensure that operations are not interrupted.

OS updates on the compute server often occurred unexpectedly, causing computation to stop. The settings of OS updates were changed to cope with this problem.

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## IMPLEMENTATION

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The target building is a factory with total floor area of 27,700 m<sup>2</sup>. The target cooling plant is described below.

The proposed AFDD methodology consists of three steps: i) system simulation for faulty data generation; ii) CNN training using the faulty data; and iii) the application of AFDD by the trained CNN on real data.

In the real time implementation, the measured data are collected and stored at the site location. The data is downloaded daily on a local computer via cellular network and the AFDD software is run; the results obtained are uploaded to a server and can be monitored through a browser. In order to apply this AFDD system, the operational data (e.g., temperature, flow rate, power consumption, etc.) of each equipment is preferably recorded in time steps of 15 minutes or less. If the data resolution is not sufficient, it will become difficult to distinguish similar faults such as sensor errors and inappropriate set points.

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ADDITIONAL  
INFORMATION

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# Data Server

Upload operational data



Access to data at any time

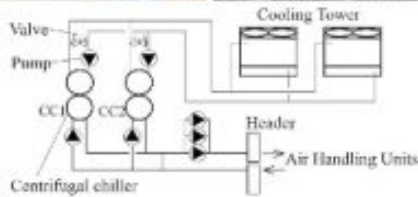
Download operational data at 0:00

Upload AFDD result at 6:00



## Calculation PC

- ✓ AFDD
- ✓ Simulate fault database
- ✓ Train CNN
- ✓ Diagnose BEMS data



## Onsite controller

- ✓ Assemble operational data

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