

# Instructional Information System using AR Technology for Chemical Plants

Atsuko Nakai, Kazuhiko Suzuki

Center for Safe and Disaster-Resistant Society, Okayama University  
Tsushima-naka 3-1-1, Kita-ku, Okayama, 700-8530, JAPAN  
[fumoto@safelab.sys.okayama-u.ac.jp](mailto:fumoto@safelab.sys.okayama-u.ac.jp)

Recently, industrial accidents have been showing an increasing trend, especially in the Japanese chemical industrial complex. A lack of safety awareness and safety knowledge as well as insufficient safety ethics are factors in these accidents. In addition, industrial technology has become highly diversified and complicated, making it difficult for operators grasp the overall situation in emergencies. This paper shows that augmented reality (AR) and image recognition technology can provide field operators with the information they need during emergencies. Chemical plant operators must make quick decisions to prevent accident expansion. This study considers the human factors, such as misjudgement and miscommunication, of accident response as well as how accidents often occur in non-steady-state operations. At the time of an accident or disaster, emergency response operation is needed. To accurately convey information about the work, it is useful to recognize information by vision in addition to the output information by sound. The developed system can recognize the operation's target device and show the working procedures. It can help chemical plant operators to make quick decisions and follow correct operating procedures without error. This system could be a part of a chemical plant's safety training.

## 1. Introduction

Improving the safety and reliability of chemical plants is essential to ensure a safe environment for workers and local residents. Consequently, a number of safety activities, countermeasures, and assessment techniques have been proposed. We need a way to detect potential risks before an accident or disaster occurs (Pasman & Knegtering, 2013). In addition, a safe process is necessary to prevent human error. Quality control issues for software and hardware increase as the economic situation changes. (Nakai et al., 2014). In a chemical plant, operators must handle their own areas to ensure the safe operation of all plant components. There are two types of operators—field operators and board operators. Field operators are responsible for operating equipment in the field. Board operators control refineries from a control room. To achieve a smooth operation, field operators and board operators should work in cooperation. (Nakai et al., 2014).

Human judgment and communication errors often cause accidents. Accidents also often occur in non-steady-state operations (Suzuki, et al. 2013), which are situations in work procedures and chemical plant conditions that change with time (e.g., start-up, shutdown, and emergency response operations). When an accident or disaster occurs, emergency response operators must make quick, accurate decisions despite the high pressure on them during the situation (Nakai et al., 2013).

At present, operational guidelines and procedures have not been fully developed. Accurate judgments and the corresponding operational steps are very important to prevent the accident from escalating (Suzuki et al., 2013). However, opportunities for the young operator to receive safety education and training have decreased in recent years. We are concerned that workers' flexible response capabilities also have been reduced with the retirement of skilled workers.

In this study, we developed a system to provide instructional information for field operators by using augmented reality (AR) and image recognition technology in chemical plants. AR can enhance real-world environments by using virtual objects, such as computer graphics (Jürgen, 2013). The system can distinguish between operation target equipment and others by image recognition techniques based on the SURF

(speeded-up robust features) algorithm (Bay et al., 2006). Using the SURF algorithm, the training system developed for chemical plant. (Yating et al., 2015) Field operators can confirm the required operation procedures in the field. Furthermore, the operator can recognize the proper operating equipment by using a camera-equipped mobile tablet. Our system was designed to support chemical plant operators in making quick decisions and in taking the correct operating steps. The developed system's concept is shown in Figure 1. To convey accurate information about the work, it is useful to recognize visual cues and audio information (Nakata, 2007). Our system can support chemical plant operators to help them follow correct operating procedures without human error.

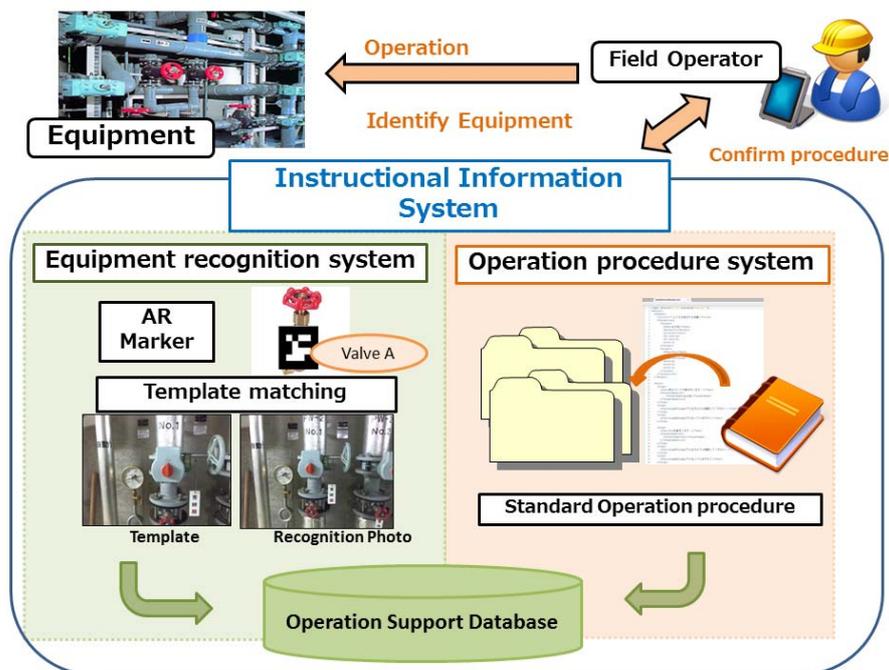


Figure 1. Concept of the instructional information system

## 2. Purpose and Approach

In chemical plants, a large amount of dangerous chemical fluids flow through pipes, and the equipment is arranged in close proximity. Board operators manage the process from raw materials, based on information from the distributed control system (DCS). Board operators instruct field operators about necessary operations by monitoring plant conditions. When an alarm is issued, field operators perform according to instructions from control room. Operating instructions are qualitative indications, not quantitative data (e.g., "Turn the valve to the right") and are received from the board operators. Due to the installation of similar-looking pipes and valves in close proximity to one another, there is a risk of serious damage occurring by operating the wrong valve. In recent years, immature operators are being forced to handle complicated facilities with fewer people, due to retirements in the aging workforce. As a result, human error has been increasing in chemical facilities (Hara et al., 2015).

The developed system shows relevant operating procedures and accurate equipment information using AR and image recognition. The field operators visualize the equipment through the camera of a tablet. The display shows the name of the equipment and its operating information. With advances in computer technology, AR can function in ways that enhance one's current perception of reality (Ishii et al., 2013). It does so by incorporating computer vision and object recognition, so the information about the user's real world becomes interactive and digitally alterable, meaning that virtual information can be overlaid on the real world. The AR marker shows an image of a set pattern, which is indicator for specifying the installation site and displaying additional information, e.g., the name of the equipment and the process condition (Fujisawa & Kato, 2009). The operator identifies the target equipment with the camera and can confirm the correct operating procedure on the tablet. The work information is displayed to the operator first; after the task is completed, the next work procedure is presented by updating the plant information.

Human errors often occur when a field operator works alone or in a non-steady-state operation (Komatsubara, 2008). The purpose of this study is to support the work of young, immature operators and reduce human error. The use of new computer technology in safety education has been reported to be very beneficial (Norton et al., 2008).

### **3. Instructional Information System**

#### **3.1 Outline of Instructional Information system**

The developed system consists of two subsystems (an operating procedure system and an equipment recognition system) and an operation support database. The operation support database stores plant information for the operating procedures and presents it as required. Operators can confirm the procedures and recognize the target equipment by using the system through the camera-equipped tablet.

Under this system, these are the workflow steps:

1. Check the displayed procedure on the tablet screen.
2. Search the equipment, based on the instructions from the system.
3. Recognize the operation target device.
4. Operate the target device.
5. Check the operation and proceed to the next task.

After the operation is finished, the work information is stored in the operation support database. This system can make operation reports as requested for the safe management of chemical plants.

#### **3.2 Operating Procedure System**

Traditionally, the standard operating procedure (SOP) is created on printed paper. It is displayed in the form of a list, with no detailed information provided about the timing or the operation. Operating manuals lack descriptions of operational targets and their locations. The instructional information presented to workers is, therefore, not considered sufficient. Conventional SOP is hard to understand intuitively. In order for the operator to perform without a trainer, considerable money and time must be spent. Furthermore, as more skilled workers retire, their experience and skills are not being sufficiently transferred to young workers. Moreover, skilled workers may not remember the procedures of non-steady-state work. Operating procedure systems compensate for the gaps in knowledge. The system indicates the work procedure. The field operator operates the equipment with reference to the work procedure the system outlines, and then refers to the tablet and advances to the next task. In this study, we propose ways to present chemical plant operators with the correct operating procedures to use in the field.

#### **3.3 Standard Operating Procedures**

Existing operating procedures are presented in a list on paper. To systematize the operating procedures on paper, the procedure should be divided into steps. The SOP contains too much information to be absorbed easily; therefore, the role of workers needs to be described clearly. Accordingly, we sorted the information by using the 6w2h method—6w refers to “what,” “who,” “when,” “where,” and “whom”; 2h refers to “how” and “how many” (Nakai et al., 2013). The procedure of each operation is further divided and described in length so it can be understood at once.

#### **3.4 Operation Support Database**

The created procedures, plant conditions, and template photos of the equipment are stored in the operation support database. After work is done using this system, the operation information is stored in the database; it can be safety management information of the plant equipment. Field operators can request procedures and equipment information from the database by operating the tablet. The information in this database is updated by performing the plant operation in the simulator; this can be presented to the worker. The next procedure is updated for display after the completion of the first procedure to prevent a slip-up in operations. The information in the database is capable of being modified when necessary and can be further expanded.

#### **3.5 Equipment Recognition System**

The equipment recognition system identifies equipment using the camera on the tablet. AR markers and image recognition, based on SURF, are used to recognize the plant equipment; the system then presents the target device to the field operator. The AR marker in an equipment recognition system, is an indicator for specifying a position to display additional information and the image of a set pattern. When the AR system recognizes the marker or template match, it can display information that has been specified so it can overlay the real image. Simple black-and-white graphics or QR codes are often used as AR markers. The valves and

pipes in chemical plants look similar to each other; installing a marker on the operation target device helps the system identify and determine the correct operational target and thereby allowing the system to choose the correct operating procedure. In addition, this system can automatically recognize the target using an AR marker or image recognition technology. There is a huge amount of the plant equipment, so putting AR markers on all the valves wouldn't be practical, but AR markers can be used for recognition in the equipment area. This system can recognize the target equipment using AR markers and the SURF algorithm. Under the system, workflow is performed based on SOP from the database. The operator checks the procedure in the field and identifies the AR marker of the target equipment with the help of the tablet's camera. When the camera captures the correct target equipment, the device recognition system displays a captured photo. If a field operator tries to operate the wrong equipment, the system shows a red edge around the photo. If the captured photo of the target equipment is correct, the tablet shows a green edge around the photo. After the camera detects the target equipment, it displays the equipment information, followed by the operating procedure. Then the field operator can perform the procedure displayed. If the operating instructions cannot be understood, the operator can refer to additional information in the system. When the camera recognizes the operation target equipment by the AR marker, it presents the name of the target equipment on the tablet. Figure 2 displays the system screen that shows AR marker and image recognition based template matching.



Figure 2. Operation procedures and target device recognition using AR and SURF technology

#### 4. Operating Experiment of the HDS Plant Procedure

This system is supposed to the SOP of the hydrodesulfurization (HDS) process. It includes the reaction that comes with hydrogen separation and the removal of sulfur content from petroleum under high temperature and high pressure; it also produces products with low kerosene and sulfur content, as well as light oils. In this experiment, we applied this system to the fieldwork. In this paper, we referred to an operating procedure that had experienced Vacuum Gas Oil (VGO) charge pump failure. The overview of the corresponding operations is follows:

1. The field operators need to switch from the main pump to the spare pump very quickly.
2. The must also pay attention to the rising temperature of the furnace, due to the rise in reactor temperature.
3. The board operator should operate the DCS cautiously, monitoring any changes in the temperature of the furnace inflow and outflow.
4. A field operator should confirm the level of tanks D-402 and D-406 to prevent a rapid decrease liquid level.

To present the procedure on the system screen on the left side, the photo of the target valve is shown the right side of the screen on the tablet. Figure 3 shows a screen shot of the development instructional information system.

##### 4.1 Operating procedure

Operation procedures using this system are conveyed based on the progress of the work. We used extensible markup language (XML) to write the procedural information. XML defines a set of rules for encoding documents and allows users to specify their own tags. It is possible for users to create their own meaning, structure, and hierarchy in a unified manner. XML is also useful for creating files to store data (Nakai et al., 2013).

The operating procedure to be used in this system is divided into steps <Step>, the ID information of each device <Target>, name <Name>, and the associated markers <Marker>. By using XML, documentation can be easily created, changed, and appended (Nakai et al., 2013).



Figure 3. The developed system recognizes the target equipment.

## 5. Discussion

In this paper, we developed a system to provide instructional information for field operators by using AR and image recognition technology for chemical plants. By using these technologies, this system makes it possible to recognize target equipment accurately with the help of a camera-equipped tablet using AR markers and image recognition technology. The field operators can detect the correct equipment needed to perform procedures and more easily differentiate between similar equipment, such as pipes and valves. Thus, the system can reduce the risk of serious accidents caused by operator errors. After the procedure is completed, the next procedure is displayed after updating plant information. The board operator in the control room manages the amount of equipment the field operator operates. In addition to presenting detailed plant information, the system should expand to include presenting instructions to board operators as well.

In the future, this system could be implemented with actual controls and systems, and by using real plant data. Inherited technology and past accomplishments are essential factors in enhancing competitive production. Figure 4 shows the operation report using the function of the system. The information in this report can be used for risk communication and management. This developed system takes down the issue of human error by recognizing equipment correctly, presenting relevant information, and confirming actions to prevent erroneous operation.

| プラント操作支援システム: 操作記録検索 |                   |   |    |
|----------------------|-------------------|---|----|
| 戻る                   |                   |   |    |
| 作業記録                 |                   |   |    |
| 項目                   | 内容                |   |    |
| 日付                   | 2016-02-19 11:25  |   |    |
| 操作種別                 | VGOフィードトラブル対応操作手順 |   |    |
| オペレータ                | スズキ               |   |    |
| 時刻                   | 操作                | 写真  | 備考 |
| 2016-02-19 11:25     | バルブ(HV811)を閉く     |  |    |
| 2016-02-19 11:26     | バルブ(HV813)を閉じる    |  |    |
| 2016-02-19 11:27     | バルブ(HV811)開度調整    |  |    |

Figure 4. The operation report using the function of instructional information system

## 6. Conclusion

In this study, we developed an instructional information system using AR and image recognition technology for chemical plants. This information system can indicate real-time operating procedures and accurate equipment information for field operators. There have been rapid generational changes in the Japanese workforce. We are gradually losing the techniques and knowledge of highly skilled workers. Inherited technology and past accomplishments are essential factors in enhancing competitive production. Human errors often occur when a field operator works alone or performs non-steady-state operations.

This system can reduce human error by recognizing correct equipment, presenting relevant information, and having a confirmation function to prevent erroneous operation. In order to prevent accident escalation, workers must perform the correct operations. This system could help operators achieve this level of accuracy. Furthermore, the system could also be used for safety education and training. We especially hope that our system can help the next generation of operators in the field and help clarify non-steady-state operations.

## References

- Bay H., Ess A., Tuytelaars T., Gool L.V. (2006). SURF: Speeded up robust features, Paper presented at the ninth European Conference on Computer Vision, Graz, Austria.
- Fujisawa M., Kato H. (2009). Interactive fluid simulation using augmented reality interface. Proceedings of Human-Computer Interaction International, pp. 431-438, San Diego, USA.
- Hara H., Kuwabara H. (2015). Innovation in field operations using smart devices with augmented reality technology, FUJITSU. 66(1), pp.11–17, in Japanese.
- Ishii Y., Ooishi K., Sakurai Y. (2013). Industrial augmented reality—Innovative operator assistance in collaboration with augmented reality (Yokogawa Technical Report English Edition Vol. 56 No.2).
- Jürgen, S. (2013). Process and Plant Safety—Research & Education Strategy to Keep Long Term Competences. Chemical engineering transaction, 31, 421-426. DOI: 10.3303/CET1331071.
- Komatsubara A. (2008). Human Error (second edition). Japan: Maruzen Publishing.
- Nakai A., Kaihata Y., Suzuki K. (2014). The Experience-Based Safety Training System Using Vr Technology for Chemical Plant. International Journal of Advanced Computer Science and Applications. 5(11), pp. 63–67. DOI: 10.14569/IJACSA.2014.051111
- Norton C., Cameron I., Crosthwaite C., Balliu N., Tade M., Shallcross D., Hoadley A., Barton G., Kavanagh J. (2008). Development and deployment of an immersive learning environment for enhancing process systems engineering concepts, Education for Chemical Engineers. 3(2) e75–e83.
- Nakata T. (2007). Wisdom for Preventing Human Errors: Can all mistakes be eliminated? Japan: Kagaku-Dojin Publishing.
- Pasman H., Knegtering B. (2013). What process risks does your plant run today? Chemical Engineering Transactions. 31, pp. 277–282, DOI: 10.3303/CET1331047.
- Suzuki K., Munosawa Y., Nakai A. (2013) Recent Accidents and Safety Activities in Japan. AIChE Spring Meeting and Ninth Global Congress on Process Safety, USA.
- Yating Y., Yamasaki Y., Kajihara Y., Akashika T., Izumi K., Jindai M(2015). Development of a system for practical skill training of maintenance personnel, Innovation and Supply Chain Management, Vol.9, No.3, pp.83-88, (2015)