DEVELOPMENT OF AR BASED SAFETY EDUCATION SUPPORT SYSTEM IN CONSTRUCTION SITE

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In this research, we developed the experience-based safety education support system that can assess the risk easily in the construction site. This system can put information tag about some dangerous spots where the labour accident such as falling and colliding are easy to be happened in the real construction sites through the tablet typed PC or the smart phone. The accumulated information as the dangerous spots can display in the construction site through the tablet typed PC or the smart phone. When an information tag indicated on the display is touched, the more detail information about the dangerous spot is displayed and we can do the risk assessment just on site. And also, it is able to share the risk information with all workers in the construction site through the smart phone. Moreover, various risk information accumulated by using this system can be confirmed on the map of the construction site, and these information can be also shared and utilized for the safety education in the construction site.

Introduction

Among all the industries, it is said that most fatal accidents occur in the construction industry. In the past, countermeasures were implemented with the main focus on facilities (Uta *et al*., 2011). In order to utilize time and space effectively, more safety education for workers is being conducted in a classroom. However, it is also true that, from the perspective of construction companies, safety education should be conducted not only in a classroom but also in a way to improve workers' awareness of danger more effectively (Okami, 2010). Taking into consideration the various work schedules and costs, conducting enough safety education on site regularly is not easy (Hirokane *et al*., 2008). Without taking work schedules and costs into consideration, it was reported that the most effective safety education methods on site were safety training, discussion of accident cases, and collecting and sharing the workers' near-miss stories (Hirokane *et al*., 2010). Some companies conduct experience-type safety education to increase awareness of danger by letting the workers experience simulations (Okami, 2010). Experience-type safety education means to conduct practical training in front of the workers for instances such as when steel stock on a construction site falls or a worker falls from a high elevation. Although this type of training is the most effective to increase awareness of danger, there is a problem with the amount of time required for preparation of space and equipment. Therefore, safety education which does not require much time and space but effectively increases on site awareness of danger in a short time is preferable.

In this study, we tried to construct a system to enable easy and experience-type safety education on site. Concretely, using Augmented Reality (AR) technology on a smart phone or tablet-type device, we registered the accident prone areas. Via the smart phone or a tablet-type device, the registered information was shown as a tag on the screen with the actual construction site as the background. Previously registered information was confirmed by tapping the tag on the screen. Using this system, we constructed a portable shared system utilizing a smart phone or a tablet-type device.

Outline of AR based safety education support system

This system registers detailed information of dangerous locations together with the mapped location information taken from a GPS. Utilizing technology to display the results after more information is added to the registered information using computer and AR technology, disaster information and information on dangerous locations can be displayed. As the medium, having taken into consideration the cost, operability and functionality to use the AR technology, the system was constructed so that it could work on a tablet-type device, such as a smart phone. A portion of the registered information is shown in Table 1. This table is actually used for on-site risk assessment, and the following items can be registered: Date of Inspection, Name of Inspector, Type of construction/Job name, Risk/Hazard, Possible accident, Estimation, Assessed Rate (probability and severity), Assessment (level and degree of risk), Risk reduction/Removal method, Measurement for possible accident, Preparation plan, Implementation process, etc. The information can be reviewed on the screen as detailed.

Table 1. Input items for risk assessment

Date of inspection	
Name of inspector	
Type of construction / Job name	
Assessed rate	Probability Severity
Assessment	Level Degree of risk
Risk reduction / Removal method	
Plan of measurement action	
Situation of measurement action	
Evaluation of measurement action	

Input method of risk assessment information

In order to register information, we registered accident prone locations on a smart phone which was loaded with the system constructed in this study. By entering information on each location, the mapped location information from the GPS was referenced, and the risk information per location was recorded. You can register various danger spots, and the registered information can be shared using tags, greatly simplifying the gathering of information.

Confirmation method of risk assessment information

As detailed information, the information including Date of inspection, Name of inspector and Type of construction/Job name is registered (Table 1). Each category can be checked by tapping the tag. The flow to register detailed information is shown in Figure 1. For Figure 1, Date of inspection, Name of inspector, Type of construction/Job name to be Assessed, Estimation, Assessed rate (probability and severity), Assessment (level and degree of risk), Implementation process and Evaluation of implementation are entered first, and then the accidents thought to be a risk or hazard are entered per item. Because the risk or hazard information is the information added after the accident occurs, the information on Risk reduction/Removal and Implementation process are entered after the selection. As for Possible accident, it is the information on which

type of accident is likely to occur and the information regarding it, such as Measurement for Possible accident and Method of implementation, which should also be registered.

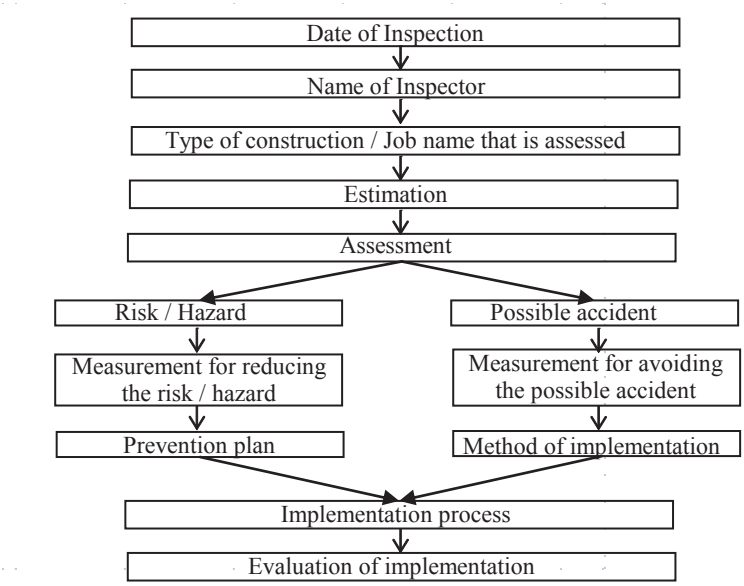

Figure 1. Input items and flow of input process

Design of Tags

In this study, additional information is displayed on a projection screen using the camera function of a smart phone with the image of the actual construction as its background. We made the additional information easy to understand intuitively and visually using tags. By not displaying detailed information until the user taps the appropriate tag, we prevented additional information and the image of the construction site from being highlighted on the screen. Figure 2 shows an example of the tag display. Figure 2 shows an area where a fall can occur, and the area is easily checked while walking around the construction site. The tag becomes larger as the user nears the dangerous area so that the user can intuitively understand where the dangerous area is. In order to inform the user which type of accident can occur depending on the risk type, the tags of different designs are used. For example, if the risk is slipping or falling, the top two tags of Figure 3 are used. If the ceiling is low or there is a danger of electric shock, the bottom two tags of Figure 3 are used. We had the tags designed to represent the most prevalent accidents, but the type of risk can be added later.

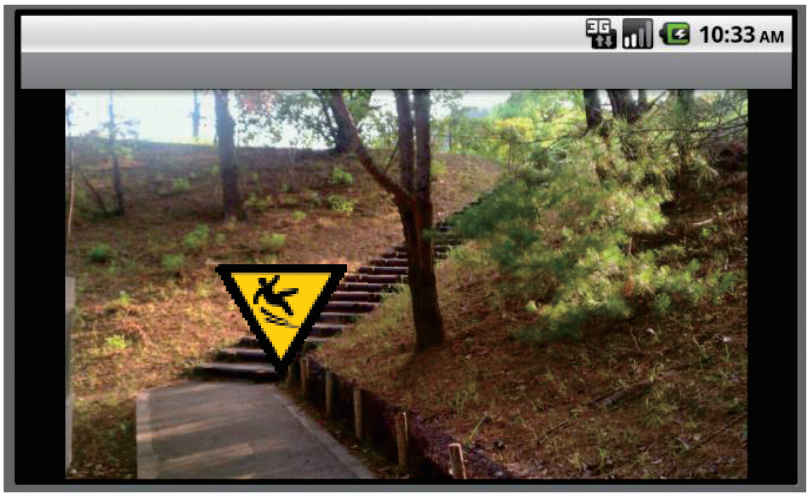

Figure 2. Example of tag displayed on the screen

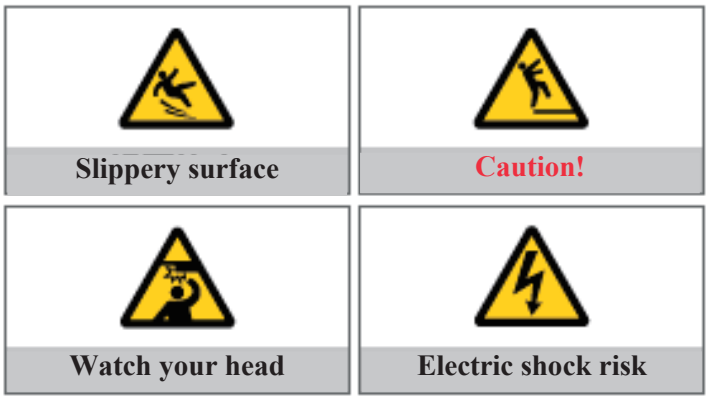

Figure 3. Design example of some tags

Input screen on a smart phone

On the registration screen, the user registers the information as shown in Table 1, such as Date of inspection, Name of inspector, Type of construction/Job name, Risk/Hazard, Possible accident, Estimation, Assessed rate (probability and severity), Assessment (level and degree of risk), Risk reduction / Removal method, Measurement for Possible accident, Preparation plan, Implementation process, etc. By letting the user select the items, we aimed to simplify the registration and reduce entry errors. Figure 4 shows an example of the registration screen on a smart phone. The Date of Inspection can be adjusted using the "＋" and "－" keys. The Name of inspector column can be entered freely, and when various situations can be expected such as countermeasures and the implementation process, this method was utilized. As for Type of construction, we adapted the selection method. Figure 4 shows the screen to select the type of construction after tapping the "Type of construction" box. For Job Title, Risk / Hazard and Possible accident, the selection method is used. Stars are used to show the level of risk visually. Figure 4 shows the risk level of 3.5. The risk level can be selected from 5 different levels by tapping the screen.

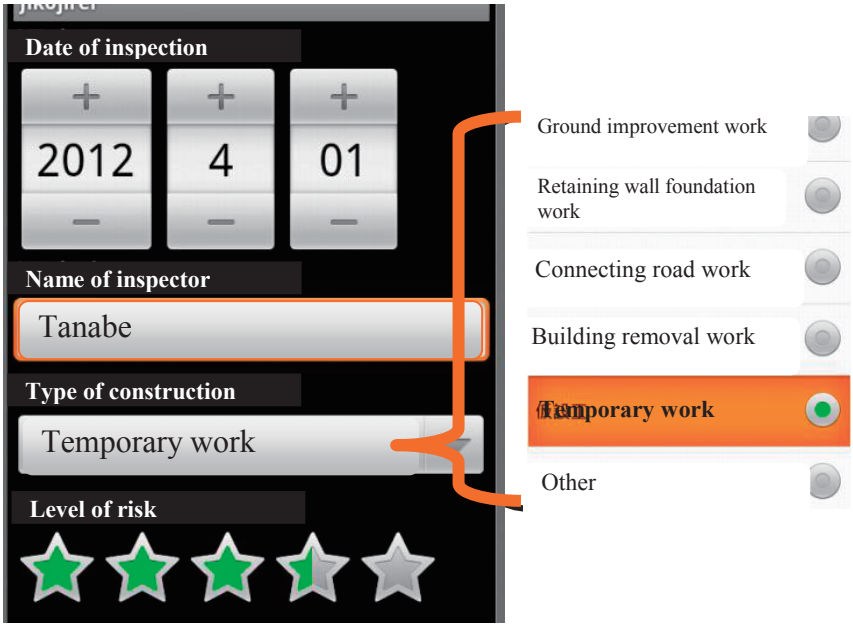

Figure 4. A part of input screen on a smart phone

Display on the interactive map

In this study, we constructed a system using AR technology to place a tag on the image of the actual construction site taken with the camera function of a tablet-type device. We also added a function to place a tag to display the registered information of the dangerous areas on the aerial photograph of the Google Map utilizing the GPS information obtained at the time of registration.

Figure 5 shows an example of a tag being displayed on the aerial photograph based on the location information recorded at the time of registration. By tapping the tag, the user can see detailed registered information as described in the previous section. Using this function, we made it possible to use it in the pre-education program for workers and show them the dangerous areas of the construction site before they commenced work.

Figure 5. An example of a tag display on the interactive map

Conclusion

Today, safety education which does not take up much time and space and still can improve the safety awareness of construction workers effectively in a short time is required on construction sites. In this study, we tried to construct a system to share safety management information utilizing AR technology. We believe that our system can provide experience-type safety education quickly and easily as a part of classroom education, experience-type safety education and safety training. Unlike existing experience-type safety education, the safety education using our information sharing system does not require preparation such as equipment. All you have to do is to ask the workers to hold a smart phone, loaded with our system, and walk around the construction site and go through safety training exercises, such as identifying dangerous areas. Other workers can check the tags by placing their smart phone cameras toward the dangerous areas previously registered using our system. The tags contain safety information and accident information. When workers get close to the dangerous areas where the tag is displayed and tap the tag, they can display the detailed information registered about the area on the screen. By reading and seeing the registered information regarding the dangerous areas and accident areas and learning from that experience, workers can visualize the dangerous areas easily. If workers repeat this operation, they can apply their knowledge to additional areas similar to the dangerous areas registered. They can improve their safety awareness and recall safety information. Participating workers can also provide feedback to the registrant on dangerous areas which are yet to be registered and may find dangerous areas that the registrant did not consider dangerous. By asking the workers to provide feedback, you can provide an opportunity for them to stay aware of dangerous areas of their own accord. In addition, utilizing the display function with the

interactive map, we made it possible to use it in the pre-education program for workers and show them the dangerous areas of the construction site before commencing work. Furthermore, the registered information can still be utilized after the particular work has finished and can be used as training material for safety education at an additional construction site.

In the future, we would like to add mode display functions using the interactive map and establish a connection between the registered information and past accident cases. Not only that, we would like to utilize the information as part of on-site safety education whereby the evaluation of the utility of our system and modification need to be implemented. Lastly, this study was supported in part by MEXT.KAKENHI (23510213).

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