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Design and Implementation of Sensor Network Device Control System with AR Technology

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Abstract. Sensor networks, which can immediately detect events and situations and automatically control actuators, are expected to proliferate in the future, even though their visualization of sensor networks has not been emphasized. Identifying broken nodes in real environments remains difficult using a traditional visualization tool that plots the virtual diagram on which sensor nodes are put. In this paper, we propose and implement a control system of sensor network devices with AR technology. Our proposed system displays sensor data and network information such as the link status, the packet data, and the traffic in the sensor network on an AR interface. In addition, we control the sensor devices through the AR interface. Our proposed system allows users to intuitively acquire the status of sensor networks. We can also control the devices through the AR interface.

1 Introduction

Sensor networks are being used in such fields as disaster prevention and security because they can immediately detect an event or a situation and automatically control an actuator. Their proliferation is expected to continue.

On the other hand, the visualization of sensor networks has not been emphasized. Traditional visualization tools use virtual network diagrams that map sensor nodes on virtual 2D space. For example, if a certain sensor node is broken in the sensor network, identifying it in real space is difficult using a virtual network diagram.

In this paper, we propose Embodied Visualization with Augmented Reality for Network Systems (EVANS), which is the control system of the sensor network device with Augmented Reality (AR) technology. We can intuitively acquire both the resource and network information of sensor devices through the camera images of a real environment and control them through the EVANS interface.

2 Proposed System

2.1 Overview. We propose EVANS, which is a control system for sensor network devices. EVANS, which shows the virtual information of sensor networks on an interface using AR technology, allows us to intuitively acquire sensor data and link status among nodes. In addition, we can use EVANS to actually control the device in real space by manipulating virtual objects on an AR interface. The virtual information means the network information and the resource information. The network information includes the link status, the packet data, and the traffic in the sensor network. The resource information includes the network address, the sensor data, and the state of the switches.

The virtual information is displayed as annotation using AR Technology in the camera image. Since users control the sensor network devices through the AR interface, the annotation in the AR interface should be what users can associate real information with. Thus, for instance, numerical data are drawn without any changes, and the link status of the network is drawn as line annotation that connects nodes with cable.

2.2 Augmented Reality Technology. AR technology can provide the images generated by overlapping virtual information on real environmental images captured by cameras. The virtual information called an annotation includes the information associated with certain objects in real environments.

In general, AR technology uses AR markers to detect the camera's position and orientation, which is two-dimensional code. The pattern data of the AR markers are registered for the AR application in advance, and the application can recognize the object in real environments by tracking the AR markers with the camera.

2.3 Architecture of EVANS. Figure 1 illustrates the architecture of EVANS, which consists of three nodes; sensor, management, and EVANS. Sensor nodes, which run their own programs, are connected to the management nodes, which use a database to manage the status of the sensor nodes and receive requests from the EVANS nodes. An EVANS node is equipped with a camera and generates AR images, which integrate the real images taken by the camera and the annotation that users cannot see directly. Users operate the AR interface on the EVANS node to acquire the information of the sensor nodes and to control them.

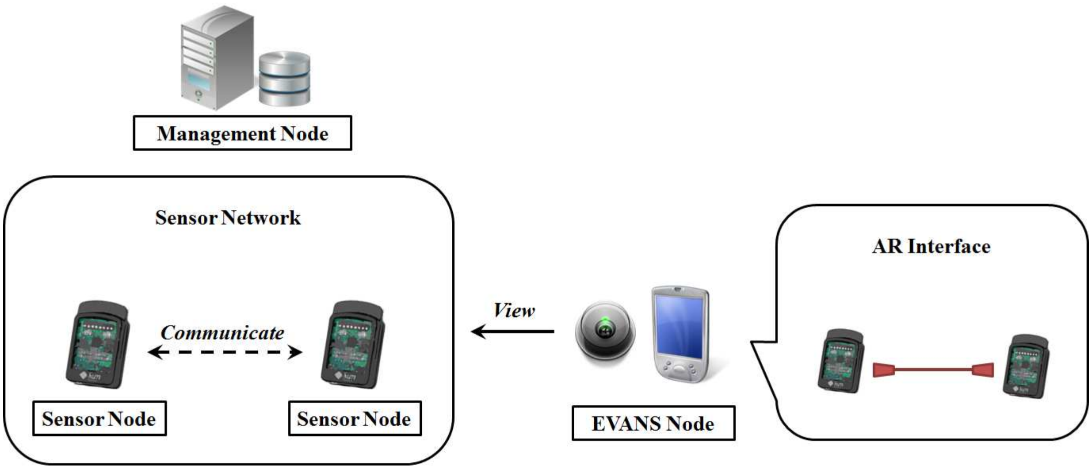

Fig. 1. Architecture of EVANS

(A) Sensor Node
A sensor node obtains the data from the actual environment and periodically communicates with the management node. Sensor nodes require hardware and/or software switches to change their states. To create AR images, our proposed system allocates a specific AR marker to each sensor node.

(B) Management Node
A management node deploys a database to manage the resource and the network information of the sensor nodes and the operations from the EVANS node. This database has tables based on the properties of the sensor nodes, and the fields of each table change accordingly.

(C) EVANS Node
An EVANS node has information about the relationships between the AR markers and the sensor nodes. Since an AR application operates on the EVANS node, users can see the AR images on this node. When users track the markers with the camera equipped on the EVANS node, it generates AR images that integrate the camera image and the annotation corresponding to the AR marker.

In our proposed system, we can manipulate devices in real space by manipulating virtual objects on the AR interface. When a user manipulates a switch on the AR images, a request message is transferred to the management node, which receives and sends this request to the sensor node. When the sensor node receives the request, it changes its status and returns a response message to the management node. The management node receives the response message and updates the database. Finally, the AR images are updated by reading the new data in the database.

3 Design and Implementation

3.1 Module Design. Figure 2 illustrates the software module designs of EVANS on each node. Each communication module can communicate with other communication modules. The following lists describe the role of each module.

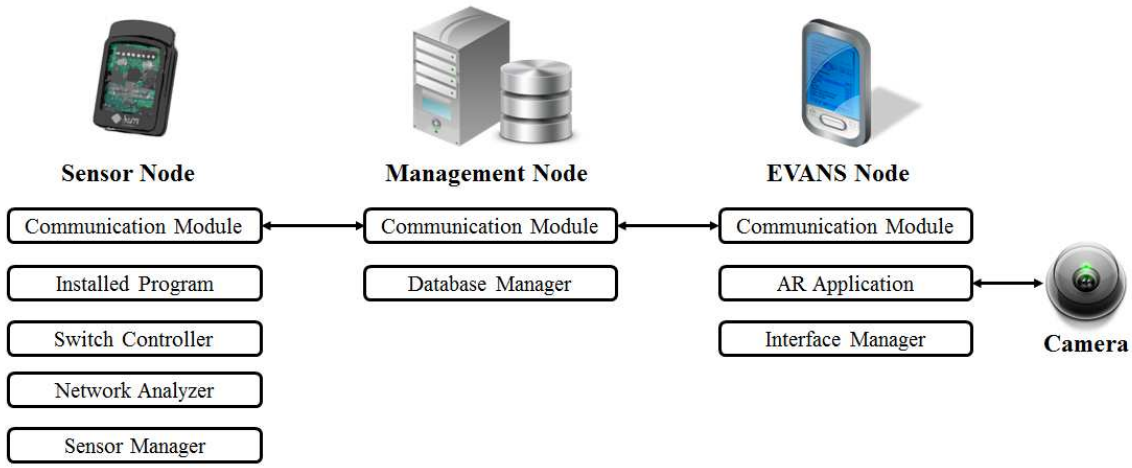

Fig. 2. Module design of EVANS

(A) Sensor Node

- Installed program:

  an independent application installed on a sensor network. The application behavior changes based on the switch's state.

- Switch controller:

  a module that controls the switch's state. When the virtual switch in the AR interface of the EVANS node is pushed, this module changes the switch's state. When the switch is directly pushed on the sensor node, this module sends the current switch state to the database.

- Sensor manager:

  a module that generates sensor data and sends them to the management node.

- Network analyzer:

  a module that generates such network information as the link status, the packet data, and the traffic.

(B) Management Node

- Database manager:

  a module that manages the network information, the resource information, and the operations from the EVANS node.

(C) EVANS node

- AR application:

  a module that provides users with an AR interface to operate EVANS. This module generates AR images that integrate the camera image and the annotation corresponding to the type of sensor node selected from the interface module.

- Interface manager:

  a module that sends the annotation to the AR application. It has annotations that correspond to the AR marker.

3.2 Prototype Implementation. We implemented a prototype system of EVANS using Sun Small Programmable Object (SunSPOT) [1] as the sensor node and NyARToolkit for generating the AR images. NyARToolkit [2] is a Java version Artoolkit [3], which is a class library for building AR applications. SunSPOT, which is a wireless sensor network device, can measure temperature and illuminance and is also equipped with a push button switch.

Figures 3 and 4 show the link status image of the prototype system captured by the camera of the EVANS node. In real world images, we cannot directly see the connection and the sensor information between sensor nodes, but this system allows us to directly acquire the information through the AR images.

This prototype system has two operation methods. One shows the resource information. When users tap the sensor node on the AR interface, the resource information is displayed. Another controls the connection between sensor nodes. When users drag and drop between sensor nodes, the switches of both nodes are toggled. In the installed program, if the switch of each node is turned on, these nodes communicate to other sensor nodes. If the switch of each node is turned off, the connection of these nodes is interrupted. When the connection is interrupted, the virtual link cable of the AR image disappears.

Fig. 3. AR image: link status

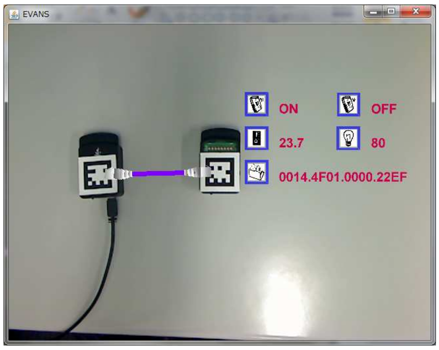

Fig. 4. AR image: sensing data

4 Related Works

uMegane [4], a visualization system of sensor data with AR technology, easily acquire easily sensor data for users who are unfamiliar with sensor technology. Extate [5], a visualization system of a wireless network with AR Technology that enables users to acquire the network status, such as the packet data, the type of network, and other network information.
Our proposed system not only can acquire sensor data and the network information but it also controls the sensor node and the sensor network. Thus our system is different from these existing researches.

5 Conclusions

In this paper, we propose an Embodied Visualization with Augmented Reality for Network System (EVANS), which is a control system of sensor network devices, and implement a prototype. Since most sensor network devices do not provide the displays, users cannot directly acquire the resource information or the sensor network information. But our proposed system allows users to easily acquire such resource and network information. In addition, users can control sensor network devices through the AR interface.

Since our proposed system recognizes the type of sensor node that corresponds to AR markers, it cannot support sensor nodes set up far away or hidden sensor nodes. Future work will display the annotation using GPS information instead of the AR markers.

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