FUJITSU

Fujitsu Composite AI

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Executive Summary

In recent years, Composite AI has been attracting attention for its ability to combine different AI technologies and apply /fuse them to business operations while improving learning efficiency. Fujitsu Composite AI is Fujitsu's unique AI that understands abstract business problems through chat-style dialogue, and automatically searches for and proposes concrete solutions by selecting and utilizing the most appropriate AI models and data. Fujitsu Composite AI is Fujitsu's proprietary AI that understands abstract business problems through chat-style dialogue and automatically searches for and proposes concrete solutions by selecting and using the most appropriate AI models and data. Fujitsu Composite AI can accelerate the cross-industry deployment of AI, including customers and partners, by using Fujitsu Composite AI. Fujitsu Composite AI will accelerate the cross-industry development of AI, including customers and partners, to further solve social issues.

1. Trends in Composite AI

AI has developed remarkably in recent years, and with the emergence of generative AI, it has become more accessible and is being used for a variety of business issues. On the other hand, building AI in its current state requires a high level of expertise and a great deal of time and money. In addition, a single AI model often solves only a part of the original business problem and does not deliver the expected results. In order to solve the original business problem, it is necessary to divide the problem into multiple sub-problems and build an AI to solve each sub-problem, but this requires both business knowledge and AI expertise, which is a high barrier to realization. The Composite AI initiative has been attracting attention as an effort to solve these issues.

Although there is currently no firm common definition of Composite AI, Gartner defines it as "the combination and application (fusion) of different AI technologies to improve learning efficiency and expand the level of knowledge representation.*[1] Traditional machine learning, optimization techniques, rule-based reasoning, and graph analysis, which have been used as decision-making intelligence, are expected to make significant progress when combined with the emergence of generative AI. The market size is also expected to grow from USD 0.9B in 2023 to USD 5.8B in 2030 (CAGR 36.7%).

There are two major examples of Composite AI: framework examples and orchestration examples. The framework is Microsoft's Semantic Kernel, a lightweight SDK that combines LLM prompts with traditional programming languages to develop applications. It provides a mechanism for the kernel's orchestration function to accomplish its goals using the skill-memory connector based on user requirements. This facilitates integration into Microsoft's Copilot offering and enables rapid development of enterprise-specific AI applications. An example of orchestration is HuggingGPT, which uses ChatGPT to automatically select and execute from a variety of models available on HuggingFace, and can combine multiple models and perform multimodal processing including text, image, and voice data. It is also possible to combine multiple models and perform multimodal processing including text, image, and audio data.

A related technology to Composite AI is Autonomous Agents, which Gartner defines as "complex systems that achieve defined goals without human intervention. Composite AI is expected to use Autonomous Agent technology to automate the combination of AI technologies.*[2] Composite AI is also expected to benefit from this Autonomous Agent technology when automating combinations of AI technologies.

(*1 https://www.gartner.com/en/information-technology/glossary/composite-ai

(*2 https://www.gartner.com/en/newsroom/press-releases/2024-03-11-gartner-predicts-one-third-of-interactions-with-genai-services-will-use-action-models-and-autonomous-agents-for-task-completion-by-2028

2. The World We Aim for with Composite AI

What Is Fujitsu Composite AI?

Fujitsu Composite AI is Fujitsu's unique AI that can understand abstract business problems through chat-style dialogue, and automatically search for and propose specific solutions using optimal AI models and data from among countless solutions. Fujitsu Composite AI dramatically expands the scope of AI application by proposing and building combinations of multiple AI technologies. This enables Fujitsu Composite AI to address complex business issues that could not be addressed by a single AI model. As a result, AI can be provided quickly and at low cost to businesses that have previously been difficult to reach with the benefits of AI.

The intended users of Fujitsu Composite AI are general business users who have extensive business knowledge but no expertise in AI. In a typical B2B company, these users would be salespeople and system engineers. While these types of professionals understand the customer's business and can make appropriate judgments about what the customer needs, AI is positioned as a tool, and they often do not have the complex AI expertise. By using Composite AI, it is expected that non-AI specialists will be able to make full use of AI technology to improve business efficiency and achieve innovation.

The processing logic of Fujitsu Composite AI can be represented as the following Fujitsu Composite AI Triangle. From the user's point of view, it appears that passing an abstract request to Composite AI produces results that are directly related to decision making. Fujitsu Composite AI can be said to be performing these processes on behalf of the AI experts. Fujitsu Composite AI can be said to be performing these processes on behalf of AI experts.

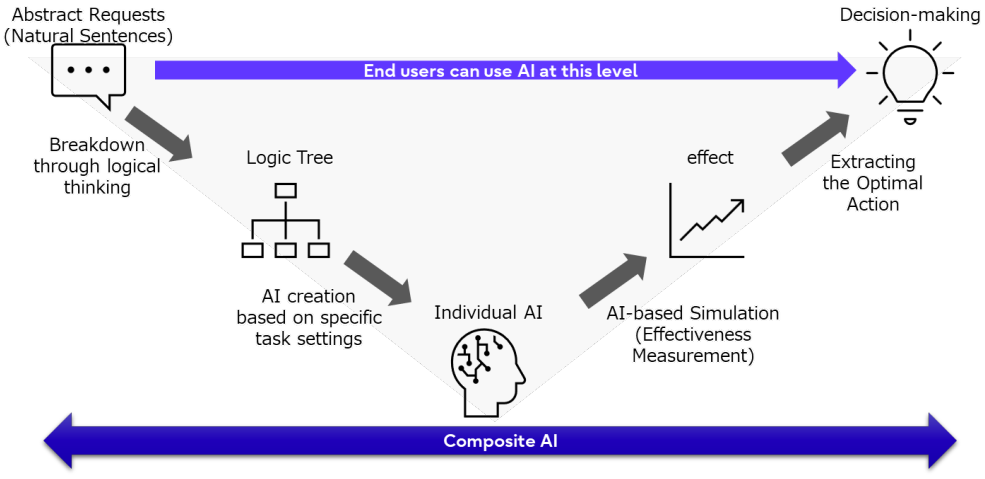

Figure 1: Fujitsu Composite AI Triangle

This sequence of processes is described below.

First, Fujitsu Composite AI uses logical thinking to break down abstract requests from users into concrete actions. This process creates a logic tree. The top of the logic tree shows the "what" and the bottom of the tree shows the "how. Actions broken down to the lowest level are assumed to be specific enough to set up tasks to create individual AIs. Therefore, if sufficient concreteness has not been achieved, this breakdown is repeated. During this breakdown, general knowledge alone is not enough to be sufficiently specific, and Fujitsu Composite AI uses graph generation technology with feedback that incorporates additional requests from users and business knowledge to enable the creation of appropriate logic trees. This enables us to bring value to the created AI and overcome the gap of "AI that is created but not used," because we are able to materialize the created AI, including its integration into business processes.

Using a well-defined task configuration, the next step is to create an individual problem-solving AI to perform that task. Fujitsu Composite AI provides this capability through a large number of AI models and data, and their optimal combination. Fujitsu Composite AI uses Scikit-learn, which is used as a standard AI technology worldwide, as well as Fujitsu's proprietary technologies such as Wide Learning and DeepTensor. Fujitsu's proprietary technologies, such as Wide Learning and DeepTensor, will be used in addition to conventional machine learning technologies. This combined functionality not only expands the scope of application, but also provides the ability to generate new AI models, making it possible to create AI that responds to any task setting.

The created individual problem-solving AI is executed and its effectiveness is calculated. Effectiveness is the overall evaluation of the AI's accuracy and usefulness, which determines its value. Since a number of AIs are used in this effectiveness calculation, overall optimization is also necessary. Fujitsu Composite AI can maximize effectiveness by using AI configuration optimization technology to find the optimal settings for the system as a whole, while taking into account the trade-offs among AIs.

Using the calculated effects, the logic tree is updated with weights. However, since the logic tree contains many large and ineffective actions, it is difficult for users to understand and make decisions on all of them, Fujitsu Composite AI uses causal decision-making technology to extract the most effective actions from the weighted logic tree. Causal decision-making technology can rapidly discover valuable causal paths even in large causal graphs, thereby speeding up decision making. Moreover, by presenting users with reasons, users are able to make decisions with conviction.

The series of processes, starting with natural sentence input, are automated, making it easy for non-AI specialists to use advanced AI technology

Overall Configuration

The Fujitsu Composite AI system consists of four main parts: Foundation, Model Lake, Data Lake, and Knowledge.

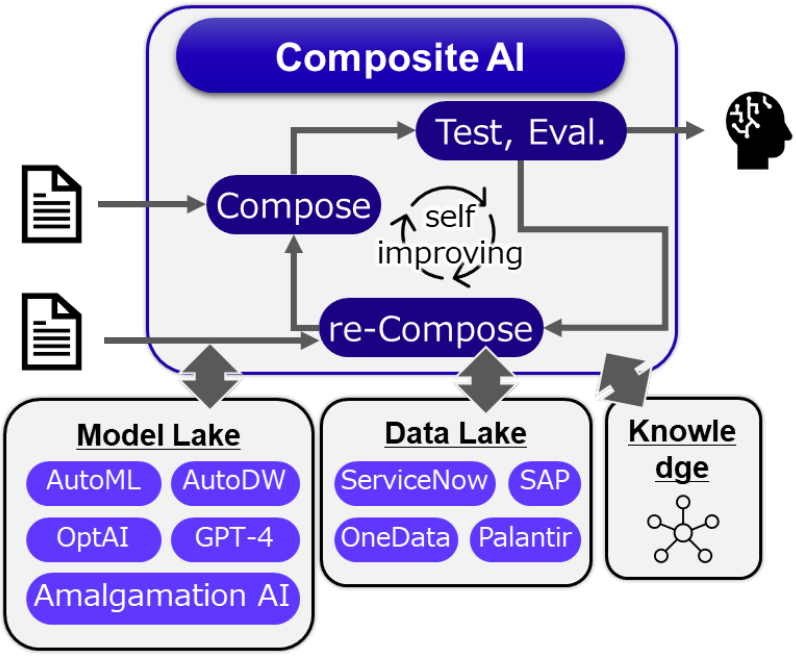

Figure 2: Fujitsu Composite AI Overall Configuration

1. Foundation: Foundation is the core control component of Composite AI. It is responsible for selecting and combining appropriate AI functions based on user requests.
2. Model Lake: The Model Lake is where the Composite AI stores the various AI skills available to it. There are two categories of skills here: Native Skills and Semantic Skills.

   - Native Skill: This is a function that is explicitly defined by programming and provides deterministic results. Examples include mathematical calculations and data processing routines.
   - Semantic Skill: This includes generative AI and machine learning models, which are functions that generate probabilistic results. This is for more complex tasks such as text generation or image recognition.

3. Data Lake: The Data Lake contains a variety of data sources; Composite AI appropriately discovers, integrates, validates, and generates data as needed based on user requests.
4. Knowledge: The Knowledge portion stores Composite AI's experience in use and knowledge related to specific domains (e.g., business knowledge, business processes, etc.). This allows AI to effectively use skills and data to meet user needs.

In order to realize Fujitsu Composite AI, which builds AI that solves business objectives, it is necessary to connect users' business issues with the Model Lake, Data Lake, and Knowledge. The "Planner" function is a function to realize this by interpreting the user's problem using the knowledge in the Knowledge and creating a configuration diagram of what specific AI model will be built and how it will work together. After designing the AI to be built, it is necessary to build each AI in concrete terms. The Fujitsu Auto Data Wrangling function is provided to ensure that the data collected from users and the data in the Data Lake are used appropriately for AI construction. When building a specific AI model from the prepared data, if an appropriate model exists in Model Lake, it is selected, but if an appropriate model does not exist, "Requirement Learning" is used to build a new model appropriate to the specifications required by the user, and "Predictive AI" is used in conjunction with Requirement Learning to build a specific AI model. Fujitsu AutoML" for classification and prediction, which creates AI models, and "OptAI" for optimization AI, which has its own functions.

Functions

This section describes the unique features that make Fujitsu Composite AI possible.

Planner

Fujitsu Composite AI builds multiple AIs and combines them to achieve the user's objectives. To achieve this, it is necessary to break down the user's ultimate goal and decide which AIs should be configured and how they should be combined with each other. For example, if the goal is to create an order plan to optimize profits for a fresh food retailer, it must be decided to build and link an AI that forecasts the demand for each product and an optimization AI that determines the number of orders to be placed to maximize profits within the budget based on the forecast results.

Planner breaks down the final goal entered by the user into detailed elements, selects the necessary factors, and automatically generates the appropriate method of collaboration. First, relevant factors are enumerated from the user's input user goals. The enumeration of those factors is performed by organizing and extracting the necessary information from the accumulated knowledge graphs and documents using a large-scale language model (LLM). For each enumerated factor, the related factors are enumerated again. By repeating this process, a hierarchical causal graph is constructed. Among the enumerated factors, elements that can be handled by AI are selected, and the paths in which AI actions are effective in achieving the goal are extracted using our unique causal analysis technology to construct a graph that represents a combination mechanism in which multiple AIs realize goal achievement. This produces a diagram of the Composite AI.

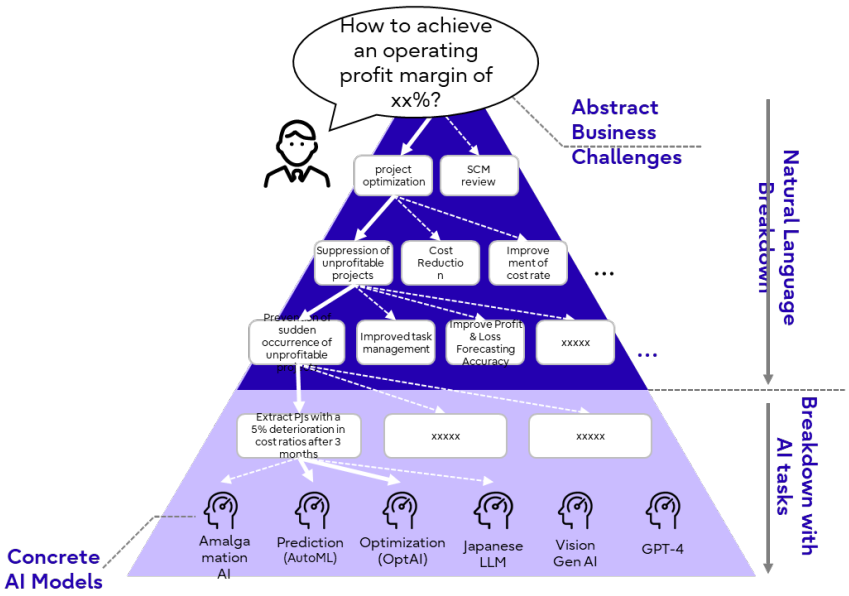

Figure 3: Example of Breakdown from Goal

Fujitsu Auto Data Wrangling

Fujitsu Auto Data Wrangling is a technology that can automatically convert tabular data into a format that can be trained by AI by utilizing generative AI, machine learning algorithms, and various automation techniques. Data scientists spend 80% of their time preparing data before using AI, and Fujitsu Auto Data Wrangling is designed to reduce that effort.

AI can do many things, including prediction and classification. For example, in the manufacturing field, it can predict the action to be taken based on the defective phenomenon of a product, the model name, and product repair data. In order for AI to perform prediction and classification in this way, it is first necessary to have AI learn data. In many cases, however, AI cannot learn from tabular data as it is. This is because the data is not organized as data to be input to AI, for example, the format of values is not consistent, and there are items such as "Remarks" that can be freely described. Even if the data is learned as is, the accuracy of AI may not be sufficient, and more data may be needed.

Therefore, until now, much time has been spent on preparatory work to convert the data into a form that AI can learn. These preparatory tasks required data formatting to unify the format of values and data enhancement, such as changing the format and structure of data to improve AI accuracy, before allowing AI to learn tabular data.

The value of Fujitsu Auto Data Wrangling is that it reduces preprocessing, i.e., the man-hours required to prepare data for AI training, and it can also significantly improve the accuracy of AI by automatically adding new data and enhancing the data.

In the following data for the app site, the "Price" column contains a mixture of units and numbers; Fujitsu Auto Data Wrangling eliminates the common unit part and only uses the numeric part as input data. The "Release" column is broken down into year, month, and day, and the data is separated into separate columns. In a comma-separated list format, such as the "Genre" column, each item is broken down into separate columns, such as the Games column, Life column, and so on.

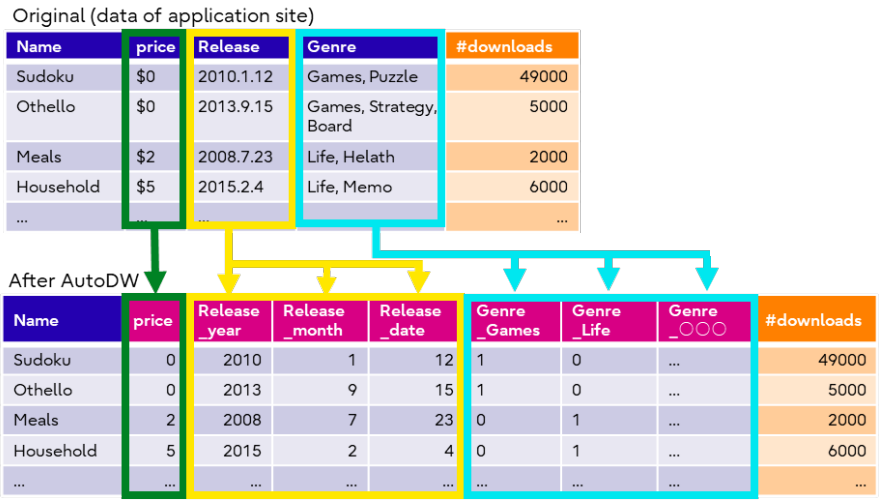

Figure 4: Example of data format change with Fujitsu Data Wrangling

This pre-processing can take a lot of time if done by a person; Fujitsu Auto Data Wrangling can do it automatically, saving more than 90% of the man-hours.

In addition, Fujitsu Auto Data Wrangling can automatically add new items to enhance the data.

Free description fields, such as "Defective Phenomenon" in the product repair data below, contain a wide variety of text. Machine learning cannot normally process such items (unstructured data) well, and Fujitsu Auto Data Wrangling can automatically extract important keywords from such items and enhance the data by adding them as new data. By enhancing data, the accuracy of AI can be greatly improved.

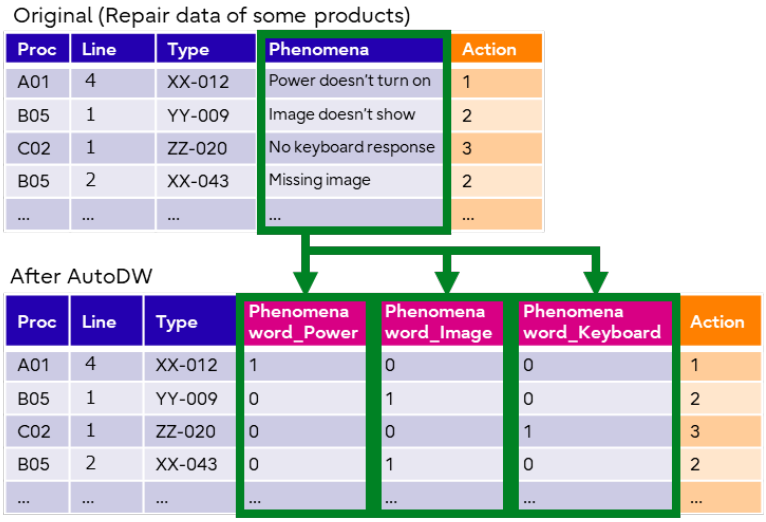

Figure 5: Example of Data Augmentation with Fujitsu Data Wrangling

Requirement Learning (Automatic Model Generation)

Even if Planner has created a Composite AI configuration diagram, each AI must be exactly as specified in the blueprint. Traditionally, creating a high-performance AI as intended has required experts to select the appropriate algorithm, translate the requirements into a mathematical representation that the AI can learn, adjust the data used, and so on. In fact, in the current situation, it often takes several months of work by experts to create just one AI, while Composite AI, which requires the creation of multiple AIs, requires an extremely large number of experts and a very long period of time.

In requirement learning, requirements for each AI are first entered into a proprietary LLM, which is internally interpreted into a format that enables the AI to learn, and then the data and model structure are adjusted accordingly while learning is conducted to create an AI that is optimal for the purpose. This functionality not only automates tasks that previously required highly specialized experts, but also enables the creation of AI that can respond to requirements that could not be directly addressed in the past, such as requirements that include performance constraints.

By learning the requirements for each AI defined in the Composite AI configuration diagram created in Planner using requirement learning technology, it is possible to create a specific Composite AI model.

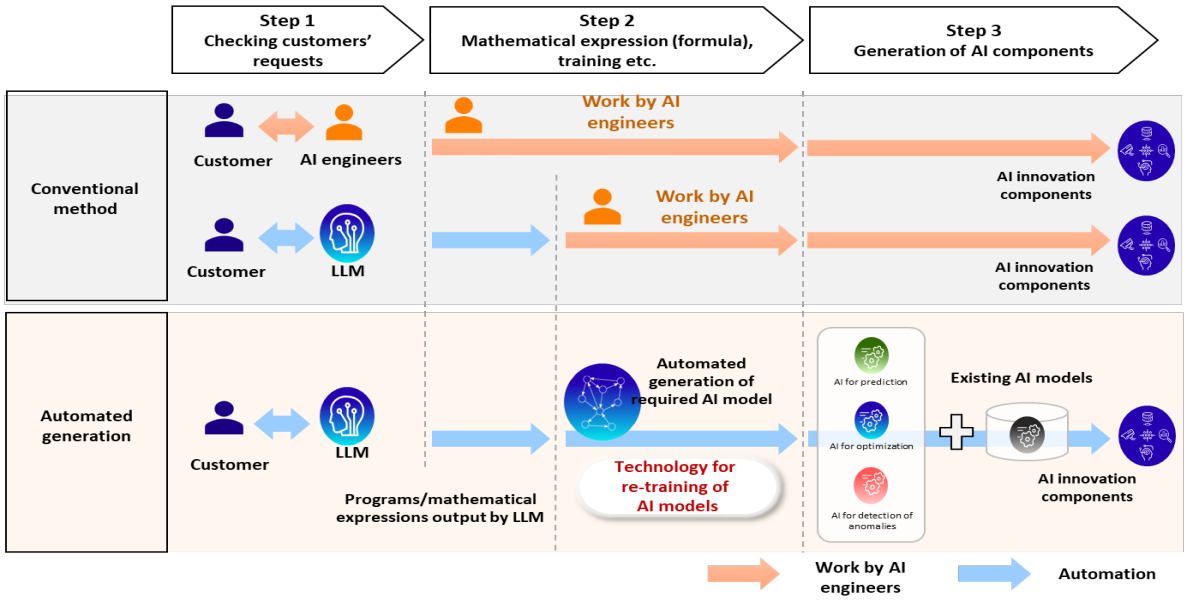

Figure 6: Overview of Requirement Learning

AI Skills in Model Lake

Here are the AI skills Model Lake is equipped with in turn.

a. Fujitsu AutoML

AutoML (Automated Machine Learning / Machine Learning Automation) is a technology that automates the various processes required to perform machine learning. Many AutoML tools are capable of automatically building machine learning models (AI models) by specifying a data set and the objective variable to be predicted by machine learning, and are attracting attention as a technology that promotes the democratization of AI. In this context, Fujitsu has developed Fujitsu AutoML, an AutoML that can generate highly accurate AI models in a short time. Fujitsu AutoML has the following two features:

Feature 1 **Learning from past highly accurate AI model building programs, appropriate processing is generated at high speed through prediction.**

Conventional AutoML technology takes a long time to process because it exhaustively searches various AI building programs. On the other hand, Fujitsu AutoML generates highly accurate AI building programs in a short time by learning more than several thousand excellent (highly accurate) programs executed in the past. Specifically, it breaks down each collected program into its components (various data transformations, normalization, sampling, AI model building, etc.) and converts them into highly accurate programs by repeatedly verifying them while replacing the components.

Feature 2 **Programs for building AI models are presented with explanations.**

The programs generated by Fujitsu AutoML are structured as a combination of components. Therefore, in each component of the output program, the corresponding component name can be commented out, making it easy for the user to understand the program.

Experiments with benchmark data show that Fujitsu AutoML performs more accurately and faster than existing AutoML technologies. *3

(*3) R. K. Saha, et al, "SapientML: Synthesizing Machine Learning Pipelines by Learning from Human-Written Solutions", 44th International Conference on Software Engineering (ICSE 2022)

b. OptAI (Optimized AI Construction)

OptAI is an AI technology dedicated to solving combinatorial optimization problems. A Large Language Model (LLM) agent, equipped with the necessary knowledge for formulating the optimization problems, takes the user's natural language input and incrementally translates it into a mathematical model. When describing their problems, users are not required to use technical terminology. Through an interactive interface, the AI understands the conventions and patterns essential for formulating the optimization problem and converts them into a mathematical form.

During this transformation process, the AI asks pertinent questions and elicits from users the information needed to deepen its understanding of the problem. This enables the LLM agent to comprehend the complexity of the optimization problem and suggest the most suitable formulation. Users do not need technical expertise to effectively formulate and solve combinatorial optimization problems.

The final results are supported not only by clear textual explanations but also by visual data displays. This entails visualization in the form of graphs and tables, which help the user intuitively understand the optimization results.

With OptAI, business users can efficiently solve problems in cooperation with AI, even without being experts in combinatorial optimization.

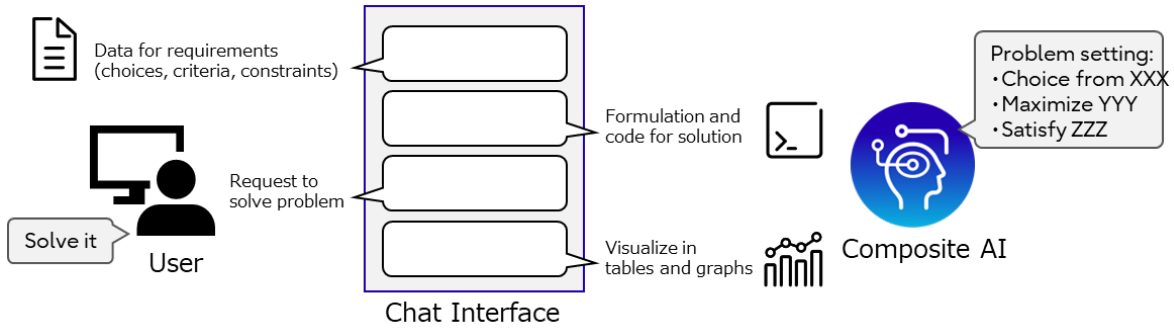

Figure 7: Overview of OptAI

3. Case Studies

Prediction

Failure Prediction (Collaboration with ARCHIMEDES CONTROLS)

The sustainable operation of data centers, which have become an infrastructure for daily life, is an urgent social issue, and with the spread of IoT, it has become possible to realize highly accurate failure prediction and abnormality detection by using AI to analyze vast amounts of data collected from various sensors, including temperature, humidity, vibration, and sound.

In this case, Fujitsu AutoML can be used to create an AI model that accurately predicts future PM values for particulate matter (PM), which has a large impact on equipment such as servers. This enables effective scheduling of maintenance for HVAC (Heating, Ventilation, and Air Conditioning) systems.

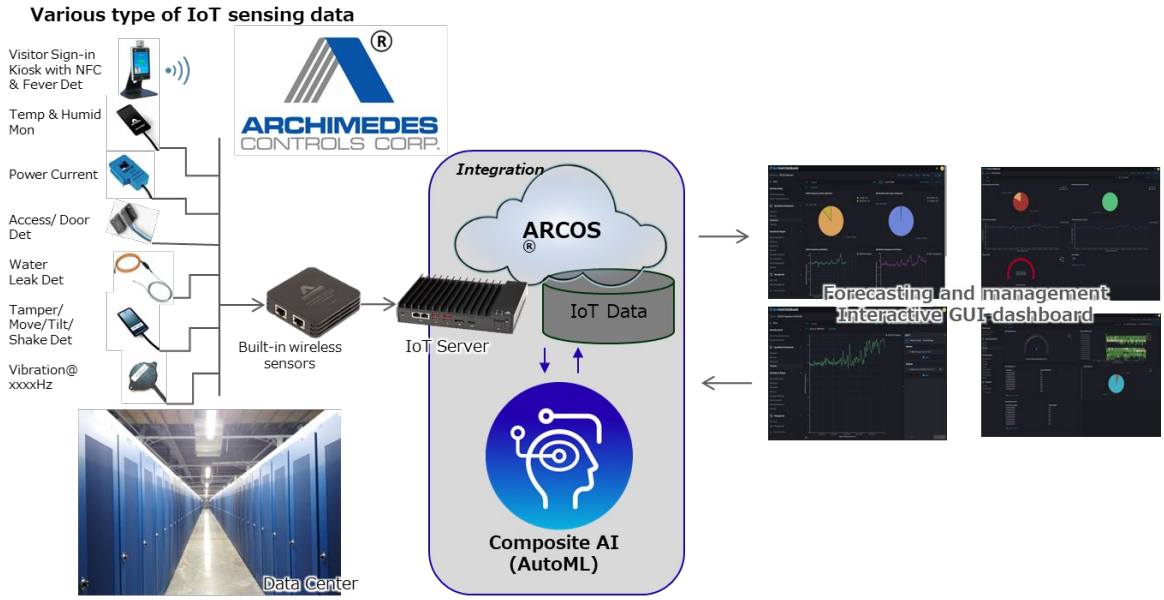

Figure 9: Flow of Container Export/Import

Optimization

Driver Scheduling (Collaboration with NAKAYAMA TRANSPORTATION)

The logistics and transportation industry are facing numerous challenges due to the labor reforms of 2024, which have imposed restrictions on driver working hours. Composite AI is expected to help address this issue.

In the case of Nakayama Transportation Co., Ltd. an automated vehicle dispatch system powered by Composite AI has made it possible to complete vehicle dispatch planning in only 10 minutes – a task that previously took several hours. The system accurately tracks driver's constrained driving hours, enabling efficient transport planning while complying with legal regulations. Nakayama Transportation highly values the system's ability to manage both vehicle dispatching and working hours with a single tool, thereby reducing labor hours and enhancing efficiency.

Container Placement Optimization Seaport Offering

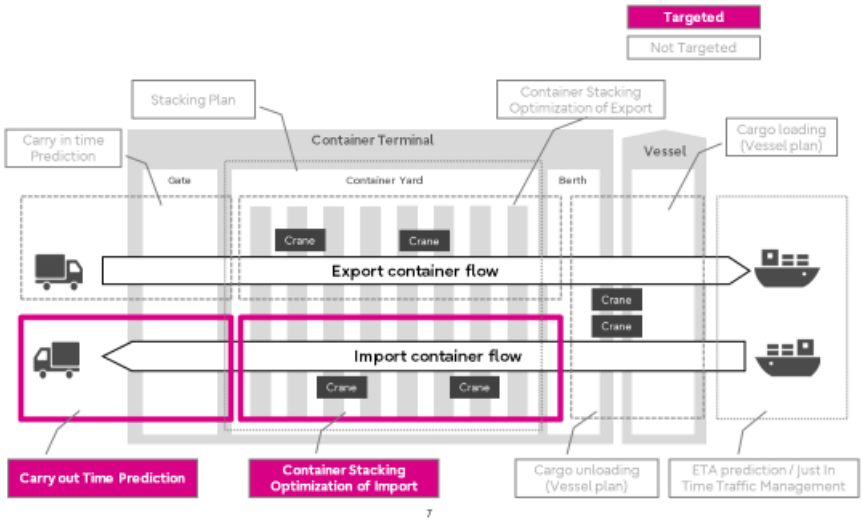

Figure 9: Flow of Container Export/Import

From 2020 to 2021, ports faced the challenge of volume of trade at global container ports increasing by 6.8% to 857 million TEU (EU: unit representing a standard container). It is assumed that the volume of containers transported by sea will continue to grow and, by 2035 reach double the current level. To maintain maritime transport, which accounts for 99% of international logistics, it is necessary to increase the volume that each port can handle (port capacity), but physical expansion of ports is limited, and there is an urgent need to increase capacity through efficiency improvements.

In this case, Fujitsu Composite AI relies on OptAI, which includes the next generation Digital Annealer, to automatically determine the optimal arrangement that minimizes the number of cargo handling operations to retrieve the desired container when the truck arrives at the yard, thereby reducing the time required to deliver the container to the truck. This improves "truck turn-around time" and "truck waiting time at the gate," which in turn improves port efficiency and translates to increased capacity.

Predictive Optimization

In the field of business, analyzing complex and intricate business processes based on their event logs, making forecasts, and optimizing resource allocation, etc., is one of the most important approaches to improving business operations.

In this case study, Composite AI was used to improve the efficiency of Fujitsu's internal customer support operations. Specifically, the incident management system logs were input to , and the first step was to predict the future of the incident (how many days will it take to resolve the issue? Will there be inefficiencies, such as a return to work?) This information is then used to optimize resource allocation (e.g., staffing), resulting in a 25% increase in efficiency compared to .

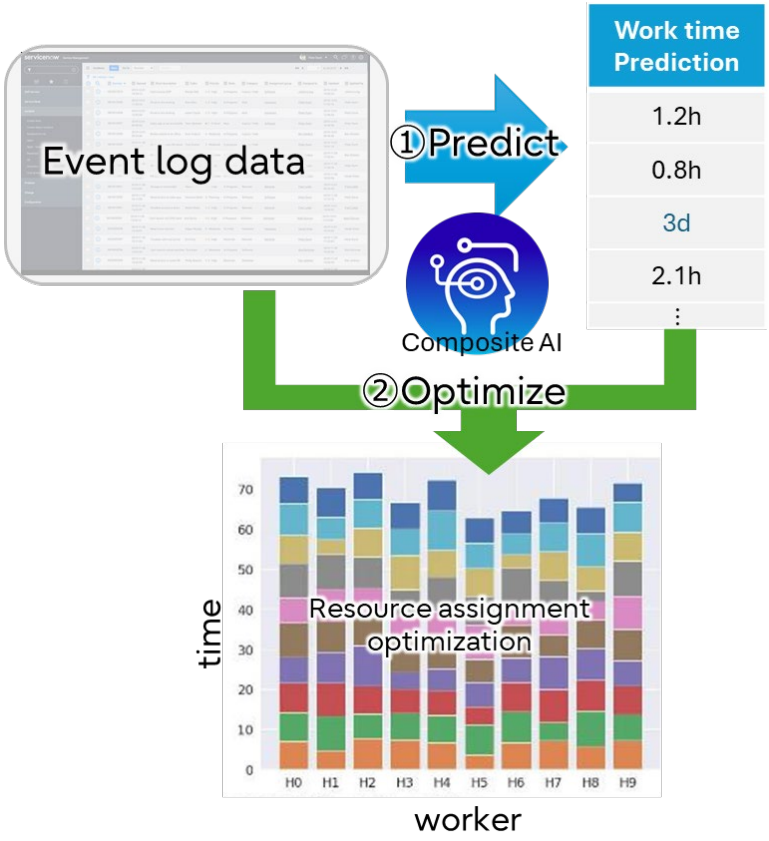

Figure 10: Predictive optimization from event log data

May, 2024