Data processing method in a context-aware system to provide intelligent robot services based on big-data

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Abstract. In order to recognize the situation and to provide robot services based on big data, it is necessary to implement a machine learning model capable of analyzing big data and a method for providing this data to the analysis model for learning. Previous researches have focused on the implementation of various data analysis models to analyze the collected big data. However, in these researches, it is difficult to recognize the new data which is not learned by the analysis model, and further research is needed to solve it. In this paper, we propose a data processing method to provide context-aware information in context-aware system based on big data to provide intelligent robot services. The proposed data processing method can convert the data generated in the domain in which the robot is running to learn data of the machine learning model and provide it, thereby continuously improving the accuracy of the machine learning model. In the experiment, the context-aware information is provided through the prototype of the context-aware system with the proposed method.

1. Introduction
Since the start of the big data paradigm, various techniques for analyzing large amounts of data and obtaining valuable information have been continuously studied and developed [1,2,3,4,5]. These techniques enable to store and analyze large amount of unstructured data, which could not be processed in the past, and the meaningful information obtained through these techniques is utilized in various fields such as content industry, advertisement, and distribution [6,7,8]. In particular, artificial intelligence technologies based on machine learning have attracted a great deal of attention recently due to the evolution of hardware, the solution of over-sum problems, the implementation of in-depth neural networks, and the large amount of big data required for learning [9,10,11,12]. They can be applied to analyze the meaning of specific data by repeatedly learning large data. In addition, these technologies have been done in many fields such as speech recognition [13], image analysis [14,15], pattern analysis [16], and time series data analysis [17,18]. These artificial intelligence technologies are actively being developed by global IT companies, universities, and through many open source projects. IBM Watson [13], Tensor Flow [14] developed by google, Berkeley University’s Caffe [15] and Deeplearning4J [16] are some of the representative enterprise projects.

On the other hand, the existing context-aware systems [19,20,21] based on artificial intelligence models are focused on the implementation of analytical models that can analyze specific data sets. In these cases, even if the implementation of the analysis model is completed, there is no way to
continuously collect and provide the data sets for learning the analysis model. For this reason, it may be difficult to operate and manage the context-aware system. In addition, additional processing is required to convert the results of the artificial intelligence model into contextual information. Therefore, artificial intelligence-based context-aware systems need not only the implementation of analytical models, but also the collection and provision of data for analytical models, and concrete methods to convert the analyzed results into contextual information.

In this paper, we propose a data processing method to provide context-aware information by using machine learning based analysis model in context-awareness system to provide intelligent robot service. The proposed data processing method is intended to improve the accuracy of the model for analyzing the big data, and allows to collect and provide the big data for learning the analysis model. The analysis model used in this paper is based on the RNN algorithm [22], which is effective for time series data analysis. In order to learn the analytical model based on the RNN algorithm, time series data of the service domain, in which the robot is operating, are needed. With the proposed method, data composed of time, environments, and index information related to execution of service can be collected at the time when context aware service is executed. The collected data are hereinafter referred to as ‘snapshot data’. Every time the context aware service is executed, snapshot data is provided for learning the analytical model after a predefined period of time. In the experiment, we show that the analytic model is learned and contextual information is provided through the context-aware system with the proposed data processing method.

The composition of this paper is as follows. In Chapter 2, we will look at existing research on context-aware systems based on Big data. Chapter 3 introduces the outline and configuration modules of the context-aware system that utilize the proposed data processing method. And the method for collecting and providing big data. In Chapter 4, we show how the big data Analysis Model based on machine learning is learned through context-aware system that implements the proposed data processing method and context information is generated and provided. Chapter 5 includes conclusion remarks.

2. Related works
In this section, we introduce the existing research works on big-data based context-awareness systems and the characteristics of big data analysis techniques used in each study.

As a general method for analyzing big data, Hadoop based on distributed processing [23], data mining, and machine learning based artificial intelligence are used. Context-aware systems, that utilize Hadoop-based big data analysis, collect big data composed of environmental information around a user and biometric information provided by the wearable device. They recognize the user’s surroundings with information obtained by processing data collected in units of day, week, and month. As a research related to this, Wireless Body Area Network (WBAN) [24] proposed a network structure for providing healthcare service by collecting and processing biometric information from sensors attached to human body.

The big data for context-aware monitoring (BDCaM) [25], which is a context-aware system for healthcare such as WBAN, uses sensor data, patient medical records and is able to provide customized medical services. BDCaM includes the Hadoop based system to analyze the collected big data, and big data analysis result is used to recognize the situation with the rule based context recognition method. Context-aware systems using these methods are mainly used when analysis results of big data are not needed in real time, and are useful when analyzing medical and life patterns.

On the other hand, context-aware systems that analyze big data based on artificial intelligence can be used when they want to process the collected real time data. These systems generally use artificial intelligence models learned from pre-collected data in a specific domain, and then analyze the current data with the model that has been terminated by the learning method. Context awareness component(CAC) [19] is the study which applied these methods. It applies the analysis result of sound data generated in the home to the existing context-aware system and focuses on improving the accuracy of context awareness in the system to provide intelligent robot services. In addition, it also
utilizes an artificial intelligence model that can analyze sound using CNN (Convolutional Neural Networks) [26] model, which are deep artificial neural networks that are used primarily to classify images (e.g. name what they see), cluster them by similarity (photo search), and perform object recognition within scenes. After collecting the voice data collected by the robot and learning the artificial intelligence model, each robot can recognize the situation using the artificial intelligence model.

3. Data processing method in Context-Aware system

In this chapter, we describe an outline of the intelligent robot's context-aware system that utilizes the proposed data processing method, the components that make up the system, and the flow that runs in conjunction with an external application to provide context aware services. The data processing method provided by the context-aware system of the proposed intelligent robot will be described in detail.

![Diagram](image)

**Figure 1.** In this case simply justify the caption so that it is as the same width as the graphic.

3.1. Overview of Context-Aware system

Figure 1 shows an outline of the context-aware system that uses the proposed data processing method. At the top of figure 1 is Robot Service Applications based Context-Awareness (RSACA), which can provide intelligent robot services. RSACA is responsible for executing the robot service when a specific situation is recognized, and forwards the execution history of the robot service to the Cloud-based big data Collection Engine (CBDCE) at the bottom of figure 1. In the center of figure 1, there is Context-Aware Engine based Artificial Intelligence Model (CAEAIM) which can provide context recognition information. CAEAIM can provide context awareness information requested by RSACA and utilizes artificial intelligence model internally. At the bottom of figure 1, CBDCE is responsible for collecting environmental information and generating snapshot data. CBDCE has a cloud-based structure and contains a number of sub-modules. The environmental information and the snapshot data collected from the CBDCE are transferred to CAEAIM and used for learning and context awareness processing of the AI model. The following is a detailed description of each component.
3.1.1. Cloud-based big data collection engine
At the bottom of figure 1 is the Cloud-based Big Data Collection Engine (CBDCE). CBDCE is a big data collecting system that provides environment information collection and snapshot data generation for providing context aware information. It has a cloud-based structure that receives data from the subsystems for data collection of object Internet sensors located in each service domain, and can modify and process the data of each subsystem into the desired data form. Then, it receives the execution event of the robot service, and can generate and store the snapshot data by combining all environment information at the time when the robot service is executed and an index number indicating the executed service. The stored snapshot data is provided to the proposed context-aware system and used to learn the AI model.

3.1.2. Context-Aware engine based on artificial intelligence model
In the middle of figure 1, there is Context-Aware Engine based Artificial Intelligence Model (CAEAIM), which is the proposed context recognition system. CAEAIM receives snapshot data from CBDCE and controls learning of artificial intelligence model. The learned artificial intelligence model is used for context recognition processing and predicting information generation. After generation, these context recognition condition and prediction information are used as transition conditions for execution of robot service. And, as the system continues to operate, it controls the accumulated snapshot data to re-learn the artificial intelligence model according to a certain period of time, so that more accurate information can be returned. The components of CAEAIM and methods for generating prediction information are explained in detail in chapter 3.2 below.

3.1.3. Robot service applications based on context-awareness
At the top of figure 1, there is Robot Service Applications based Context-Awareness (RSACA) to provide context-aware robot services. The RSACA can receive intelligence from the CAEAIM with context-aware information or predictive information to control the intelligent robot. In this paper, we propose a workflow execution engine that can execute services described in a CAWL document. CAWL [27] is a context aware workflow language that can express the flow and control of robot services based on context awareness. When the robot service is executed, the RSACA transmits the contents and the execution time of the currently executed robot service to the CBDCE to generate snapshot data for providing a prediction-based service.

3.1.4. Proposed data processing methods
This chapter describes the data processing method of the proposed context-aware system. First, we explain the detailed process of providing snapshot data for learning AI model through big data collection module. The process of transforming the analyzed result of the learned artificial intelligence model into the intuitive situation information is explained in detail.

Figure 2 is a structure diagram to confirm the execution flow of the proposed data processing method. The lower part of figure 2 is a module that collects environmental data around the user, which is necessary for the situation recognition. The sub-collection modules in each area transmit the collected data to the Cloud-based Big Data Collection Engine(CBDCE). The transmitted data is delivered to the Environmental Data Processing Module (EDPM) and stored in the big data store. When the context-aware service is executed in advance, the context-aware service application transmits the label data to the CBDCE, and the label data is collected by the Labeled Data Processing Module(LDPM). Snapshot data accumulated during a certain period is transferred to Training Data Processing Module(TDPM) and Verification Data Processing Module(VDPM) of Context-Aware Engine based on the Artificial Intelligence Model(CAEAIM) is used as the data for learning and verification of the artificial intelligence model. The Context Information Transformation Module (CITM) transforms the analysis results of the AI model into contextual information according to predetermined rules and transmits the result of the context awareness to the context aware service application so that the service can be executed. Below is a description of the process in which the
Snapshot data generated by combining environmental data and label data is used in the learning of the artificial intelligence model and the detailed process in which the analysis result of the artificial intelligence model is converted into the situation information.

**Figure 2. Structure of proposed data processing method.**

Figure 3 shows the process of providing the data for the learning of the artificial intelligence model in the proposed data processing method. In Figure 3, CBDCE is located at the bottom, and EDPM, which is a sub-module of CBDCE, stores current environmental data, and LDPM stores Label data where context-aware service is executed. LDPM sends a signal to SDPM when new label data is input, and SDPM combines the latest EDPM data with LDPM data to generate new snapshot data. The snapshot data is generated by using the latest data when new label data is input, and accumulates for the period specified by the system. Cumulative snapshot data is transferred to CAEAIM's TDPM and VDPM. 80% of the accumulated snapshot data is transferred to TDPM and the remaining 20% of the data is transferred to VDPM. This is to make learning and verification of artificial intelligence model effective, and it can increase the reliability of artificial intelligence learning result. The data of TDPM and VDPM are used for learning of artificial intelligence model, data of TDPM is used for learning, and data of VDPM is used for verification of learning rate. The learning process of artificial intelligence model is conducted by AIMCM and it controls the learning by using criteria such as learning frequency, accuracy and error rate according to the setting of artificial intelligence model.
In this chapter, through the prototype of the context-awareness system based on the artificial intelligence model that implements the proposed method of data processing of the context-awareness system, we show how the situation information is provided using the learning control process of the
artificial intelligence model and how the artificial intelligence model performs.

Figure 4 shows the screen for setting the context-aware system to generate snapshot data of the domain in which the robot is running. The settings allow you to select the data to be included in the snapshot data and control the preprocessing method of each object's Internet data.

Figure 5. Learning result screen of artificial intelligence model.

Figure 5 shows the learning process of the AI model used in the context-awareness system of the intelligent robot. In the experiment, a TensorFlow-based artificial intelligence model is used. Figure 5 shows a TensorBoard that can visually express the learning result of artificial intelligence model. As shown in figure 5, the AI model is continuously increasing the accuracy, and the proposed data processing method can process data that has not been previously learned.

Figure 6. Situational recognition result using artificial intelligence model

Figure 6 shows the result of providing context-awareness information through artificial intelligence model used in context-awareness system. Figure 6 (A), shows the information of the artificial intelligence model running in the context-aware system. The artificial intelligence model is a model that can recognize the risk situation by analyzing the attitude information of the user, and the situation recognition system returns the analysis result of the artificial intelligence model as "NORMAL" or "EMERGENCY". Figure 6 (B), shows the analysis results processed in the AI model. The data used in the experiment is data representing the state of the user's fall, and it can be confirmed that the "EMERGENCY" result is returned from the AI model.

5. Conclusion
In this paper, we have proposed a data processing method to provide context-aware information in context-aware system based on big data to provide intelligent robot services. The proposed data
processing method, makes it possible to generate and accumulate the snapshot data, which combines the data obtained from various IoT devices in an intelligent robot service domain and log data related to service execution. This data is then learned by the RNN based analysis model. As a result, the analysis model of the situational awareness system can maintain consistently high accuracy for new data. The proposed data processing method is able to apply the result of the analysis model, which can be converted into the recognized situational information, for the engine to execute intelligent robot services. In the experiment, we showed how the analysis model learns to detect the user’s fall through the context-aware system with the proposed data processing method. We also verified the effectiveness of the proposed data processing method by using the learned analytical model to improve the accuracy of user fall detection. In the future, we will expand to a data providing framework for various artificial intelligence models.

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