

# 추론엔진 JESS를 활용한 모바일 작업환경 모니터링 시스템의 연구

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## 요약

유해 작업환경에서의 근무는 작업 능률 저하 및 각종 직업병의 발생을 유발한다. 따라서 근로자의 산업재해예방 및 쾌적한 근로 환경 조성을 위해서는 위험으로부터 작업자의 안전을 감시할 수 있는 시스템이 필요하다. 이 논문에서는 추론엔진 JESS를 활용하여 모바일 기기에서 작업환경 모니터링 정보를 확인할 수 있는 시스템을 설계한다. 제안 시스템은 OSGi 기반의 프레임워크에 적용 가능하도록 JESS와 JAVA를 연동한 모니터링 인터페이스를 구현한다. 아울러 모바일 기기를 통해 작업자에게 위험 상황에 대한 즉각적인 경보를 제공한다. 제안 시스템은 특정 컴퓨팅 플랫폼에 제약되지 않으며 OSGi 기반의 미들웨어와 연동이 쉬운 장점을 가진다.

## A Study of a Mobile Work Environment Monitoring System Using Inference Engine 'JESS'

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## ABSTRACT

A detrimental work environment causes a decline in work efficiency and contributes to various occupational diseases. To prevent occupational disasters and build a pleasant work environment, it is necessary to develop a monitoring system to keep operators safe from the hazards. This paper proposes a system that makes it possible to monitor a work environment using a mobile device, an inference engine called 'JESS.' The proposed system implements a monitoring interface in which JESS and JAVA are interlocked to make it applicable to the Open Service Gateway Interface (OSGi)-based framework. A dangerous situation can be reported immediately to operators through the mobile device. The system mentioned in this paper is not constrained to a particular computer platform and can be easily interlocked with OSGi-based middleware.

Key Words : Inference Engine, JESS, Harmful Environment, Mobile Interface, Rule Base

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## I. Introduction

A detrimental work environment often causes a decline in work efficiency and various occupational diseases. To prevent occupational disasters while maintaining a pleasant work environment, it is necessary to develop a system which monitors the work environment and application services on a realtime basis. Work environments need to be monitored in workplaces where workers' uses of and exposures to hazardous materials exist. In these locations, it is necessary to minimize workers' exposure to a hazard with a realtime monitoring system.

The system should provide a mobile service environment for users in a USN environment and guarantee intelligent service functions. It should be integrated into a context-aware system that develops high-level from low-level contexts through integration, inference, and learning, in order to adapt itself to its surroundings which constantly change in a ubiquitous environment. Several context-aware systems have been developed for these computing environments [1].

A variety of practical studies must be performed on application services designed to freely provide context-aware services in USN environments. It is necessary to use middleware that can be developed in an OSGi-based framework. It is important to design a USN-based context-aware application service model in a USN environment.

This paper proposes a system in which work environment monitoring information can be monitored using a mobile device, the inference engine 'JESS.' The structure of a mobile work

environment monitoring system is designed first. Then, the knowledge base of hazardous work environment information which would be stored in JESS is defined. Finally, a virtual interface is developed and implemented. This paper implements JESS and a JAVA-interlocked monitoring interface that can be applicable to the OSGi-based framework.

## II. Related Studies

The context-aware service is based on middleware. The context-aware system creates context from sensors. The context-aware service must be clearly aware of the significance of different context information [1, 2].

A context can be defined as a user's emotional state, attention, location-direction, date-time and person-object in an environment in which he/she stays. It is defined depending on whether or not the attributes collected from sensors are included in a particular area. Therefore, a system should have a method in which a context can be decided using the raw data from sensors [3]. To provide optimum services to users, the context-aware middleware should be able to create and handle a variety of context information through integration, inference and learning [4, 5].

The OSGi service platform has implemented OSGi specifications under different devices and operating systems based on Java virtual machine. It offers basic service management functions and guarantees multi-leveled system security. It also supports various service hosting functions which are provided from different suppliers in a single gateway platform [6, 7].

The context-aware recommendation service which is based on open context-aware service architecture consists of an OSGi framework, a context provider and a context-aware application. The OSGi framework-based open architecture is comprised of service bundles, an inference engine which makes a prediction using the contexts and knowledge base in which data are stored and managed. Useful information is recommended to users through modeling, conversion and inference of contexts [8, 9].

Hazardous workplaces (ex: a manhole, septic tank, storage tank, sealed space, etc.) are exposed to health problems and serious hazards such as fire and explosion. Therefore, it is necessary to establish a system which monitors hazardous environmental information on a realtime basis and helps ensure workers are safe from hazards [10, 11, 12].

### III. Mobile Work Environment Monitoring System

A mobile work environment monitoring system targeted to monitor hazardous work environment is designed in this paper. The structure of the proposed system is shown in Figure 1 below.

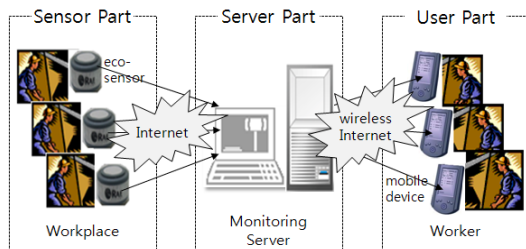


그림 1. 모니터링 시스템의 구조  
Fig. 1. Structure of the Monitoring System

Under this system, context awareness is enabled based on JESS, a rule-based inference engine. The system is not constrained to particular computing platforms and can be easily interlocked with OSGi-based middleware.

The sensor area in Figure 1 collects and transfers data using an environmental sensor module.

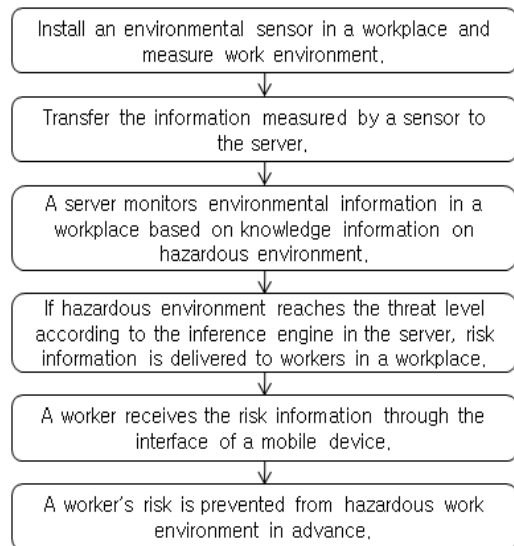


그림 2. 시스템의 기능 및 동작  
Fig. 2. System functions and operations

Figure 2 shows system functions and operations. An environmental sensor can measure work environment on a realtime basis and position its location. It can also alarm hazardous factors and automatically calibrate sensor values.

A server is divided into two modules: a module which receives sensed data and a module that controls the application data. The status of the work environment is monitored in an application service interface. Workers can check hazardous information from the server using a mobile device.

### 3.1 Monitoring Server

A system component developed on a rule-based inference engine is designed on a server. Therefore, the system contains an inference engine structure in which whether a work environment is dangerous is decided on the basis of hazardous environmental information provided from sensors in a workplace on a realtime basis.

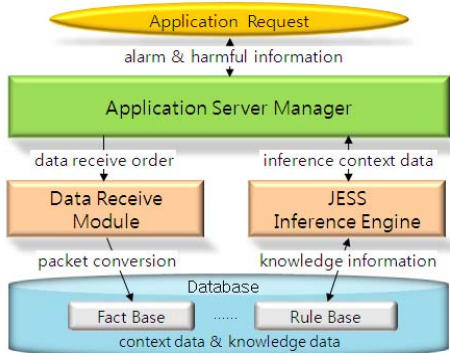


그림 3. JESS 기반의 모니터링 서버  
Fig. 3. JESS-based Monitoring Server

Figure 3 shows the structure of a server that monitors hazardous environment data in a workplace. A monitoring server module governs the operation of the entire system. It collects sensing data in a workplace and stores it in the knowledge base. It also monitors hazardous environmental data through an inference engine for realtime application services. If a dangerous situation is detected, the information is delivered through the mobile device in a workplace.

### 3.2 Hazardous Work Environment Information

A sealed workplace is exposed to health problems

and serious hazards such as fire and explosions with limited exits. In addition, it often has a lack of ventilation [13]. The following examines the impact of oxygen, hydrogen sulfide and carbon dioxide on health under this kind of work environment.

표 1. 산소 결핍이 인체에 미치는 영향  
Table 1. Impact of Oxygen Deficiency on Human Body

O <sub>2</sub> (%)	Effect
21	Oxygen concentration level in normal atmosphere
17	Difficulty in breathing, increased pulse, headache, nausea, candles will go out
12	Dizziness, vomiting and substantially weakening grip strength Risk of falling from a ladder
8	Loss of consciousness (death occurs in eight minutes)
4	Loss of consciousness within 40 seconds

Hydrogen sulfide smells like rotten eggs. It may possibly occur in sludge deposit. Even though the H<sub>2</sub>S levels in a tank are below 10ppm while you clean up the tank, the figures may increase up to 100-200ppm if you step on the mud on the bottom. In this case, you need to increase ventilation and put on protective equipment such as breathing apparatus and an oxygen mask [14]. The impact of H<sub>2</sub>S on health is shown in Table 2 below:

표 2. 황화수소가 인체에 미치는 영향  
Table 2. Impact of H<sub>2</sub>S on the Human Body

H <sub>2</sub> S(ppm)	Effect
3	Severe bad smell
80~120	Mild symptoms; endurable for about 6 hours
200~300	Smell is as mild as in a low concentration, but strong pain in eyes, nose and throat occurs in 5-8 minutes Endurable for 30-60 minutes
500~700	Inhalation for about 30 minutes can cause semi-acute intoxication
1,000~1,500	Acute intoxication, unconsciousness and death

Carbon dioxide (CO<sub>2</sub>) is common in the atmosphere. However, it is very dangerous if we breathe highly concentrated CO<sub>2</sub> in a sealed space. Despite low toxicity, it can cause a severe headache if its concentration increases. If one is exposed to the gas for a long time, he or she could die of a breathing difficulty [15]. Table 3 below briefly reveals the impact of CO<sub>2</sub> on the human body.

표 3. 이산화탄소가 인체에 미치는 영향  
Table 3. Impact of CO<sub>2</sub> on the Human Body

CO <sub>2</sub> (ppm)	Effect
6,000(6%)	Inhalation for 30 minutes can cause breathing problems, drowsiness and headaches.
100,000(10%)	Narcolepsy, dizziness and unconsciousness
250,000(25%)	Death

표 4. 템플릿의 정의  
Table 4. Definition of template

```
(deftemplate MAIN::status
  (slot search-depth) (slot parent)
  (multislot ochc2) (slot last-move))
(deffacts MAIN::initial-positions
  (status (search-depth 1) (parent root)
  (ochc2 (get_o2) (get_co2) (get_h2s)
  (get_co)) (last-move no-move)))
(defmodule SOLUTION)
(deftemplate SOLUTION::moves
  (slot id) (multislot moves-list))
```

### 3.3 JESS-based Inference Engine

#### 3.3.1 Knowledge Base

The knowledge base is comprised of rules and facts. The former refers to information on the rules that are executed in the inference engine of JESS. The latter is context information, i.e. facts that are stored in the working memory of inference engine. In JESS, template information is similar to the JAVA class declaration.

Table 4 defines a template designed to develop knowledge information on hazardous gases. Facts are stored in the working memory while the inference engine controls all context information associated with inference based on the facts. Facts that have been created with the duplicate function are stored in 'Slot Parent'. An order of rule execution and debugging criteria are determined. Several lists such as oxygen, H<sub>2</sub>S and carbon monoxide values can be stored in the 'multislot'.

#### 3.3.2 Inference Rule

Rule information is set to induce a conclusion through the inference process based on facts. The rules are defined using 'defrule' keywords. The rules defined in the Table 5 below are used to check whether or not a work environment is safe. If JESS is used, a JAVA program which is inferred based on rules can be prepared. JESS offers a method to send and receive the values between the system control module and the JESS engine via functions.

표 5. 추론 규칙의 예  
Table 5. Example of Inference Rules

Rule name	Contents
RULE-1	?node <- (status (search-depth ?num) (ochc2 ?o2&&(and (< ?o2 90) (> ?o2 75)) ?co2&& (< ?co2 25) ?h2s&&(< ?h2s 30) ?co&&(< ?co 30))) => (duplicate ?node (search-depth (+ 1 ?num)) (parent ?node) (ochc2 (- ?o2 ?*pp*) (+ ?co2 ?*pp*) ?h2s ?co) (last-move RULE-1))
RULE-2	?node <- (status (search-depth ?num) (ochc2 ?o2&&(and (< ?o2 65) (> ?o2 45)) ?co2&& (< ?co2 55) ?h2s&&(< ?h2s 50) ?co&&(< ?co 50))) => (duplicate ?node (search-depth (+ 1 ?num)) (parent ?node) (ochc2 (- ?o2 ?*pp*) (+ ?co2 ?*pp*) ?h2s ?co) (last-move RULE-2))
RULE-3	?node <- (status (search-depth ?num) (ochc2 ?o2&&(and (< ?o2 25) (>= ?o2 0)) ?co2&&(<= ?co2 100) ?h2s&&(< ?h2s 60) ?co&&(< ?co 60))) => (duplicate ?node (search-depth (+ 1 ?num)) (parent ?node) (ochc2 (- ?o2 ?*pp*) (+ ?co2 ?*pp*) ?h2s ?co) (last-move RULE-3))

표 6. 샘플 함수의 예  
Table 6. Example of Sample Function

Name	Contents
get_o2()	(bind ?din (file_read)) (bind ?o2 (call ?din readInt)) (return ?o2)
get_co2()	(bind ?din (file_read)) (bind ?co2 0) (for (bind ?i 0) (< ?i 2) (++ ?i) (bind ?co2 (call ?din readInt))) (return ?co2)
get_h2s()	(bind ?din (file_read)) (bind ?h2s 0) (for (bind ?i 0) (< ?i 3) (++ ?i) (bind ?h2s (call ?din readInt))) (return ?h2s)

Table 6 describes the functions that are used to bring external sensing data (oxygen, carbon dioxide, H<sub>2</sub>S and carbon monoxide values) that are necessary in JESS. In a JESS-based inference engine, functions

are defined using 'deffunction'. The defined function titles include get\_o2(), get\_co2(), get\_h2s() and get\_co(). Each function transmits oxygen, carbon dioxide, H<sub>2</sub>S and carbon monoxide values which are measured and transmitted on a realtime basis to the inference engine.

#### IV. Monitoring Interface

The application service interface for server control implements JAVA in order to interlock with JESS. A mobile service interface is implemented in a window mobile environment in order to make it possible to provide service using PDA or a smart phone.

##### 4.1 Interface for Server Control

An eco-sensor detects oxygen, carbon dioxide, H<sub>2</sub>S, carbon monoxide, organic compound, ammonia and sulfur dioxide levels in a hazardous workplace such as a manhole, septic tank, storage tank and a sealed space. An inference engine infers a danger based on the related rules using the information on oxygen, carbon dioxide and H<sub>2</sub>S from sensors and transmits the results.

Figure 4 identifies a user interface page for server control. A server manager sets the information on the workplace which is being monitored. In the Data Packet page, available pure packet information is provided from sensors. The received packet data are processed in working memory through the inference engine after being classified and then stored in the database.

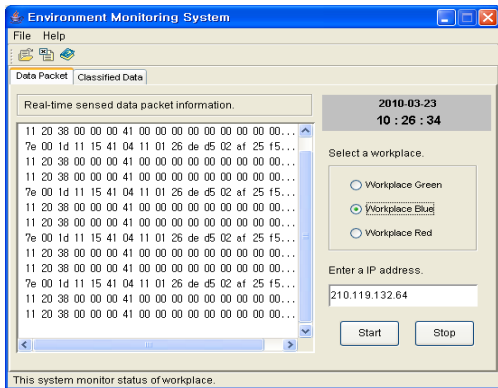


그림 4. 사용자 화면 페이지  
Fig. 4. User Interface Page

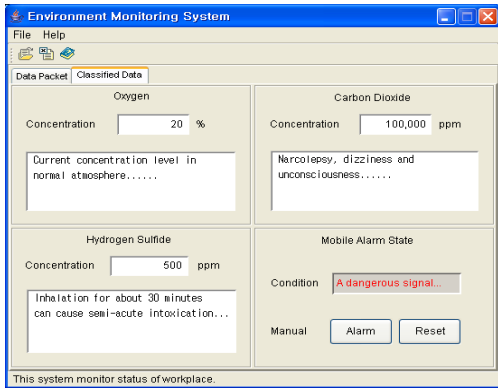


그림 5. 작업장 모니터링 페이지  
Fig. 5. Workplace Monitoring Page

Figure 5 illustrates a workplace monitoring page. The Classified Data page displays oxygen, carbon dioxide and H<sub>2</sub>S levels and related information on the hazard. The workplace interface creates objects that are necessary for the inference of a knowledge base, and performs the monitoring process. The monitoring interface, on the other hand, shows current workplace status using the information which is updated on a realtime basis. If a hazardous factor is detected, an alarm goes off, and a danger message appears on the screen.

## 4.2 Mobile Service Interface

To get mobile services, a user first needs to select a monitoring server or check the network status.

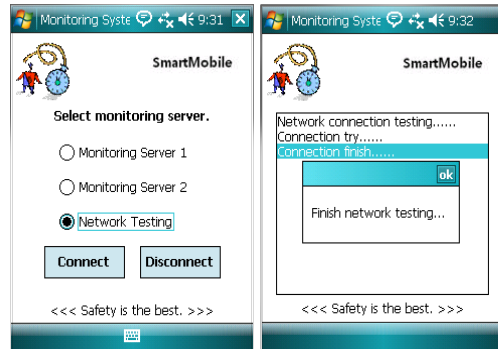


그림 6. 모니터링 서버와의 네트워크 테스트  
Fig. 6. Test on the Network with Monitoring Server

As shown in Figure 6, a user should check the current network status. If it is operating normally, he/she can obtain the mobile monitoring service. If the network is inactive, the service may not be available. Therefore, technical aspects on the use of the network must be considered in the implementation stage.

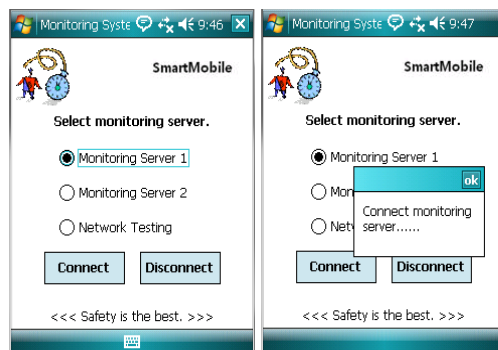


그림 7. 모니터링 서버에 접속  
Fig. 7. Access to Monitoring Server

Figure 7 illustrates a user's access to the monitoring server. A case in which two servers are operated for the smooth operation of monitoring service is introduced in this figure. In the server implementation stage, the policy and technical aspects on the operation of backup server must be considered.

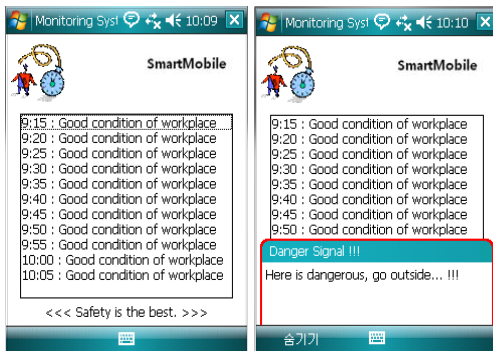


그림 8. 모니터링 서버에서 받은 위험 메시지 및 경고  
Fig. 8. Danger Message and Alarm Received from Monitoring Server

Figure 8 reveals monitored realtime context information on the mobile device. If a danger is detected in the monitoring server, danger message along with alarm appears on a user's mobile interface. An alarm processing can be differently implemented depending on the technical characteristics of a mobile device.

## V. Conclusion

This paper proposed a system that makes it possible to check work environment monitoring information using a mobile device inference engine called 'JESS.' For this, the structure of a JESS-based

mobile work environment monitoring system was described. A knowledge base on hazardous work environment information that would be stored in JESS was identified. Lastly, a virtual interface which could be developed has been implemented. A JESS and JAVA-interlocked monitoring interface applicable to the OSGi-based framework has been proposed.

The proposed system could be used for the development of an open context-aware framework in which JESS and JAVA are interlocked in mobile environment. In addition, it could be very useful for controlling contexts that are used in various ubiquitous application services such as mobile context-aware systems, home network systems, context-aware recommendation systems and LBS systems.

Requirements shown in this paper can be applied to buried structure and related industries in advance of system development. Development of a prototype is appropriate. One that can be applicable to various sectors associated with the management of buried structures such as electric and communication construction industries.

## References

- [1] A. Harter, A. Hoper, P. Steggle, A. Ward, and Paul Webster, "The Anatomy of a Context-aware Application", *Journal of Wireless Networks*, vol. 8, pp.187-197, 2001.
- [2] D. I. Ahn, C. S. Shin, and S. C. Joo, "Context Information Supporting System Based on Indoor Location for Healthcare Home Service", *Proceedings of Korean Information Science Society Conference*, Vol. 33, No. 1(D), pp.64-66, 2006.
- [3] J. Farrington, A. J. Moore, N. Tilbury, J. Chru, and P. D. Biemond, "Wearable Sensor Badge & Sensor Jacket for Context

Awareness", *Proceedings of the 3rd International Symposium on Wearable Computers*, pp.107-113, 1999.

[4] N. Priyantha, A. Chakraborty, and H. Balakrishnan, "The Cricket Location-Support System", *Proceedings of the 6th ACM International Conference on Mobile Computing and Networking*, pp.32-43, 2000.

[5] J. A. Lee, S. H. Lim, J. H. Kim, and W. D. Cho, "Design and Implementation of Monitoring System on Context-aware Middleware In Ubiquitous Environment", *Proceedings of Korea Computer Congress*, Vol. 34, No. 1(B), pp.249-254, 2007.

[6] Y. A. Ahn and J. S. Park, "Design of Location Based Service Manager in Open Context Awareness Architecture", *Proceedings of Korea Multimedia Society*, Vol. 11, pp.138-141, 2008.

[7] OSGi Alliance, "Open Service Gateway Initiative", <http://www.osgi.org>, 2010.

[8] D. J. Kim and J. H. Kwon, "Design of Recommendation Service in Open Context-aware Service Architecture", *Proceedings of Korea Computer Congress*, Vol. 33, No. 1(C), pp.19-21, 2006.

[9] M. H. Ahn, D. H. Kim, and J. H. Kwon, "Design and Implementation of OSGi-based Context-aware Service Architecture in Ubiquitous Environment", *Proceedings of Korea Computer Congress*, Vol. 33, No. 1(C), pp.16-18, 2006.

[10] J. M. Yun and P. Park, "User-Centered Design of Workplace Environment Monitoring Service using IP-USN", *Proceedings of Korea Society of IT Service*, pp.266-271, 2008.

[11] Y. A. Ahn, "Context Awareness Inference Engine for Location Based Applications", *Proceedings of International Conference on Convergence and Hybrid Information Technology*, pp.213-216, 2009.

[12] Y. A. Ahn, "Design of Rule-based Inference Engine for the Monitoring of Harmful Environments in Workplace", *Journal of the Korea Industrial Information Systems Research*, Vol. 14, No. 4, pp.65-74, 2009.

[13] D. H. Han and J. H. Lee, *New Occupational Hygiene Management*, Dong-Hwa Technology Publishing, pp.161-163, 2007.

[14] G. M. Ryu, H. H. Park, and G. J. Jeong, "Study of Cause and Prevention for Asphyxia Disaster in the Enclosed Geometry", *National Institute for Occupational Safety and Health*, Research Report 2008-140-1477, pp.72-76, 2008.

[15] B. S. Son, J. A. Park, B. G. Jang, T. W. Jeong, W. H. Yang, G. J. Kim, B. H. Lee, N. Y. Cho, S. B. Choi, and C. N. Gho, *New Environment Science*, Dong-Hwa Technology Publishing, pp.161-162, 2006.



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