A New Map Symbol Design Method for Real-Time Visualization of Geo-Sensor Data

Donglai Jiao[1]
Nanjing University of Posts and Telecommunications, WenYuan Road/Nanjing, China
jiaodonglai@njupt.edu.cn
https://orcid.org/0000-0003-4578-2715

Jintao Sun
Nanjing University of Posts and Telecommunications, WenYuan Road/Nanjing, China
sunjintao183@163.com

Abstract

Maps are an excellent way to present data with spatial components. For the large-scale geo-sensors being utilized in recent years, the map-based management and visualization of geo-senor data have become ubiquitous. Without a doubt, managing and visualizing geo-sensor data on maps will have vastly more future applications. However, current maps typically do not support real-time communication in the Internet of Things (IoT), and it is difficult to implement real-time visualization of sensor data on a map. Map symbols are the language of maps. In this paper, we describe a new map symbol design method for geo-sensor data acquisition and visualization on maps. We refer to the sensor data visual method in supervisory control and data acquisition system (SCADA) and apply it to the design process of map symbols. Based on the traditional vector map symbol, the mapping relationship between the sensor data and the graphic element is defined in the map symbol design process. When the map symbol is rendered in the map, the map symbol is integrated into the map layer. The communication module in the map that communicates with the sensor device receives real-time sensor data and triggers a refresh of the map layer according to the mapping profile. All the methods and processes shown herein have been verified in *GeoTools*.

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1 Introduction

The Internet of Things (IoT) is emerging as a major trend shaping the development of the Information and Communication Technologies (ICT) sector[12]. The possibility of seamlessly merging the real and the virtual world through the massive deployment of embedded devices opens up new exciting directions for both research and business [5]. With the development of sensors and the gradual maturity of sensing technology, the IoT is being widely applied in industrial process monitoring, production chain management, material supply chain management, product quality control, equipment maintenance and other production processes [7]. Since the IoT is becoming an increasingly trendy topic for individuals, businesses and governments, the needs for easy-to-understand visualization focused on different sensor

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state are increasing as well. Meaningful presentation and visualization are critical for IoT applications as more information is provided to consumers. These methods will also enable policy makers to convert data into knowledge, a process which is critical for helping the end user make decisions quickly [13].

Visualizing the geo-sensor data while regularly updating the presentation of the location is necessary [10]. A good way to show the information is on a map. There are many applications of sensor data visualization based on maps [9, 15, 18]. Although some GIS technologies are able to visualize real-time data[2], there is no sensor data exchange between the map and communication server. Although periodically refreshing the map is a way to visualize changing sensor data, a frequent refresh rate increases the burden of the system. In addition, an infrequent refresh rate will cause some changes to the sensor data to be ignored. Hence, there is no single, well-defined way to provide sensor data for real-time visualization through maps. The following discussion describes some of the most important design choices made in mapping between the data models of map symbols and the models required for real-time geo-sensor data visualization. In this paper, we propose to compensate for deficiencies in the methods by incorporating sensor data transmission protocol into the map symbol architecture.

2 Sensor data acquisition and visualization in IoT

Traditionally, most sensor data acquisition and visualization has been built around SCADA, which is a system for remote monitoring and control that operates with coded signals over communication channels [8, 1, 14]. In basic SCADA architectures, information from sensors is sent to RTUs (remote terminal units), which then send that information to SCADA software. SCADA software analyzes and displays the data in a Human Machine Interface (HMI) in which all the elements, such as buttons, text arrays and other objects, are represented graphically in visualization screens. In recent years, large-scope sensor arrays that are produced worldwide have been utilized. The location of the sensor data, which is commonly handled by the Geographic Information System (GIS), appears to be increasingly important, and the implementation of geographical schematics in SCADA systems has been widely accepted. Ten [16] proposed a framework to migrate a GIS database to a SCADA system in which spatial data is converted to a SVG format to appear in an HMI. Back S employ international standards from both domains to enable information exchange between the SCADA and GIS systems and then present new concepts for bridging these systems [6]. The above studies focused on how to transfer the spatial information from a GIS to a SCADA system and present it via an HMI but focused less on how to collect sensor data and perform visualization in the GIS.

For visualization of geographic objects, the map in the GIS is a “special” HMI. Cartographers design and use symbols to represent geographic features. The procedure of a map for spatial features is similar to an HMI in a SCADA system. The geographic object is abstracted to a map symbol, which is composed of graphic elements, and then the symbol is rendered on the map. The key to visualize real-time sensor data on a map is the mapping profile between the sensor data and the graphic elements in the map symbol, just as with a SCADA system.

3 Mapping profile definition between sensor data and map symbol

The traditional design principles of map symbols are based on the visual variable system[4]. Map symbols describe the different characteristics of geographical entities by the visual variables, such as size, hue, orientation, shape, location, texture and density. According to the process in SCADA, building the mapping between the sensor data and the graphic elements in a point map symbol is the key to visualize real-time sensor data on the map. Therefore, we incorporate this mapping into the traditional point symbol model. The data collected by the geo-sensor are periodic, so the sensor data in the system is presented in the form of discrete data. According to the principle of data visualization, different data types correspond to different visualization methods. For example, finite discrete data can be directly matched to different visual variables, and infinite discrete data can be divided into limited intervals, with each interval corresponding to different visual variables.

Production rules are widely used for representing knowledge in system[17]. We examine methods for expressing the mapping as a succinct collection of production rules of the form

```
IF conditions THEN outcomes
```

There is at least one set of logical expressions in *conditions*; a logical expression defines the relationship between a parameter representing sensor data and a threshold (e.g., $Gas < 5$), and different expressions are joined by logical operators (*not,and,or*), Outcomes are defined as *visual variable = value*. As an example, consider:

```
Parameter Gas
IF Gas >5 THEN TY1.fill=rgb(255,255,255)
IF Gas <=5 THEN TY1.fill= rgb(255,0,0)
end parameter
```

In this sample, the *rect* graphic element whose *id* is *TY1* in gas station map symbol notation corresponds to the sensor *Gas*, and the fill color will change to rgb(255,0,0) if *Gas* is less than 5 ton.If *Gas* is more than 5, the fill color will change to rgb(255,255,255).

4 The Map Symbol Architecture for sensor data real-time visualization

4.1 Driver Interface oriented sensor data transmission protocol

Through the network, sensor data is transmitted from the sending side to the server side. At the transmitter, sensor data is serialized into a data stream (a frame data) according to a certain sequence or organization mode. After receiving the data stream on the server, the data were deserialized in the same sequence or organization mode. The agreement of data organization is called the data transmission protocol[11]. In the design process of map symbols, establishing the mapping relationship between the sensor data in protocol and the visual variable is the key step. Therefore, the user needs to obtain the metadata information of the sensor data in the process of map symbol design, such as data type, data name, data length, data precision and so on. In the map render process, the sensor data transmitted from sending side should be converted into an open data format for data visualization. We define the metadata interface (*IMeataData*) and data-parsing interface (*IDataParser*) for data transmission protocol. The metadata interface can obtain the name and type of the item in the sensor data that is used for the design of the map symbol. The data-parsing interface takes action on server side, and transform the data stream from private format into public format. JSON is a lightweight text data exchange format[3]. We take JSON as a public format data description.

The protocol designers program the driver class, which implements the two interfaces (*IMeataData*, *IDataParser*). On one hand, the map symbol designer does not care about

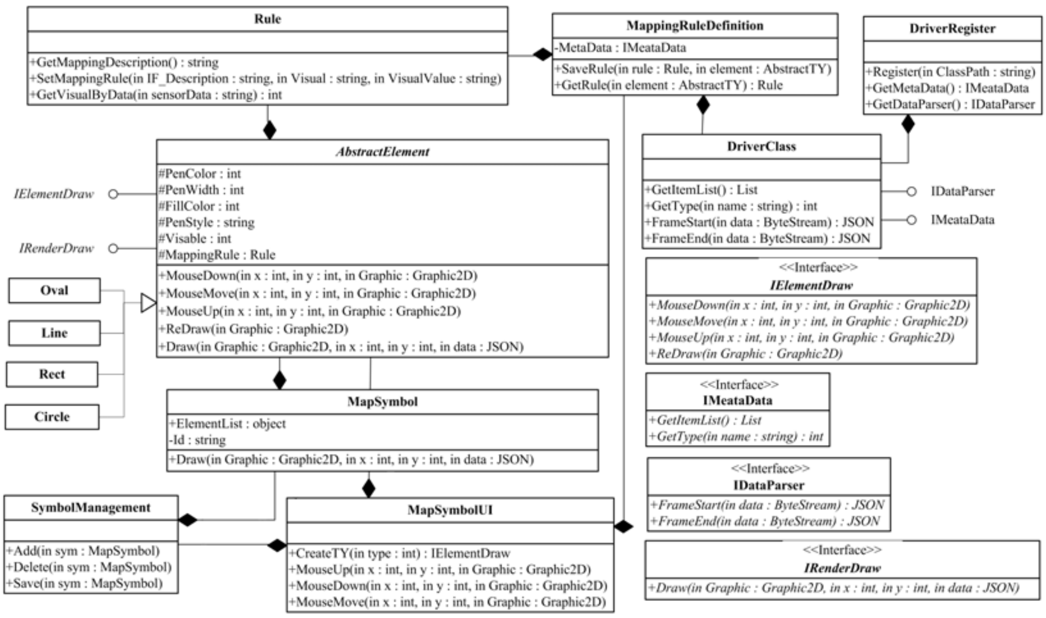

Figure 1 Outline of the model of the map symbol.

the structure of the transmission protocol. The metadata information of the sensor data can be obtained by *IMeataData* and used for mapping definition. On the other hand, in the process of the map render, the geo-sensor data frame converted to JSON format data by *IDataParser*, and then the JSON format data is used for real-time visualization.

4.2 Model of map symbol for sensor data real-time visualization

Traditionally, a sensor device was abstracted into a point symbol (graphics block) shown on a map. The graphic element is the basic component of a map symbol. From the point of view of object-oriented modeling (programming), each type of graphic element includes visual variables as properties. The functions of the graphic element can be generalized into two types: graphic design and map symbol render in map visualization. We design the two type functions separately into two interfaces (*IElementDraw*, *IRenderDraw*). IElementDraw contains the methods needed for the graphic design, such as mouse up, mouse move, mouse down and redraw. *IRenderDraw* is mainly for map rendering, which includes the method to invoke when the map is rendered. The abstract class of graph element (*AbstractElement*) which implements the two interfaces (*IElementDraw*, *IRenderDraw*) is defined in the model. All properties of each type of graphic element in a map symbol are inherited from the abstract class. In the process of designing the map symbol, *IMeataData* in the driver class show the sensor metadata information to the map symbol designer. The designer defines the mapping of the sensor data item and visual variables, and saves it. In the process of map rendering, the graphic rendering function (*IRenderDraw*) maps the sensor data into visual variables by the *Rule* class.

MapSymbolUI binds the *IElementDraw* interface and the mouse operation in the drawing area, which makes the symbol model and UI integrated. Users can choose different types of graphic elements, and use the mouse event in the drawing area to draw the symbol element, and save it into the current symbol data model. The outline of the model show as Figure 1.

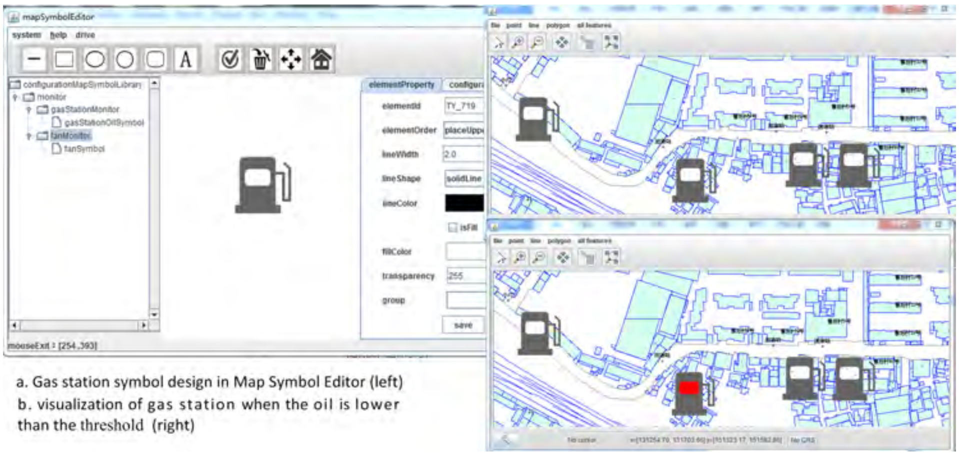

Figure 2 Map symbol design and application (Take the gas station as an example).

5 The application of geo-sensor data real-time visualization by map symbol

The current GIS is a component-based system, and the different components are coupled together through an interface. The components in GIS associated with map visualization are the layer component and the symbol component, which are coupled through a rendering interface.We add the real-time sensor data acquisition module in the layer component when the map symbols are combined with it. The data acquisition module connects with the sensor through a "long-polling" connection. When the module receives data from the sensor, the module calls the parsing interface (*IDataParser*) in the driver class to transform the received sensor data into JSON format data, and then the JSON data is forwarded to the symbol render interface (*IRenderDraw*) via a layer component. According to the mapping profile, the symbol-rendering interface changes the visual variables and then realizes the real-time sensor data visualization based on the map symbol.

In this paper, we developed a new map symbol editor in the JAVA language (Figure 2a) based on the model (Figure 1) and use *GeoTools* to verify it. We use a gas station as an example, the new map symbol editor designs a gas station symbol (Figure 2a). When the oil of the gas station is below the threshold, the rectangle box of the map symbol is changed to a red filled circle (Figure 2b).

6 Conclusions

We have described the design and implementation of the map symbol for real-time sensor data visualization on the map. We have identified aspects in the map symbol that are needed to implement real-time visualization of sensor data. These aspects include the following:

- Define how the sensor data can be mapped to the visual variable of map symbols.
- Develop a new map symbol design system oriented real-time geo-sensor data visualization.
- Verify the real-time visualization by map symbol in *GeoTools*.

The present research focuses on how to achieve real-time visualization of sensor data on a map. At present, there are only a few types of graphic elements in the symbol system, and the change of graphic elements is relatively simple. In the future, we hope to design a variety of graphic elements and design more diverse graphic elements that change according the mapping profile.

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