A study on the real-time management and monitoring process for recovery resources using Internet of Things

Sangyun Choe[1], Juhyung Park[2], Sumin Han[3], Jinwoo Park[4], Hyeokjin Yun[5]

[1]Ph.D. Candidate, Dept. of Industrial Engineering, Seoul National University, Seoul, Korea
[2]Master's Candidate, Dept. of Industrial Engineering, Seoul National University, Seoul, Korea
[3]Ph.D. Candidate, Dept. of Industrial Engineering, Seoul National University, Seoul, Korea
[4]Professor, Dept. of Industrial Engineering, Seoul National University, Seoul, Korea
[5]Team leader, Convergence Transportation Technology Research Team, Korea Railroad Research Institute, Uiwang, Korea

---***---

Abstract - *Globally, natural disasters, such as earthquakes, typhoons, and heavy rainfall, are causing damage to water perimetric structures. Traditional response system of disasters is managed inefficiently and it cannot reflect the real situation properly.*

This study suggests real-time process of managing recovery resource and monitoring system using IoT (Internet of Thing) technology. Additionally, we design the classifier of equipment activity that figures out motion and condition of equipment. Eventually we contribute the prompt, efficient and real-time response system of disaster in real situation.

Key Words: Internet of Things, Resource Management, Activity Recognition Model

1. INTRODUCTION

1.1 Natural disaster and Korean disaster response system

Every year, various countries face experience natural disasters, which result in significant amounts of damage. According to the Annual Disaster Statistical Review 2016 (Draft), released by the Center for Research on the Epidemiology of Disasters (CRED) at Louvain Catholic University in Belgium, as of 2016, 102 countries have been hit by a total of 301 natural disasters, resulting in 7628 lives being lost and causing direct or indirect damage that affect 411 million people. The property damage is reported to be as much as US$97 billion (about KRW 118 trillion). In the case of South Korea, according to the Statistical Yearbook of Natural Disaster 2016, by the Ministry of Public Safety and Security, South Korea has had an annual average of 22 casualties and property damage of KRW 525.2 billion for the last 10 years (2006–2015) [1]. In addition, compared with the estimated total damage of KRW 5 trillion, the damage recovery costs are as much as KRW 11 trillion, indicating that recovery incurs more than twice the cost of the damage.

In South Korea, the National Disaster Management System (NDMS) has been established to provide systematic disaster safety service by integrating disaster prevention, preparation, response, and recovery services and 119 services via ICT [2]. The Ministry of Public Safety and Security is playing a leading role in operating NDMS, but the Korea Meteorological Administration, the Ministry of Land, Infrastructure and Transport, the Korea Forest Service, and Korea Environment Corporation are also a part of the system. In addition to the major government offices, NDMS includes 18 fire headquarters, 197 fire stations, and 229 local government offices. It is also connected to personal information systems.

Although NDMS is a very comprehensive disaster management system led by government offices, it still lacks a real-time recovery resources management system and focuses on administrative process rather than real-time management and monitoring.

This paper proposes a real-time monitoring process for response and recovery resources based on the availability and utility of Internet of Things (IoT) technology and devices. Using IoT technology, the proposed method is able to produce meaningful information from collected data. A resource activity recognition process that improves the accuracy of information about the state and operation of equipment obtained through IoT technology at recovery sites is also proposed.

1.2 Related works on disaster response using IoT

During the disaster response stage, employing big data and ICT such as sensor technology, cloud computing, LTE networks, and artificial intelligence would significantly help to produce scientific and objective solutions quickly. These technologies may also enable prediction, thereby improving disaster prevention capabilities. Recently, public awareness about natural disasters has increased in South Korea, and IoT has emerged as a base technology for disaster prevention [3].

Kim (2015) proposed a methodology that applies the technological stability and economy of IoT and big data-based decision making to the process of preventing, preparing for, reacting to, and recovering from disasters. The methodology establishes an effective disaster management system [4].

Lee and Huh (2016) constructed an IoT-based sensor network at a site and implemented real-time monitoring of precursors of earthquake to improve recognition accuracy. Public data about disasters in the region were applied to enhance recognition accuracy for precursors. They also proposed an earthquake prediction analysis platform that provides alerts for earthquakes. The platform performs complex analysis using various types of data to sense earthquake precursors, and the analysis results enable effective earthquake preparation [5].

Choi and Min (2016) proposed an effective method of using the Disaster Resources Sharing System (DRSS) run by the Ministry of Public Safety and Security in which general-purpose ICT is applied to excavators used at recovery sites. The application of ICT using GPS makes it possible to allocate the nearest excavators to a recovery site, and enable more rapid responses to disasters at the initial stage [6].

As exemplified by the studies cited above, much research has been conducted using IoT technology. However, most of the studies do not go beyond utilizing the data collected via IoT technology to predict disasters or simply provide information. Only a few studies have focused on the problems associated with realistic response and recovery after disasters. Further, the use and maintenance of "equipment," which is the most important factor during the response and recovery stages, has not been actively studied. This paper presents a detailed process for applying IoT to real response and recovery work, and proposes a method that actualizes real-time monitoring by using activity recognition modelling of equipment at work sites.

1.3 Problem definition

Existing disaster response systems such as NDMS have various problems that need to be compensated or rectified. Considering response and recovery after a disaster and the necessary resources for recovery work at disaster areas with respect to "real-time management (synchronization)" and "monitoring," several problems are clear. First, there is no system for synchronizing recovery resources. No recovery resources database and no updating system exist. Further, a network of related national organizations is used to manage a limited number of resources.

During recovery work in disaster areas, the communication network is more intensively monitored than "recovery resources." When an unexpected incident is detected, an inordinate amount of time is taken to analyze the situation and take action. There is also no data management system for the equipment used for recovery work, which makes it difficult to monitor the status and operation of the equipment in real time.

This paper focuses on response and recovery resources management after a disaster, and proposes a real-time management and monitoring process for resources based on IoT. The real-time management includes collecting the latest information about individual items of the recovery resource in real time and establishing a database of the resources. The resources information is also updated in real time. As regards monitoring, IoT is utilized to obtain monitor and obtain information in real time and to analyze and rapidly respond to unexpected situations. In addition, a resource activity recognition process that quickly identifies the operational states of resources and monitors the processing rate and reallocation of resources in real time is proposed.

As shown in Fig -1, this proposed approach distinguishes the "resources management process" before disaster and "real-time management and monitoring process" after disaster. A process for utilizing IoT to collect and provide resource-related information is also proposed. In connection with resources monitoring, a resource activity recognition process is designed to manage the recovery process.

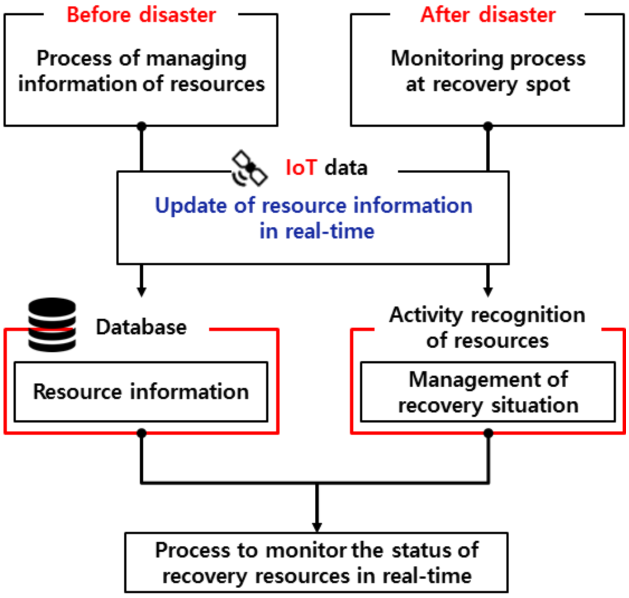

Fig -1: Two main parts of this research area

1.4 Overview of the IoT-based recovery resources management process

This study primarily focused on the scope and mode of application of IoT for recovery resources management during the disaster response phase. For this purpose, with the assumption that a real disaster has occurred, the following practical response process is proposed. The process before disaster is the "resource information management process," in which the database containing basic information about individual resources is updated to the latest state. Following a disaster, the "process of executing a resource allocation plan," in which the real-time status of individual resources is monitored, is applied. Finally, the resource activity recognition process classifies resource activities to improve the accuracy of the IoT information at recovery sites and to support the monitoring system. These three processes comprise the overall process of real-time management of recovery resource information.

2. Updating process for recovery resource information

2.1 Resource information management process before disaster

When a disaster occurs, recovery resources are deployed to disaster areas. Specifically, for initial reaction or emergency recovery while the disaster is unfolding, necessary recovery resources need to be drafted and allocated quickly. Therefore, it is necessary to collect and sufficiently manage the resources information before disasters occur. Fig -2 presents the resource information management process followed before disasters.

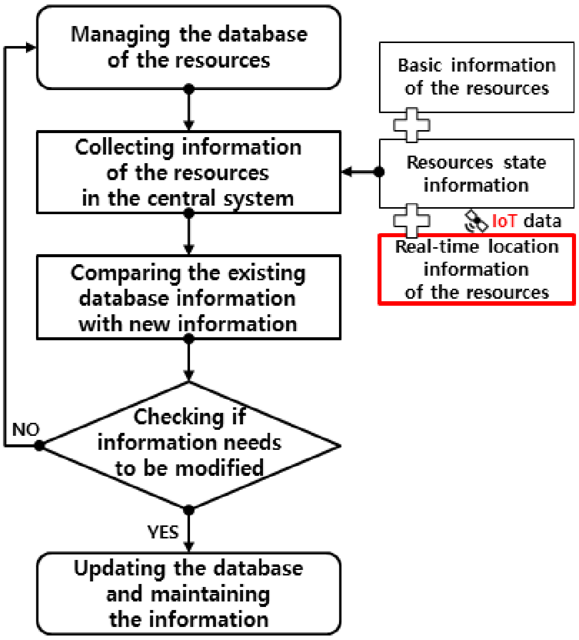

Fig -2: Resource information management process

Initially, the recovery resources information is managed in the central database system. New information on the status of resources is collected once a week or at regular intervals. In addition to basic information such as "item," "type," "management company," "person in charge," and "phone number," real-time information such as "status," "location (address)," and "stock at each location" should be sufficiently collected. Resource status is very important information that indicates availability or abnormality of resources. The availability of resources should be frequently checked and recorded. In particular, after a resource is used, it should be inspected without failure to ensure that no abnormality will occur during subsequent use.

The location of resources is also important because it is directly related to time and distance, which are decision-making factors in the allocation of resources to disaster areas. This information uses IoT technology as GPS and is recorded with a final location coordinate and an address, which need to be collected in real time whenever a resource is used. If multiple resources are located in the same address, those resources need to be itemized in order to facilitate more efficient decision making on resource allocation. For example, if four backhoes are required for recovery work, selecting four backhoes at the same location is more efficient for managing movement of real resources than selecting four backhoes from different locations but at the same distance apart.

When new resource information is collected, it should be compared with the existing information in the database to check whether any modification is necessary. In case modification is needed, the existing database information is updated and maintained with the latest follow-ups, thereby synchronizing resource information.

2.2 Monitoring the status of recovery resources

When a disaster occurs and urgent recovery is required, adequate resources should be searched for and retrieved quickly through the resource management database mentioned above. Further, real-time checks should be performed to determine whether the drafted resources have been move to their allocated disaster area. In addition, it should be determined whether the recovery work is proceeding smoothly after the resources arrive in the area.

When a disaster occurs, the latest resource database information, which is maintained by the central system, should be searched for necessary resources in the vicinity of the disaster area. After the resources are selected, resource evaluation is performed to choose the most suitable ones and an allocation algorithm is executed. An allocation plan is produced based on the results of the algorithm. When the central system has called the actual resources by using IoT technology based on the allocation plan, the status of the resources is ascertained by collecting information in real time. If an unexpected situation occurs, the corresponding response scenario is implemented [7].

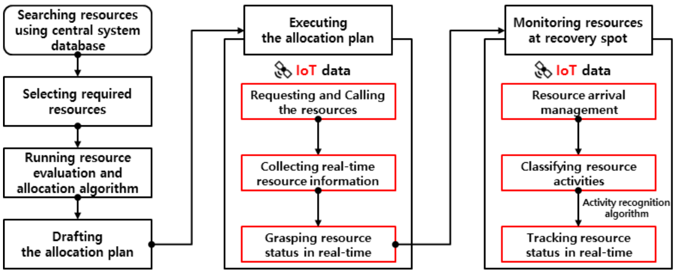

Fig -3: Process for monitoring recovery resources

In the next step, checks are made to ascertain whether the resources have arrived at the recovery work site. Once the work starts, the resource activity recognition algorithm is executed to observe the recovery work process. In this way, the status of the resources is monitored in real time. Fig -3 illustrates the monitoring process for recovery resources after disaster. The application of IoT technology to each process is examined in the next section.

3. Real-time management of resource information using IoT

3.1 Application of IoT for resource status monitoring

If urgent recovery work is carried out while a disaster is still unfolding, real-time management of recovery resources can make recovery work effective. IoT technology can synchronize resource information as it updates the information in real time. This section analyzes in detail the process of applying IoT technology to real-time management of resources when a resource allocation plan is executed after a disaster.

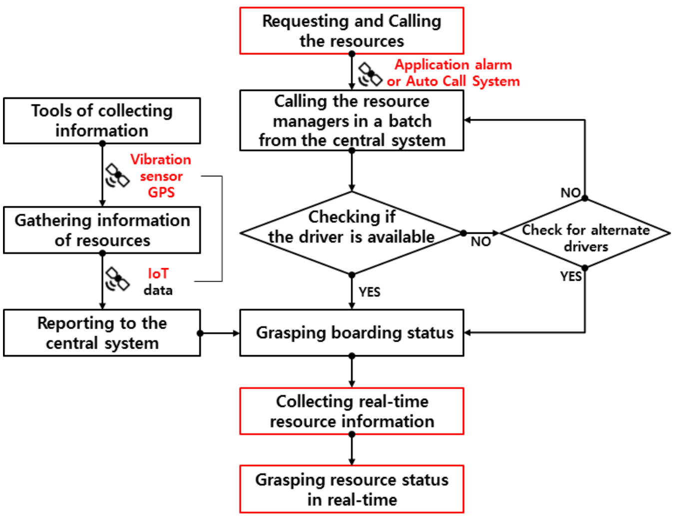

Fig -4: Internet of Things application process for resource status monitoring

The first step is to request and allocate real resources. As Fig -4 shows, the central system sends notifications to operators or field staff through the auto call system (ACS) or via smartphone applications. The operators then check the availability of their resources. If possible, the operational readiness of the resources is also checked. In this scenario, the resources are assumed to be heavy equipment; therefore, it should also be ascertained whether the operator is sitting in his/her seat. If the operator is sitting in the seat, the resource can be regarded as ready to use. A vibration sensor and GPS are used to identify whether the operator's seat is occupied. When the operator starts the ignition, the sensor identifies the vibration generated by the startup and determines the mode of GPS operation. Subsequently, when the resource starts moving, a network access point using GPS and mobile communication and an acceleration sensor collect “movement,” “location,” “distance traveled,” “velocity,” and “remaining time and distance to destination” information. In this way, the status of the resources is monitored in real time.

3.2 Resource status monitoring at recovery site

Resource arrival management should be conducted to make all the necessary resources arrive at the disaster area or recovery site. Lack of any necessary resource makes it impossible to complete the recovery work. The ratio of arrived resources to all the necessary resources is calculated as the “resource arrival rate,” which can contribute to the smooth preparation of recovery work. The resource arrival management can be conducted naturally with the help of GPS and a network access point.

4. Recovery resource activity recognition

4.1 Necessity and effect of resource activity recognition

In cases where emergency recovery is needed, rapid recovery is impossible without rigorous management of recovery resources. Productivity may be increased by reducing idle time or the number of unnecessary operations as much as possible. If idle resources are identified, a quick decision needs to be made on whether they can be used for other recovery work. Thus, it is very important to identify and manage the resource activity. However, directly observing every single resource during a disaster situation is difficult. If a supervisor had to check and identify the location and status of every recovery resource with his/her own eyes, the process would be very difficult, dangerous, and time consuming. Consequently, technology that identifies various equipment activities in real time is needed.

Resource activity can be monitored through IoT technology. However, detailed classification of such activities is not possible using data solely from IoT. In disaster situations, in particular, sensor data may be missing or inaccurate, and it may not be possible to identify various activities reflecting the characteristics of equipment. For instance, with mere sensor data, only movement and the stopping of an excavator can be distinguished, other activities such as scooping or dumping soil and rotating cannot be identified. For this reason, resource activity recognition is needed to ascertain the various activities being carried out by the equipment. If a resource activity recognition process is implemented, the length of time consumed by resource activities can be measured and the actual time for recovery work calculated. Calculation of the actual working time of the resources should give the operation rate of the resources. In addition, if the workload of the necessary resources can be estimated in the resource allocation plan, the process rate can also be determined. Thus, a resource activity recognition process contributes not only to recovery site monitoring but also to construction quality management and calculation of stocks and recovery cost.

4.2 Resource activity recognition classifier

A trained resource activity recognition classifier is the most important factor in the resource activity recognition process. To make such a classifier, sufficient data associated with each activity of a specific resource need to be collected as supervised learning.

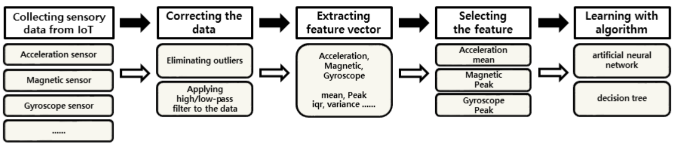

Fig -5: Process for classifier of resource activity

For data collection, IoT technologies such as acceleration sensor, gyroscope sensor, magnetic sensor, orientation sensor, and rotation sensor are used. However, the data collected from sensors may be different from real activities. For example, the output velocity of the acceleration sensor is slower than that of the real activity. In order to compensate for this, outliers are eliminated and a high/low pass filter is applied. Subsequently, the features of each dataset are extracted. Such features include mean value, maximum or peak value, quartile, variance, and standard variation for each type of sensor. After adequate features are chosen, an activity recognition algorithm such as decision tree or artificial neural network is implemented for the learning of those features. The classifier is complete after learning through such an algorithm. Fig -5 shows the process involved in creating a resource activity recognition classifier.

Let us now look at the process of completing an activity recognition classifier for an excavator. Table -1 classifies the activities of an excavator and presents descriptions.

Table -1: Activities of excavator

Activities	**Description**
Idle	waiting state for next work or Inactive state with start-up
Moving	just going state
Scooping Up	A state of excavating something
Turning	Rotating state
Dumping	A state of putting down something

Data associated with these activities are collected by smartphones or terminals containing various sensor technologies. Table -2 presents activity data that can be collected by each sensor. As resource activities are not effectively classified by only one type of sensor data, collecting data through a combination of multiple types of sensors is a much more effective method.

Table -2: Sensors for activity data

Sensors	**Activities**
Acceleration	Idle, Moving
Gyroscope	Scooping up, Dumping up
Rotation	Turning
Orientation	Scooping up, Dumping up
Magnetic	Turning

Following data collection, features such as maximum and mean value are set and then a machine learning algorithm such as decision tree is used to complete the classifier. Studies have shown that such a classifier has an accuracy of approximately 80% [8]. On the other hand, Ruan et al. (2016) argue that more than 95% of complicated human behaviors can be distinguished through sensors embedded in a smartphone. Therefore, if sufficient data are given and the associated algorithm is improved, the accuracy would be close to that of human eyes [9].

4.3 Resource activity recognition process and construction

When a classifier that recognizes resource activity automatically is completed, it can be deployed to the recovery site for real-time resource activity monitoring.

As shown in Fig -6, if the data obtained from various types of sensors are input into a trained classifier, the activity of the current resource can be identified. Then, when the results of identification are conveyed to the central system, the work process of each resource can be monitored in real time. At this final step, both real-time management and monitoring for recovery resources are accomplished.

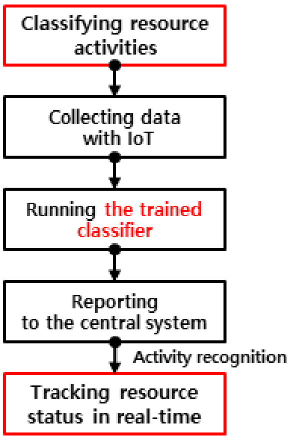

Fig -6: Process for resource status monitoring with trained classifier

5. CONCLUSIONS

In this study, two types of IoT-based recovery resource management processes were designed. The first is a resource information management process that is implemented before disasters. The entire process, from collection of basic resource information by the control center to updating the database of recovery resources, is based on IoT data. The second is a real-time management and monitoring process for resources that is implemented following disasters. In this case, the IoT data flow starts from the establishment of a resource allocation plan and information on the work process at recovery sites is collated. Finally, a resource activity recognition process was proposed for recovery sites. In this process, the state and activity of recovery equipment are identified, thereby supporting the onsite monitoring.

The IoT data-based real-time response process proposed in this paper can be applied to real disaster situations and provides information about resource status and onsite situations more quickly than conventional systems. As the overall status and situation of resources, which are the most important factor for recovery, can be monitored and managed by the proposed process, when this process is applied to emergency recovery sites, it is expected that the challenges associated with conventional disaster response systems will be overcome.

The resource activity recognition process will be improved and experiments will be carried out to classify the activities of various pieces of equipment in more detail in further studies. In addition, simulations or field verifications that assume the occurrence of a disaster will be conducted to evaluate the performance of the overall process.

ACKNOWLEDGEMENT

This work was supported by a grant from the Construction Technology Research Project funded by the Ministry of Land, Infrastructure, and Transport/Korea Agency for Infrastructure Technology Advancement (0418-20160023).

REFERENCES

[1] Ministry of Public Safety and Security, 2015 Disaster Annual Report, 2016.

[2] Ministry of Public Safety and Security, SAFE KOREA (National Disaster Management System), 2014.

[3] Kang, H.J., Smart Disaster Safety Management Utilizing IoT and Big Data, Proceedings of KIIT Summer Conference, 2016, pp. 85-87.

[4] Kim, Y.H., Disaster Management Using Big Data in the IoT Environment, Proceedings of KIIT Summer Conference, 2015, pp. 287-289.

[5] Lee, J.S., Huh, E.N., An Analytics Platform for Earthquake Prediction Using IoT and Disaster Data, Dept. Computer Science and Engineering, Proceedings of Symposium of the Korean Institute of communications and Information Sciences, 2016, pp. 1101-1102.

[6] Choi, W.J., Min, S.H., A Study on Application of ICT for Excavator of Disaster Management Resources for Emergency Recovery Support, Journal of Korean Society of Hazard Mitigation. Vol. 16, No. 5, 2016, pp. 157-161.

[7] Hwang, G.S, Han, S.M., Choe, S.Y, Hwang, C.H., Park, J.W., and Yun, H.J., Development of the Response System for Disaster Recovery Action Plan Using Internet of Things, Journal of Korean Society of Hazard Mitigation, Vol. 16, No. 2, 2016, pp. 315-323.

[8] Akhavian, R., Behzadan, A.H., Construction equipment activity recognition for simulation input modeling using mobile sensors and machine learning classifiers, Advanced Engineering Informatics, Vol. 29, No. 4, 2015, pp. 867-877.

[9] Ruan, W., Chea, L., Sheng, Q. Z., Yao, L., Recognizing Daily Living Activity Using Embedded Sensors in Smartphones: A Data-Driven Approach. In Advanced Data Mining and Applications: 12th International Conference, ADMA 2016, Gold Coast, QLD, Australia, December 12-15, 2016, Proceedings 12, 2016, pp. 250-265.