Panasonic

Pre-Detection Method of Refrigerant Leakage with Home Air Conditioner

Panasonic Corporation
Heating & Ventilation AC Company

Keita Kikuchi
Gaku Hayashida

VITALIZE THE FUTURE WITH A I R

About Me

Keita Kikuchi

Biography

2014~ Panasonic Corporation

- Create new value through IoT data analysis for home air conditioners
  - Develop fault diagnosis technology
  - Develop electricity bill forecasting function

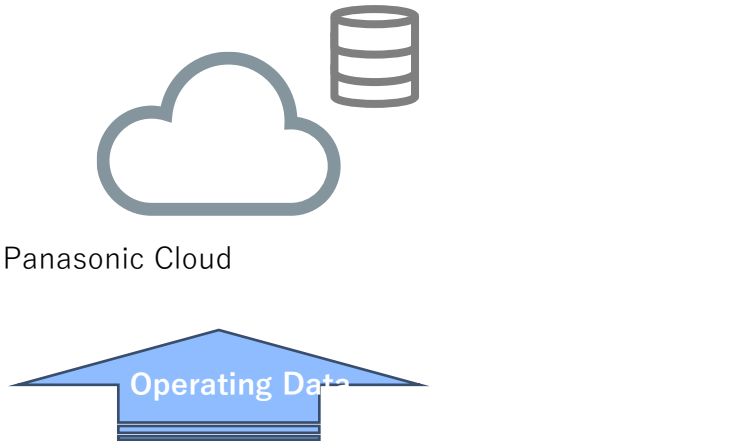
Engaged in other activities

Speciality

- Time series data analysis
- Machine Learning
- Cloud Environment Development

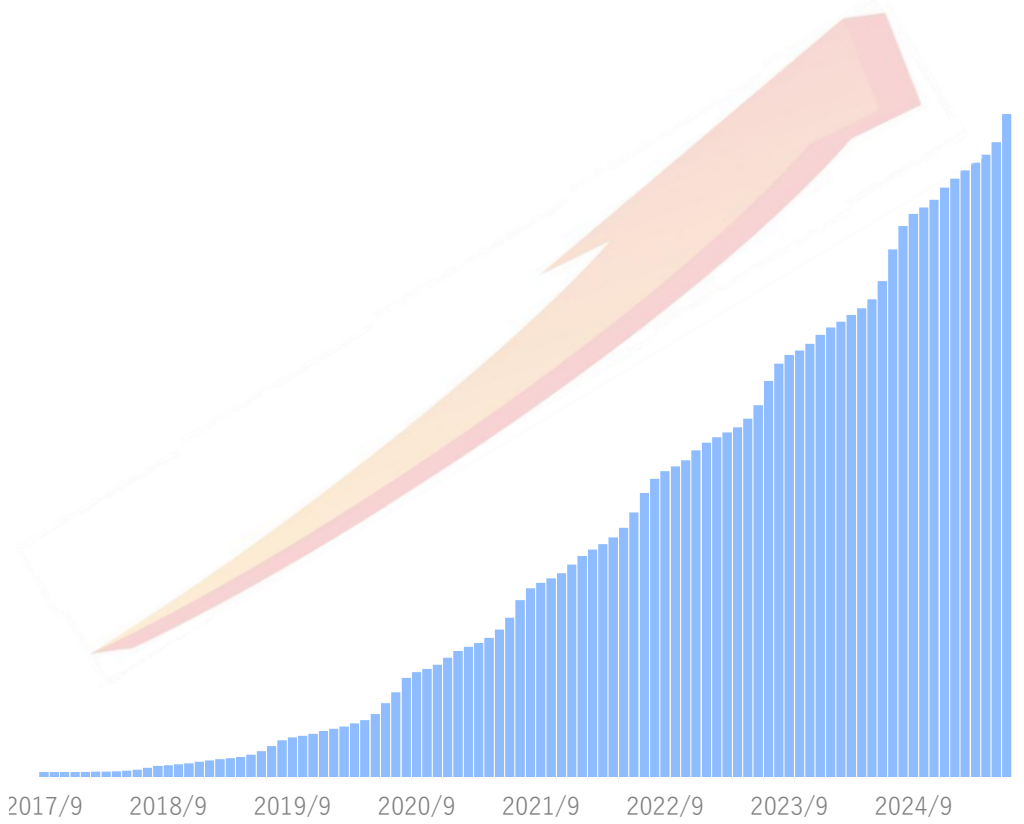
Panasonic's adoption of IoT for home air conditioners

- ✓ Started collecting home air conditioner operation data in 2014
- ✓ Number of units connected to IoT is increasing year by year



2014 ~
Wireless Adapter

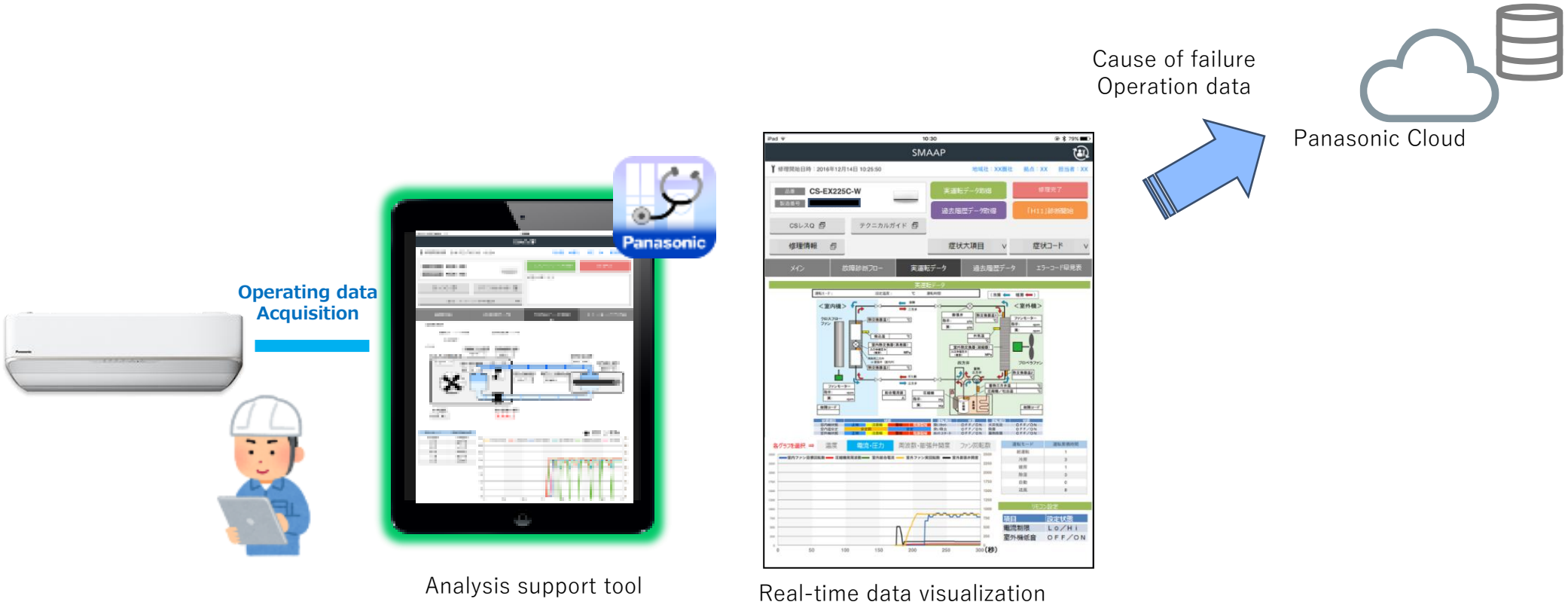
2017 ~
Built-in WiFi



Panasonic WiFi Built-in Home Air Conditioners
Trends in the Number of IoT Connections

Innovations in Panasonic Repair Operations

- ✓ In 2017, we introduced a tool that enables real-time acquisition and analysis of operation data at repair sites.
- ✓ The cause of failure determined by repair personnel at the site is linked with operation data and stored in the cloud.

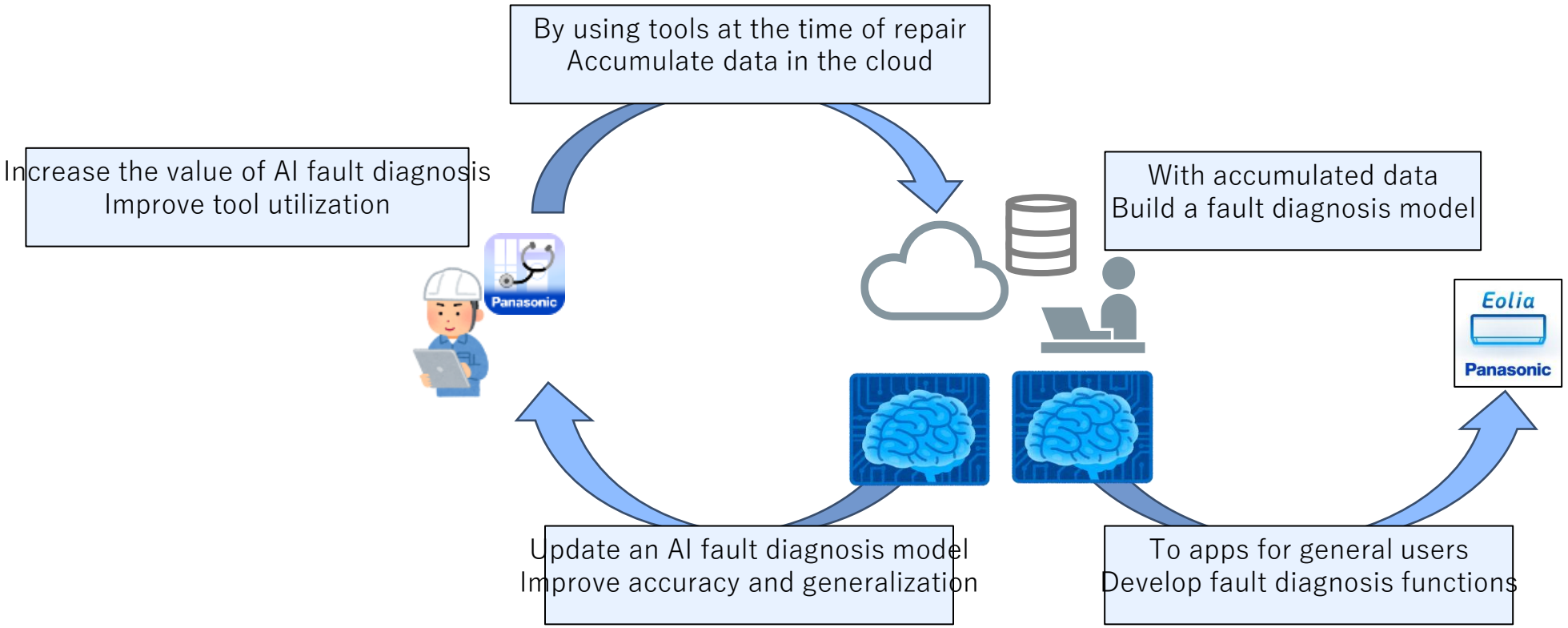


Early construction of a system to accumulate operation data linked to the cause of failure at the time of repair

Acceleration of data collection through thorough use of tools by employees, especially for home-use products repaired by manufacturers

Development of fault diagnosis technology for home air conditioners

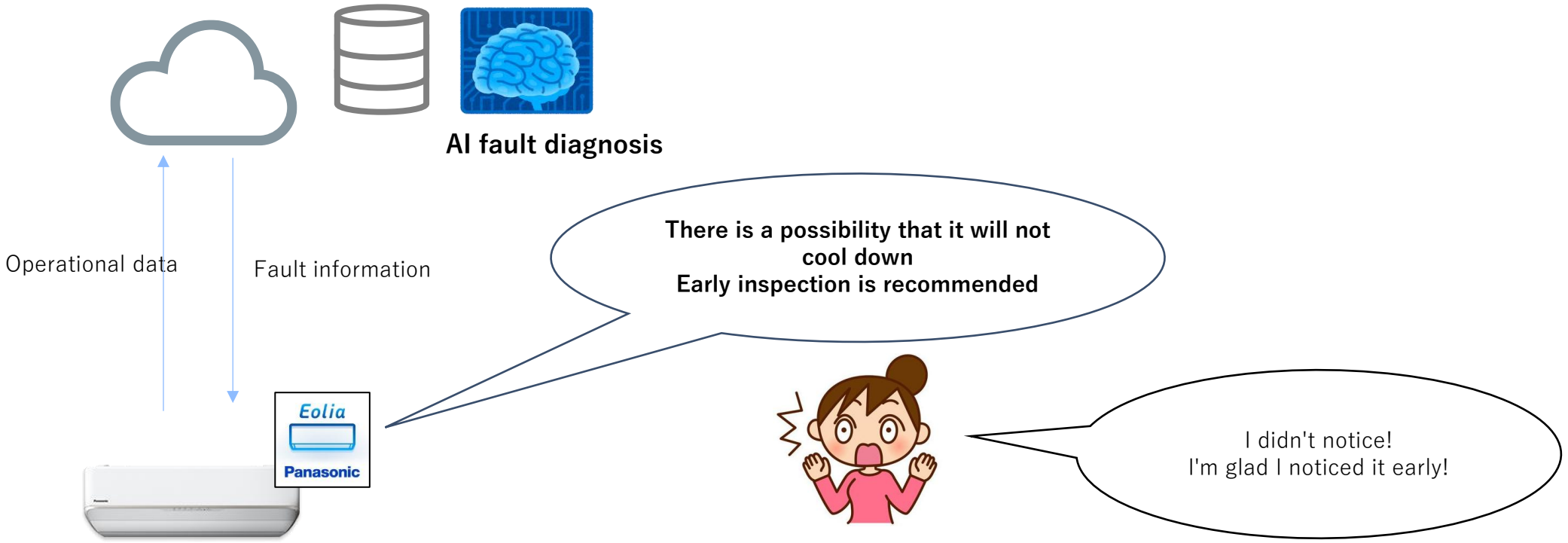
- ✓ Development of **AI fault diagnosis** using operational data accumulated through tools
- ✓ Formation of a virtuous cycle by improving the accuracy and generalization of AI fault diagnosis through improved tool utilization



In the future, we aim to provide fault diagnosis functions not only for internal use but also for general users.

Fault diagnosis service for general users of home air conditioners

✓ Service image



Early detection of malfunctions is expected to reduce downtime waiting for repairs

Technical requirements for fault diagnosis services

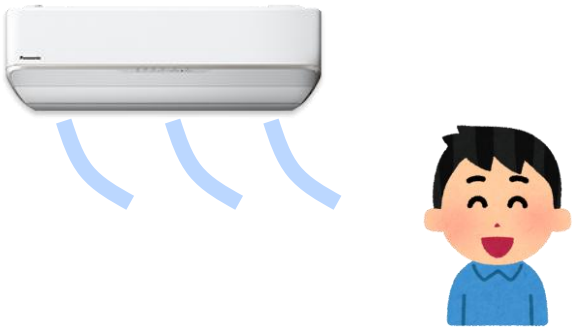
- ✓ Technical requirements
  - ✓ To be able to detect signs of failure before customers feel they are not getting cold or warm
  - ✓ To be able to minimize false alarms (which may lead to unnecessary expenses for customers)

- ✓ Problem setting for technology development
  - ✓ Target symptom is **refrigerant leakage** which is the main cause of not getting cold or warm
  - ✓ Aim to detect warning signs as early as possible with high accuracy based on failure date (**warning sign detection**)

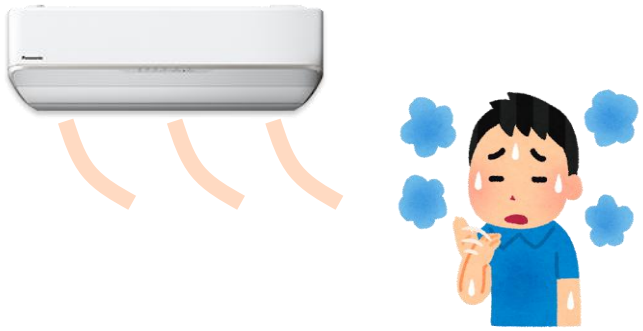
Definition of failure date in this approach

Day when refrigerant leakage is insufficient to cool (warm) the room enough for the user to notice

Normal Day: The day the user feels cold



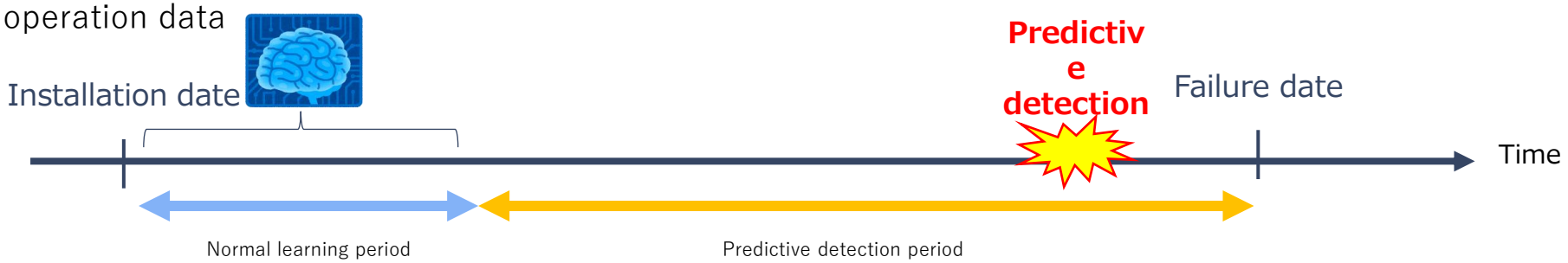
Failure Day: The day the user feels cold



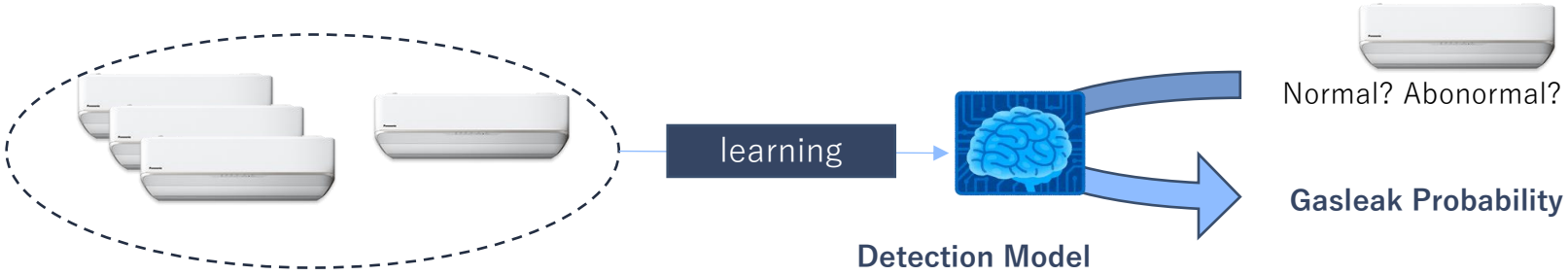
*Failure date is specified by rule-based logic based on room temperature and piping temperature

Previous research

- ✓ Learning normal operation data over a certain period of time and calculating the deviation from normal operation data for future operation data



- ✓ Issues in previous research
  - ✓ A normal learning period is required, and signs during that period cannot be detected
  - ✓ In particular, it is possible that the learning period for normal data cannot be secured for home air conditioners because the absolute amount of refrigerant is small and there is a short time to lose capacity.
- ✓ Policy of this study
  - ✓ Consider constructing a general-purpose model by learning equipment labeled as malfunctioning or normal, and determining signs of air conditioners whose malfunctioning or normal status is unknown.



Ingenuity in Learning

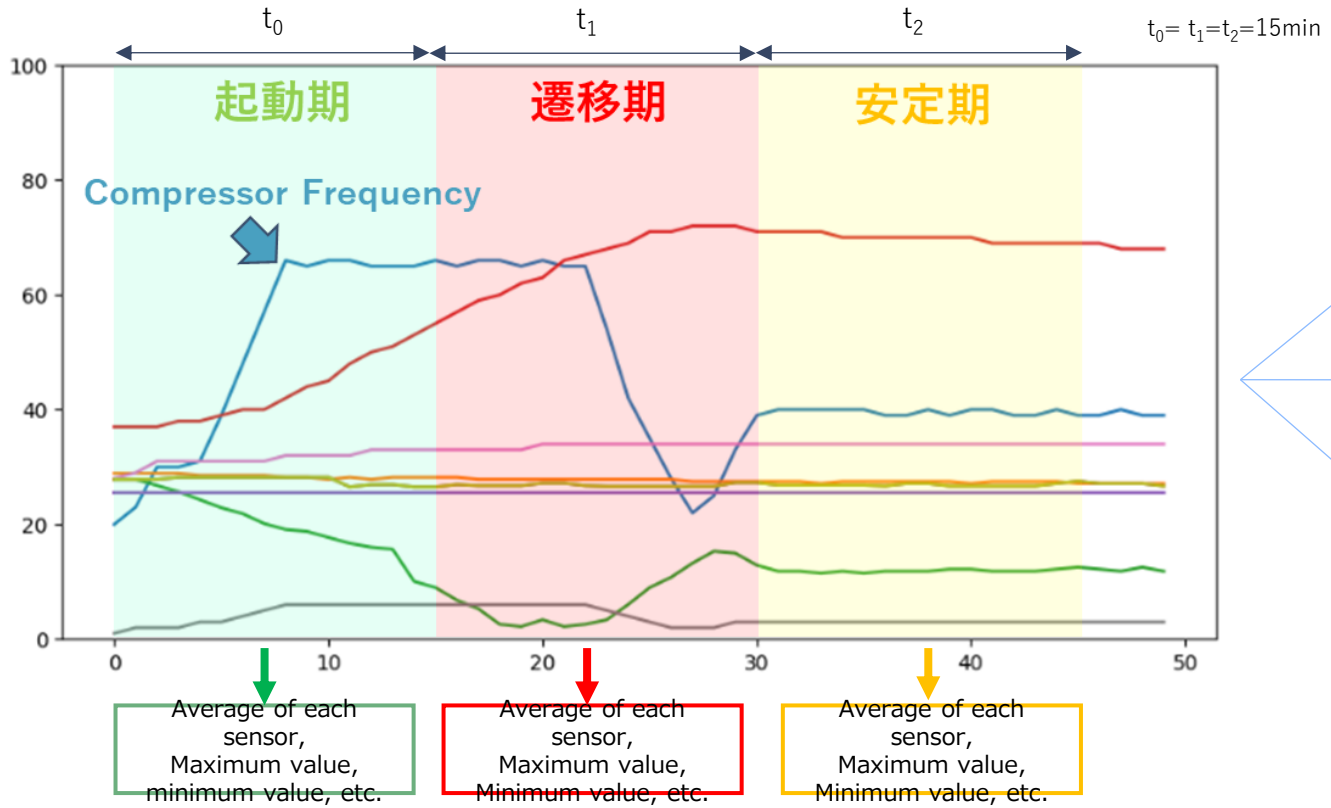
Hypothesis (1): The warning sign of refrigerant leakage may appear in any period between the start and stop of the air conditioner.

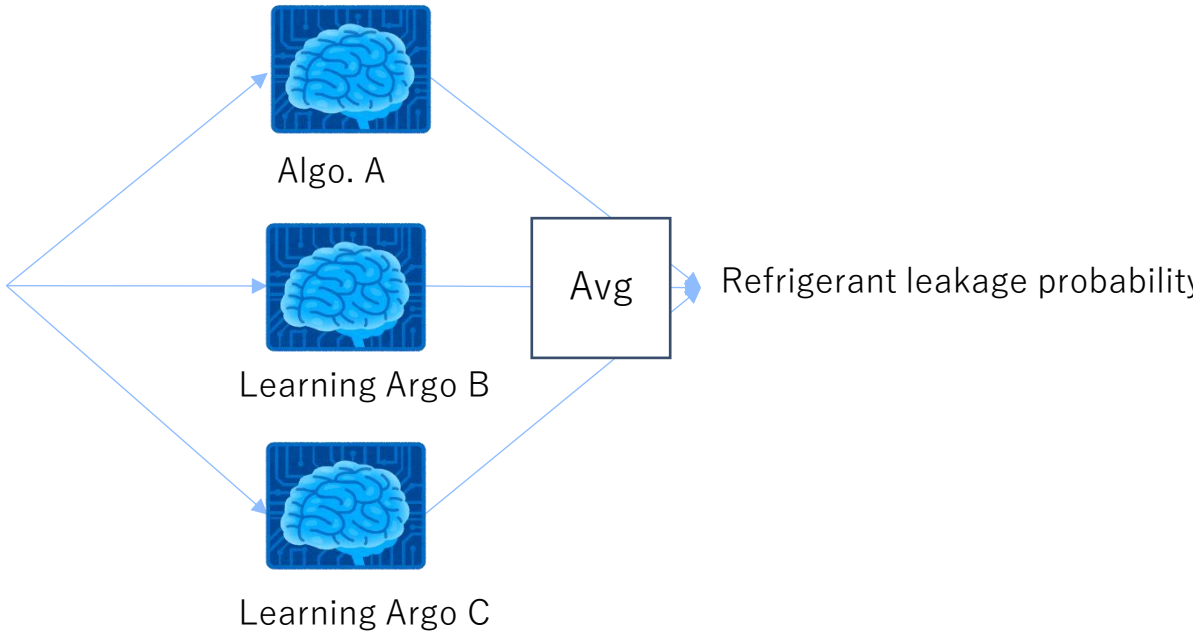
Are there different features to focus on depending on the condition of the air conditioner?

Proposal (1): Divide the condition of the air conditioner into three periods: start-up period, transition period, and stable period, and extract feature values for each period.

Hypothesis (2): Are there different effective learning algorithms for start-up period, transition period, and stable period?

Proposal (2): Combining the results of multiple different learning algorithms (ensemble learning)





Experience

- ✓ Dataset
  - ✓ Cooling operation data for Panasonic's high-end home air conditioners from 2021 to 22

Normal Devices	Abnormal Devices
161,120 operations	1,237 operations

- ✓ Control Experiment

	Feature		Learning Algorithm	
	3 Terms	1 Term	**Ensemble※1**	Single※2
Cond. 1 ★Proposed	○		○	
Cond. 2	○			○
Cond. 3		○	○	
Cond. 4		○		○

※1:XGBoost, Random Forest, Logistic Regression
※2:XGBoost

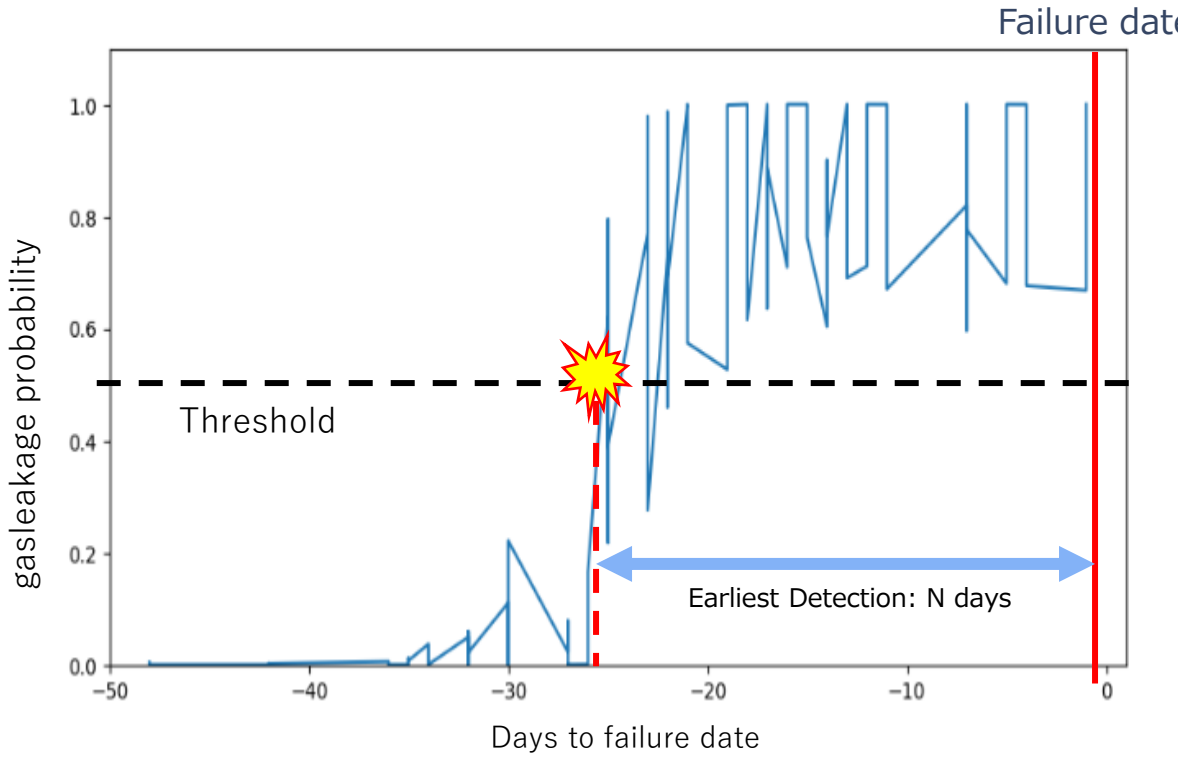
Definition of Key Metrics

- ✓ Precision
  - ✓ TP/(TP+FP)
    = How accurate is our detection ?
- ✓ Recall
  - ✓ TP/(TP+FN)
    = How many anomaly devices can we detect ?

		Detected as	
		Anomaly	Normal
Actual	Abnormal	True Positive (TP)	False Negative (FN)
	Normal	False Positive (FP)	True Negative (TN)

- ✓ Avg of Earliest Detection

= How many days before the failure date the warning sign was detected for the air conditioner for which the warning sign was detected before the failure date.



Result

✓ Evaluated using the average of 5fold CVs

	Period extraction		Algorithm		Recall	Precision	Avg of Earliest Detection
	3 Terms	1 Term	**Ensemble**	Single			
Cond. 1 ★Proposed	○		○		0.932	0.939	19.220 days
Cond. 2	○			○	0.932	0.880	19.520 days
Cond. 3		○	○		0.932	0.939	19.064 days
Cond. 4		○		○	0.932	0.890	19.358 days
Request for repair	-						- 9.679 days

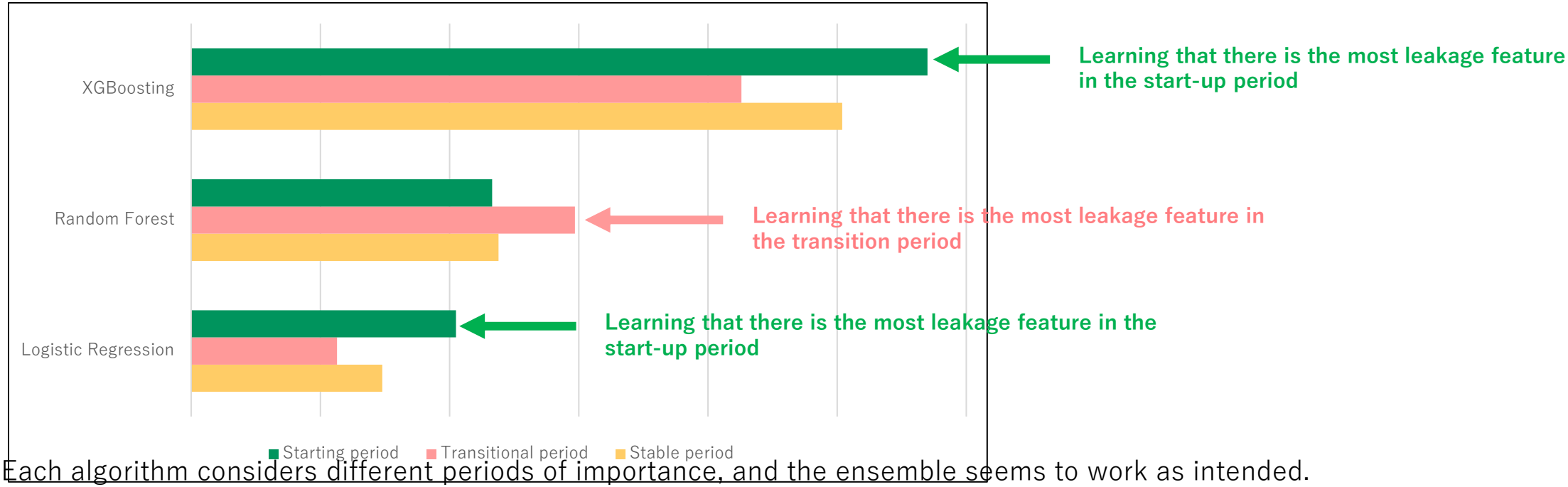
Compared to the feature quantity of 1 period
By using the feature quantity of 3 periods
15% of the equipment
Detected at least 1 day earlier

Requested repair
Occurs on average 9 days after the failure date

✓ Although a single model can detect signs the fastest, it is effective if Precision is low and false alarms can extent.
✓ Combining ensemble models is effective if false alarms are to be suppressed.
✓ It was confirmed that the proposed method can detect signs earlier than conventional methods while achieving high Precision.

Analysis of the proposed method model

✓ Comparison of average feature importance values for each period in ensemble learning for each detector



✓ Each algorithm considers different periods of importance, and the ensemble seems to work as intended.

Summary and Discussion

- ✓ Taking advantage of the fact that a large number of labeled operating data have been accumulated for residential air conditioners, this study aimed to detect signs of failure by constructing a general-purpose model using supervised learning.
- ✓ It was confirmed that this approach could detect signs about 19 days before the failure date.
- ✓ The effectiveness of this approach was confirmed for residential air conditioners where leakage detection is required as early as possible by devising ways to extract feature quantities from three periods: start-up, transition, and stabilization.
- ✓ It was confirmed that this approach could achieve early leakage detection while suppressing false alarms by learning feature quantities from three periods in an ensemble.
- ✓ For the realization of customer-facing services, improvement of explainability is a future issue.

Thank You