Development of a Virtual Reality Training System for Live-Line Workers

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This article presents a training system for live-line workers. The developed training system is based on immersive virtual reality and automatic speech recognition technology. The training is focused on live-line Cut-Out-Switch (COS) replacement work in a distribution system. Most work in power systems must be free of interruption, so it is carried out by live-line techniques. However, these techniques have increased the number of accidents by electric shock. Because most electric accidents are due to live-line work, it is important to train live-line workers. The proposed training system provides repeated and cost-effective training for a small space. It also guarantees safety during training operations. In this article, the background of live-line techniques and the work procedure of COS replacement are presented. The architecture of the developed system, the creation of the virtual work environment, and the collision detection among virtual objects are also described.

1. INTRODUCTION

Electricity is a key element in modern society, providing the energy required to run manufacturing plants, light homes, and power our communications and computer systems. These days, sensitive electrical loads are used in all sectors (residential, commercial, and industrial). Industry is becoming increasingly reliant on automated systems to achieve maximum productivity, and their computer systems tend to lose track of their memories and processes upon interruption. Thus, interruptions these days have become a more serious problem than loads were just a few years ago. Some

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customers have requested the implementation of a reliable power distribution system that eliminates all single points of failure. Such an implementation forces the electrical utility concerned to perform live-line maintenance to deal with problems in their power system. Live-line maintenance can provide customers with "zero" interruption in their power supply but increases the workers' risk of severe electric shocks. Most accidents are related to workers' careless mistakes, the use of defective equipment, and poor work environment. Because accidents involving high-voltage power lines can be lethal, it is important to train the workers sufficiently so they can perform their job safely in this dangerous environment. Insufficient training may lead to fatal damage of not only the worker but also other persons and the system. Hence, live-line workers need to have repeated training in a simulated work environment, which should be as realistic as possible.

This article presents a Virtual Reality Training System (VRTS) for live-line workers. The developed VRTS takes advantage of Virtual Reality (VR) and automatic speech recognition (ASR) technology (Woodland, 1998) to provide repeated and cost-effective training for limited space. In addition, the immersion-type VR (Brooks, 1999; van Dam, Forsberg, Laidlaw, LaViola, & Simpson, 2000) helps to make this VRTS more effective, because it allows the trainees to feel as though they are performing real live-line work. The training is focused on the live-line work of replacement of a defective Cut-Out-Switch (COS) with new COS in an electric distribution system.

2. VR FOR TRAINING

Immersive VR makes an artificial environment seem real and allows one to become immersed in it and to interact with various objects in the virtual world by using specific devices, such as the Head Mounted Display (HMD), sensing glove, spatial tracking system, and so on. The most important aspects of immersive VR are that it allows the user to act as he or she wishes and to interact with various objects in the virtual world. Moreover, the VR can provide users with opportunities to experience various environments and situations. These distinctive features of immersive VR are particularly useful for educative and training applications.

Many training applications based on VR have been developed. These applications include training for medical surgery (Heng et al., 2004; Lu, Pan, Lin, Zhang, & Shi, 2005; Silverstein et al., 2002; Sojar et al., 2004), manufacture (Fernandes, Raja, & Eyre, 2003; Jiung-Yao, 2003; Lin, Ye, Duffy, & Su, 2002), construction (Assfalg, Del Bimbo, & Vicario, 2002), maintenance (Li, Khoo, & Tor, 2003), and military operation. However, this technology has not been actively applied in the field of electric power systems. Some VR applications for power system personnel training were developed (Arroyo & Arcos, 1999; Garant et al., 1995; Okapuu-von Veh et al., 1996; Tam et al., 1998; Tam, Badra, Marceau, Marin, & Malowany, 1999). However, these trainings were focused on simple tasks such as control switching operation, and most of them were carried out by use of a simple desktop-based VR training system and not the immersion type. Such systems are inadequate to train live-line workers who need to have high field adaptability.

In this work, the developed VRTS is based on immersive VR technology. Furthermore, ASR technology is added to the developed VRTS so that VRTS can create a virtual environment that is as close to the real world as possible. The live-line maintenance is performed with two or three workers communicating with each other. Such a situation is implemented to the developed VRTS by ASR technology. The trainee can feel as if he or she is working with another skillful engineer or coworker. The ASR technology can improve the reality and immersivity. Through a training system based on immersive VR and ASR technology, live-line workers can be trained effectively and repeatedly to have high field adaptability in different work environments.

3. LIVE-LINE COS REPLACEMENT WORK

3.1. Live-Line Maintenance

Live-line maintenance mainly deals with the maintenance of an energized line without any interruption to the power line. Live-line maintenance techniques for overhead power lines can be grouped into three classes: hot stick, bare hand, and rubber glove and barrier methods. In the hot stick method, the worker performs live-line work using different kinds of insulated hot sticks, with the worker maintaining the minimum approach distance from energized parts. In the bare hand method, the worker performs live-line work after the electric potential of the workers is equal to that of the energized parts. Workers can access the components by insulated ladders, insulated boom, cranes, or helicopters. The bare hand workers must wear a conductive suit composed of pants, jackets, socks, and gloves made from a cotton, asbestos, and stainless steel thread to shield them from the electric field. Generally, the bare hand work is conducted on energized EHV/HV transmission lines.

In the rubber glove and barrier method, the worker is fully insulated from energized parts with the approved rubber gloves and sleeves rated for the voltage and insulating work platform. The worker can get to the worksite using an insulated ladder or insulated bucket truck and carry out the work on a charged line with his or her hands. Generally, the live-line COS replacement work, which is the focus of the training, is based on the rubber glove and barrier method. The workers can touch energized parts wearing their rubber gloves, but the most energized components in the work area should be insulated for safety. The COS fuse holder operation must be performed by using a telescoping disconnect stick as a kind of hot stick at a safe distance to prevent harm due to electric spark.

3.2. Work Procedure of Live-Line COS Replacement

Generally, in an electrical distribution system, the live-line work for replacement of a defective COS with a new COS is performed according to the following work procedure.

- Step 1: Insulation of neutral line and low-voltage wires.
  1. Put on a protective outfit, wearing rubber gloves, sleeves, and goggles.
  2. Protect and insulate the neutral line and low-voltage wires.
- Step 2: Insulation of COS and power lines by using insulation covers. (Figure 1 shows the insulated COS and power lines on an electric pole.)
- Step 3: Installation of a bypass jumper cable between temporary COS and transformer's first bushing.
  1. Connect temporary COS to branch ring using COS clamp.
  2. Connect the first clamp of a jumper cable to the lower line terminal of the temporary COS.
  3. Connect the second clamp of the jumper cable to the transformer's first bushing terminal.
  4. Install fuse holder in the temporary COS.
  5. Close the temporary COS fuse holder using an insulated telescoping disconnect stick. (Figure 2 shows the installed temporary COS and jumper cable on the pole.)
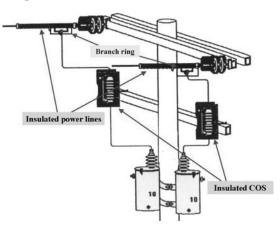

FIGURE 1   Insulated COS and power lines on a pole.
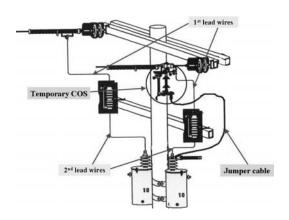

FIGURE 2   Installed temporary COS and bypass jumper cable.

- Step 4: Replacement of the defective COS with new COS.
  1. Remove the insulation cover of the defective COS.
  2. Open the fuse holder of the defective COS by using a telescoping disconnect stick.
  3. Remove the second lead wire between the defective COS and transformer's first bushing terminal.
  4. Remove the first lead wire between the defective COS and branch ring.
  5. Replace the defective COS with new COS.
  6. Install the second lead wire between the lower line terminal of the new COS and transformer's first bushing terminal.
  7. Install the first lead wire between the upper line terminal of the new COS and branch ring.
  8. Close the new COS fuse holder using a telescoping disconnect stick.
- Step 5: Removal of the installed bypass jumper cable.
  1. Open the fuse holder of the temporary COS using a telescoping disconnect stick.
  2. Remove the second clamp of the jumper cable from the transformer's first bushing terminal.
  3. Remove the first clamp of the jumper cable from the lower line terminal of the temporary COS.
  4. Remove the temporary COS.
- Step 6: Removal of all installed insulation covers on the pole (see Figure 3).

4. IMMERSIVE VRTS PROTOTYPE DEVELOPMENT AND ARCHITECTURE

4.1. Hardware

The hardware system of the developed VRTS consists of an HMD, sensing glove, spatial tracking system, and powerful workstation with 3D graphics acceleration. In addition, a microphone and a specific sound card are needed for ASR.
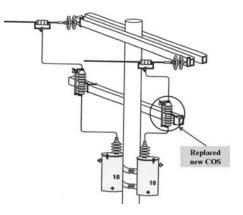

FIGURE 3 An electric pole of removed insulation covers and the end of live-line COS replacement work.

HMD.   An HMD is a key element of the immersive environment. It consists of two miniature displays that are mounted in front of the user's eyes with a head mount. It also contains two headphones so the user can also experience the virtual environment aurally. The user cannot be distracted by events outside of the world being viewed. The developed VRTS utilizes 5DT's HMD 800 Stereo (http://www.5dt.com/products/phmd.html).

Spatial tracking system.   An important component of the VRTS is the spatial tracking system, required for tracking the position and orientation of the hand and viewpoint of the trainee. Polhemus's FASTRAK system (Polhemus Inc., 2000) is used as the spatial tracker. The FASTRAK tracker system is a six degree of freedom (DOF) measurement system. It supports one transmitter and four receivers that measure the absolute position and orientation. The transmitter produces a magnetic field, and the receiver detects a displacement.

Sensing glove.   A sensing glove is an input device that measures the movements of the wearer's fingers and transmits them to the computer. The developed VRTS utilizes Immersion's CyberGlove. The CyberGlove is a widely used hand motion tracking device. The CyberGlove interface with the VRTS was developed by using the Virtual Hand Toolkit (VHT; Immersion Technologies Inc., 2001), which allows integration with WorldToolKit (WTK). The VHT is a development library including support for hand interaction management. The used CyberGlove model has 18 sensors as shown in Figure 4. The 18-sensor model features two bend sensors on each finger; four abduction sensors; and sensors measuring thumb roll, palm arch, wrist flexion and wrist abduction. To measure the position and orientation of the hand, FASTRAK 6 DOF tracking sensors can be mounted on the glove wristband.
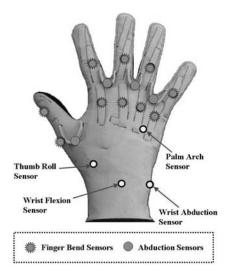

FIGURE 4 A CyberGlove model and sensor positions.

4.2. Software

To make interactive VR application, a real-time 3D graphic library such as Open GL (Silicon Graphics) or Direct X (Microsoft) is used. Generally, Open GL is used in scientific application, and Direct X is used in entertainment such as a 3D game. Software for 3D modeling is also needed to make virtual objects look real. In addition, to develop an ASR application, the software development kit (SDK) for ASR is required.

3D modeling. Objects involved in virtual live-line work environment are modeled as 3D shapes to give them a more realistic appearance. All of the equipments that are used in live-line COS replacement work are modeled as accurately as possible. Autodesk's 3D Studio MAX (3ds max; http://www4.discreet.com/3dsmax/) was used to model the objects. It is a widely used tool for 3D object modeling. Figure 5 shows the graphic user interface (GUI) of 3ds max and the 3D model of real work environment.

WorldToolKit. The main program of the VRTS was developed by using Sense 8's WTK (Sense8 Product Line., 1999), which is an Open GL–based VR Application Programming Interface (API). The WTK is a portable cross-platform development tool for building high-performance, real-time, integrated 3D applications for scientific and commercial use. It has a library of over 1,000 functions written in C that enable the programmer to rapidly develop new VR applications. The WTK functions have object-oriented naming convention and are organized into more than 20 classes. These classes include Universe (which manages the simulation and contains all the other objects), Geometries, Nodes, Viewpoints, Windows, Lights, Sen-
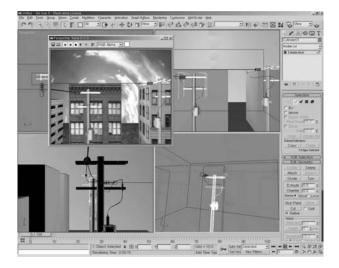

FIGURE 5 The graphic user interface of 3ds max and the 3-D model of work environment.

sors, Paths, Motion Links, and others. The functions are included for device instancing, display set-up, collision detection, loading object geometry from a file, dynamic geometry creation, specifying object behavior, and control rendering. The WTK applications differ from conventional windows systems where they are intended for use in situations where the user's viewpoint or objects in the universe are continuously changing. The WTK is designed for use in real-time applications.

ASR API. The live-line COS replacement work is done at the top of the pole in an insulated bucket truck. The bucket truck operator moves the bucket position, following the orders of the workers. Such a situation is implemented to the developed VRTS by ASR technology. The trainee can move his or her own position in the virtual world freely, as if he or she were in the bucket truck, by using voice commands such as "go," "back," "up," "down," "left," "right," "stop," "ok," and so on. The trainee can also import needed equipment into the virtual work environment by calling out the equipment name. In this work, Scansoft's L&H ASR API 1500SDK was chosen to develop the ASR application. L&H ASR can recognize continuous voice, including the dynamically changing contexts of words. It also provides function libraries that control multiple voice recognition engines. In SDK, two additional tools are included to enhance the performance of ASR engine. The first one is ASR Evaluator, which evaluates the probability of the performance of the SDK-developed program and the functions of ASR. It is used to create contexts of voice recognition and measures the reliability and sensitivity of various parameters in real time. The second one is LexTool, which is used to test the contexts and dictionaries, to add a new word to the context vocabularies, and to edit the mark of pronunciation of each vocabulary.

4.3. VRTS Structure

The developed VRTS is composed of four main parts. The first part is a workstation, which performs the simulation of the trainee's action and recognizes the trainee's voice commands. It also displays the trainee's view onto both HMD and the instructor's monitor continuously. The second part is interface with VR hardware such as HMD, FASTRAK, and CyberGlove. Two receivers of the FASTRAK are mounted on top of the HMD and trainee's hand, respectively. The trainee can see the virtual world through the HMD, which provides an immersive stereo view. The position and orientation data from the FASTRAK receivers are transmitted to the workstation. The CyberGlove is an input device that measures the movements of the trainee's fingers and transmits them to the workstation through a serial cable. The third part is the interface with ASR hardware such as microphone and sound card. A good microphone reduces noises coming with the voice and also provides clear voice signal to the sound card. The trainee's voice commands are inputted into the workstation from the microphone through the sound card microphone port. The fourth part is the interface with the instructor for enhancing the effect of training. The instructor can watch as trainee performs the work through a monitor and instructs needed work through the trainee's headphone. If the trainee

makes a mistake during training, the instructor can guide the trainee to take proper measure. Figure 6 shows the overall structure of the developed VRTS.

4.4. *Software Architecture and Data Flow in VRTS*

The developed VRTS is built on the Windows platform, as shown in Figure 7. The main window and GUI of VRTS are implemented by using Windows API. Most functions related to VR simulation, such as 3D rendering, sensors management, collision detection and loading 3D geometry models, are implemented by using WTK API. The WTK API provides high-level functions for configuring, interacting with, and controlling real-time 3D simulations. The CyberGolve library is developed by using WTK API and VHT API. The CyberGlove library has functions for initializing CyberGlove, connecting with the receiver of FASTAK, importing hand geometry model, transforming coordinate, and so forth. The movement data of fingers and the position and orientation data of hand are sent to the simulation loop of the main program. The hand model in virtual world is rendered according to the trainee's hand action. At the core of an application, written using the WTK, is a simulation loop, which reads the position and orientation data obtained from the sensors, updates objects, and renders a new view onto the display. When the main program is running, the simulation loop is repeated. The ASR server is implemented using L&H ASR API. The ASR involves the transformation of an acoustic speech
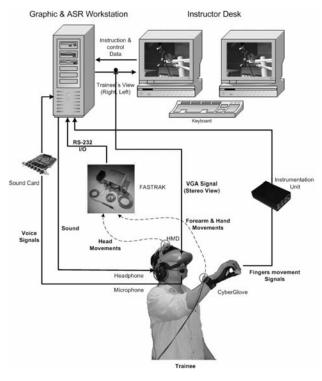

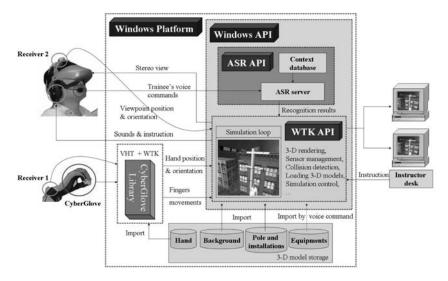**FIGURE 6** Structure of VRTS.

FIGURE 7   Software architecture and data flow in the VRTS.

signal into written text. The words and sentences, which should be recognized by the ASR server, must be defined in the context database. The ASR server always checks for speech events. The ASR server receives the trainee's voice commands, and using the recognition event callback function, it informs the main program when a recognition result is available. The callback function passes a handle to the main program, which is used to retrieve the result. The callback is optional function provided by the application and called by the API at an appropriate time to deliver each event.

5. SCENE GRAPH AND VIRTUAL OBJECT MODELS

5.1. Scene Graph

The architecture of the WTK was designed to incorporate the power of scene hierarchies. Simulations are built by assembling nodes into a hierarchy called a scene graph. To construct a simulation, the WTK assembles the geometry nodes into a hierarchical scene graph, which dictates how the simulation should be rendered and allows all the efficiencies of a state-preserving, stack-oriented rendering architecture. The scene graph is the structure that holds all the current elements of the scene, such as geometries, lights, and positional information. Figure 8 illustrates the simplified scene graph of the developed VRTS and traversing order. The traversing order is the order in which the nodes in a scene graph are processed while the simulation is running. WTK traverses the entire scene graph once per frame. The root node is the entry point into the scene graph and is the point where WTK starts to draw the scene. The light node specifies lights to illuminate all geometries in the virtual world. WTK supports four types of light: ambient, directed, point,
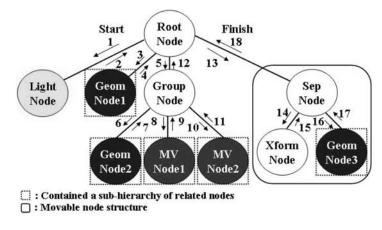
FIGURE 8 Simplified scene graph and traversing.

and spot lights. The lights used in VRTS are ambient and directed lights. WTK performs the actual act of drawing when it encounters a geometry node in a scene graph. The Geom-Node1 contains a subhierarchy of geometry nodes and other related nodes to display the background geometry models in the virtual work environment. The group node allows several nodes to be grouped together and managed as a single entity. The Geom-Node2 displays nonmovable geometry models such as electric pole, transformer, power lines, cross arm, and so on. The MV node1 contains a subhierarchy of movable nodes to display and handle the movable installations models on an electric pole, such as COS, fuse holder, lead wires, and so on. The MV node2 contains the movable equipments models for live-line work such as insulation covers, clamps, telescoping disconnect stick, jumper cable, and so forth. A movable node is a special kind of node that streamlines the process of creating objects, moving them with xform nodes and isolating them from each other with separator nodes. A movable node is a combination of three different nodes: a separator node, an xform node, and a geometry node. The separator node prevents state information from propagating from its descendant nodes to its sibling nodes. The xform node is a transform node containing position and orientation information. The Geom Node3 displays the trainee's hand geometry model. The hand model also is organized into a hierarchical node structure of geometries such as forearm, palm, and fingers geometry. The xform node sets position and/or orientation information of the trainee's hand. The hand model should move according to trainee's movements. To achieve the trainee's movements, such as getting on a bucket truck, the xform node is used.

5.2. Geometric Models and Collision Detection in VRTS

All geometry models involved in the live-line COS replacement work are modeled in 3D shapes. The models can be classified into two large groups: static and interactive models. The static models such as background geometries cannot be touched

or grasped by the virtual hand, but the interactive models such as the installations on an electric poles and live-line equipments can be touched and grasped by the virtual hand. The developed VRTS has easy interface for importing different background models and sounds into the virtual world. Live-line maintenance is performed in many different work environments. The VRTS can provide trainees with opportunities to work in different environments and situations. Although learning to replace a COS through the training is important, identifying the objects that must be handled with caution for safety is more important, as the COS replacement under live-line condition is a very dangerous task. Although workers can handle energized parts with rubber gloves on, all energized parts around the workers on the pole should be insulated for safety, and the COS fuse holder operation must be performed by using a telescoping disconnect stick at a safe distance to prevent damage from an electric spark. If the trainee touches or grasps energized parts without insulation or opens or closes COS fuse holder with the hand not using a telescoping disconnect stick, the VRTS sounds an alarm and displays a warning message, so the trainee is made fully aware of energized parts that must be handled with caution. While the simulation is running, the main program can detect collisions between the hand model and the energized components. Figure 9 shows the organization of important virtual object models and the collision detection in the developed VRTS.

The collision detection in the developed VRTS is based on the oriented bounding box (OBB) tree. An OBB is a rectangular bounding box at an arbitrary orientation in 3D space. The OBB algorithm (Gottschalk, Lin, & Manocha, 1996) is applicable to all general 3D models. It precomputes a hierarchical bounding box structure of the models. It provides accurate and fast collision detection for most VR applica-
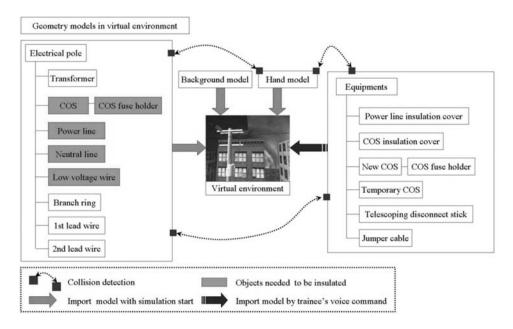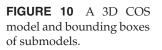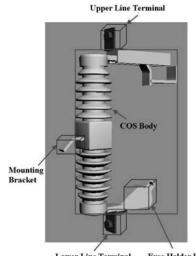

FIGURE 9   The organization of important virtual object models in the VRTS.

tions. The main program of the VRTS detects all the contacts among the interactive models and between the interactive models and virtual hand. Each interactive model can be divided into several geometry models. That is, one interactive model has several bounding boxes for collision detection. For example, a COS model consists of five submodels, such as the COS body, upper line terminal, lower line terminal, fuse holder link, and mounting bracket, as shown in Figure 10. To install a fuse holder in a COS, the trainee must know the location of the COS fuse holder link and then install the fuse holder at the fuse holder link. The success of the task depends on the result of collision detection between the fuse holder link and fuse holder.

5.3. Electric Spark Effect

To increase the sense of reality, an electric phenomenon such as electric spark is implemented in VRTS. In an actual live-line condition, an electric spark is generated at the closing of a COS fuse. The electric spark effect can be achieved by using the 3D animation or 2D texture animation. However, the 3D animation of an electric spark using WTK functions would be very difficult and time consuming. In this work, the electric spark effect is implemented using the texture animation. Because an electric spark is a phenomenon that occurs in a short time, the texture animation method is effective in creating a lifelike spark. This method needs less memory and computing power than the 3D animation. The texture animation can be easily archived by using WTK functions. An example of electric spark in a virtual world is shown in Figure 15. The sequential image files of an electric spark are needed for the texture animation. Then a polygon is created at the location where an electric spark is to appear in the virtual world to act as a moving billboard. This board should be facing the trainee's viewpoint. The image files are used one by one as textures on the polygon, creating a flipbook animation.

FIGURE 10 A 3D COS model and bounding boxes of submodels.

6. TRAINING FOR LIVE-LINE WORKERS USING VRTS

For the training exercise, the trainee needs to put on HMD and CyberGlove, which are attached to FASTRAK receivers, as shown in Figure 11. Then the trainee can act freely, interacting with various objects in virtual world.

When the instructor pushes the start button, the VRTS informs the trainee of the task to be performed, both through text displayed on the HMD's screen and through oral speech via the trainee's headphones. The instructor can watch the trainee's performance through the instructor's monitor and direct the trainee on the work to be done via the trainee's headphones. The training is performed step by step according to actual work procedure. The trainee can go to the next step only after he or she completes the task on hand.
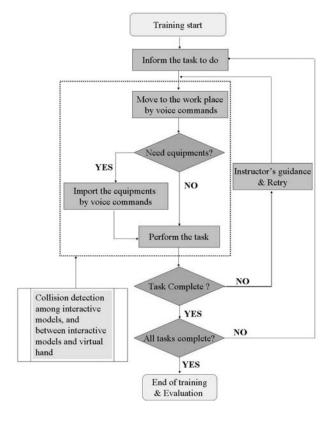
The trainee can move his or her own position to the workplace by using voice commands and then can perform the needed task. Figure 12 shows the flowchart of the training.
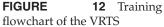
The following list gives some examples of tasks using the developed VRTS.

1. Task: Insulation of the power line on the pole using an insulation cover. According to instructions received from the instructor, the trainee moves to the position of the power line to be insulated. Then the trainee imports a power line insulation cover by using voice command. The trainee can grip and manipulate the insulation cover by using the virtual hand. The grip state is judged by collision detection between fingers, palm, and the insulation cover. When the trainee spreads the palm, the insulation cover is released from hand. Being cautious not to touch the power line directly, the trainee covers the power line with the insulation cover. Task completion depends on collision detection between the power line being insulated and the insulation cover. When the trainee installs the proper equipment in the correct place, the task is completed. Figure 13 shows the scene of the power line being insulated by the trainee.

FIGURE 11 A trainee is replacing a COS in the virtual world.

FIGURE   12 Training
flowchart of the VRTS

2. Task: Installation of a bypass jumper cable between the temporary COS and transformer's first bushing. Figure 14 shows the scene of an installed bypass jumper cable between the temporary COS and transformer's first bushing.

3. Task: Closing the temporary COS fuse holder. Figure 15 shows the trainee closing the temporary COS fuse holder by using a telescoping disconnect stick. At

FIGURE 13 Trainee is insu-
lating the power line using an
insulation cover.

FIGURE 14 An installed jumper cable between the temporary COS and transformer's first bushing.

FIGURE 15 Scene of the fuse holder being closed with the occurrence of an electric spark.

the point of closing the fuse, an electric spark is generated in the COS. In this task, the trainee must keep a safe distance to prevent injury.

4. Task: Replacement of the defective COS with new COS. The trainee removes the defective COS and installs new COS (see Figure 16).

5. Task: Removal of the first clamp of the installed jumper cable from the temporary COS (see Figure 17).

6. Task: Removal of all installed insulation covers on the pole. When the trainee removes all insulation covers, the COS replacement work is complete. Figure 18 shows the electric pole with replaced new COS.

7. TESTING AND SUGGESTION

The developed VRTS has been tested by 24 linemen who are familiar with the live-line COS replacement work. The dominant opinion (18 of 24) was that the developed VRTS is effective and adequate to complement the current training process. Their responses are summarized as follows:

FIGURE 16 Trainee is installing a new COS on the pole.

FIGURE 17 Trainee is removing the first clamp from the temporary COS.

FIGURE 18 Removal of insulation covers and the end of work.

- In the simulated environment, trainees can learn the COS replacement work procedure faster and more effectively than by texts or conventional passive lectures.
- The voice recognition interface can help to learn about work equipment effectively.
- Through repeated training, trainees can naturally recognize hazardous objects and situations.
- With training in different virtual work environment, it is possible to increase a trainee's field adaptability.
- The proposed training system is safe and convenient to use, and it can shorten the training time.

They also suggested some points for the system improvement. They include a group training system for two or three trainees together and the realization of haptic interface to increase reality. Some linemen also indicated the need to add various voice commands and the use of wireless devices.

8. CONCLUSION

This article presented an immersive VRTS for live-line COS replacement work. The developed VRTS enables trainees to have more field adaptability, because the combination of the immersive VR hardware, 3D graphic engine, and ASR technology makes them feel as though they are in the real work environment. The prototype of the developed VRTS can be applied to other live-line work training. Even though the trainee cannot make use of all of the senses of his or her body with the developed VRTS, the level of immersion provided by the HMD, CyberGlove, and ASR engine significantly enhanced the efficiency of the training, in the case of live-line work. Moreover, with advancements in VR hardware and technology, training applications using immersive VR will have even greater potential in the near future.

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