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Mobile System for Monitoring Over the State of Engineering Systems

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***Abstract*—The paper presents distinctive features of mobile systems for monitoring over the state of engineering systems. Such systems are distinguished by relatively small volumes of graphic information that can be represented in a display at the same time. In some cases, this allows backing away from visualization of an engineering system using mnemonic diagrams and applying methods based on demonstration of relationships between parameters. The developed mobile visualization system is used to visualize data center metrics. The system enables us not only to obtain information on the data center state but to compose an image in a convenient and understandable format ensuring a quick response to an emergency.**

Keywords—visualization; engineering system state monitoring; mobile systems.

I. INTRODUCTION

In recent decades, intensive development has been observed in the area of process supervisory control systems. Such systems focus on the application of a client-server approach and operate on the basis of PCs as well as graphic panels. The industry demonstrates trends related to creation of products ensuring large-scale application integration for process controllers (PLCs) and supervisory control systems (SCADA).

For instance, in the Siemens TIA Portal system, PLC and SCADA programming is carried out in a single environment with an option to access PLC tags in the SCADA project based on an integrated connection. Current integration-related trends also focus on monitoring and diagnosing PLC problems, including, among other things, software failures. For instance, the TIA Portal system provides for the PLC Code Display tool to monitor the controller code.

A comparison of TIA Portal visualization systems for PCs and graphic panels shows that the manufacturer pays considerable attention to the interface ergonomics. For that purpose, special templates are provided to efficiently allocate standard process monitoring and control components in the display workspace.

Meanwhile, under current conditions, applied use of smartphones in areas not directly related to communication is becoming more widespread. Those are spheres of navigation, payments, entertainment, etc. It is possible to use mobile devices for process monitoring and control by means of SCADA server screens via browser and the Internet. However, this method is largely limited by inconvenience related to perceiving information on the smartphone screen. Moreover, many SCADA functions are not required for monitoring over the state of engineering systems in household or in the field of IT infrastructures. Fig. 1 illustrates differences between the functions required.

Such well-known and well-proven monitoring systems as Zabbix, Hyperic, Naglos can be used as a platform to create mobile control systems. For instance, the Zabbix monitoring system supports integrated diagrams, triggers, SMS-alert. Moreover, the system is free.

The Zabbix system includes the following:

- monitoring servers (regular data acquisition, alert script processing, analysis and launching);
- databases (MySQL, PostgreSQL, SQLite or Oracle);
- PHP-based web interface;
- an agent — software to monitor local resources and applications (such as hard drives, memory, processor statistics, etc.) in network systems working with the Zabbix agent.

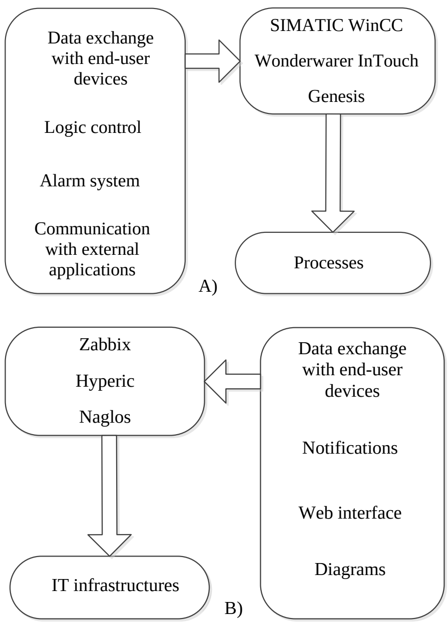

Fig. 1. Differences between the functions of process supervisory control systems (A) and mobile systems for monitoring over the state of engineering systems (B)

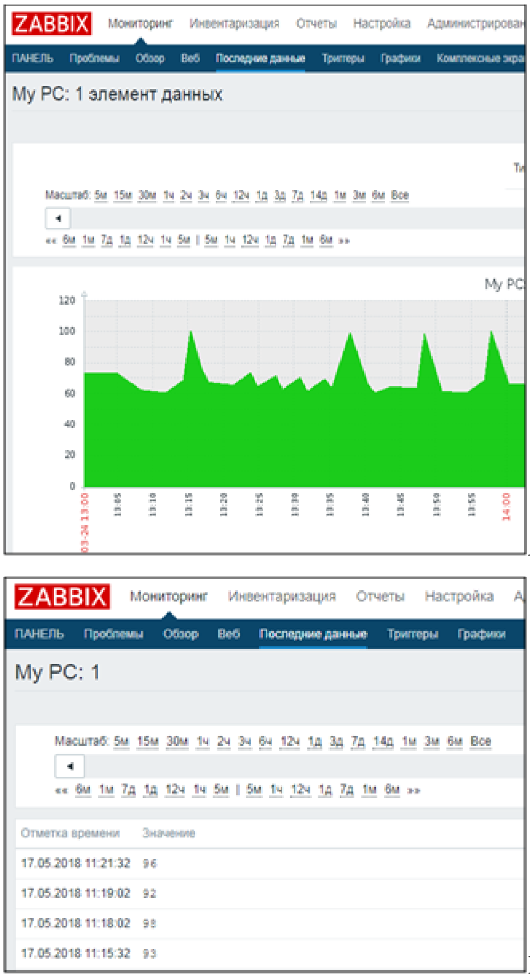

Fig. 2. Example of Web-interface showing data in the form of a diagram (A) and in the form of a list (B)

However, the Zabbix system lacks effective means of providing large amounts of data. For example, the Web-interface of the system offers data visualization in a form inconvenient for a mobile monitoring system form (Fig. 2).

The system has other disadvantages as well. For instance, when an error occurs, SMSs are sent as spam. There is no mobile application. In order to solve the issues, it is reasonable to supplement the functions of the monitoring system with new features determined by the task of mobile monitoring.

II. Functions of the Developed Mobile Monitoring System

The developed system for mobile monitoring is integrated with Zabbix and, therefore, has the following functions: displaying data in diagrams; collecting data from devices; SMS alert. The system was programmed using the Python language. The py-zabbix library provided by the developer was used for working with zabbix-api. The PyQT graphics package is used for development of the visualization interface.

New features of the system include the possibility to select different templates to visualize critical parameters of the engineering system on compact devices, as well as visualization of archive information.

Data visualization requires information to be submitted in the form of images that can facilitate data understanding. The following shall be ensured:

- focus on different aspects of the data;
- big data analysis;
- reducing information overload of a person and hold his/her attention;
- unambiguity and clarity of the output data;
- revealing correlations and relationships between different parameters.

Various recommendations for the use of infographics to visualize the state of engineering systems are available. For instance, the paper by Yulina and Kharitonov [1] contains recommendations for design of the graphical user interface to display analytical information on energy and resources consumption. However, no recommendations are provided for compact monitoring devices.

In her paper, Sysoeva [2] performed an analysis of the existing classifications of data visualization tools and proposed a classification accounting for the purpose of a tool, type of a software product, as well as analytical and statistical functions. However, there is no classification based on device sizes.

It may not always be convenient to display a process as a mnemonic diagram. If too many sensors concentrate in certain parts of a mnemonic diagram to be displayed on a mobile device, this requires decomposition of the general diagram into a number of screens or creation of diagram options to control individual types of parameters.

In her paper, Romanova [3] described various classifications of visualization methods, including classifications by visualization objects, as well as by coordinates and data conversion methods. The author stated that the primary aspect of the visualization task is its practical purpose, namely, facilitation of data understanding for its subsequent analysis, for example, obtaining influence patterns for parameters of the system being considered.

When visualizing large systems, it is important to have the possibility to quickly relate the groups of parameters observed on the screen with one or another process subsystem. It also ensures quick identification of the process subsystem when solving issues of fault diagnosis.

However, when visualizing small and medium-sized systems, an expert can memorize and keep in mind the equipment layout with quite many details. In this case, it may be more useful to display data taking into account the interrelations between the subsystems and the mutual influence of various process parameters.

During system development, various visualization methods listed in the periodic table of visualization methods [4–6] were evaluated from the perspective of mobile monitoring. Three methods were selected (Funnel, Tree, Technology roadmap) which served as a basis for development of customizable screen templates for mobile visualization. The methods focus on demonstrating the relationships between process data in a form different from that of the structural mnemonic diagram of the process.

[9]. Taking into account that staff skill improvement is

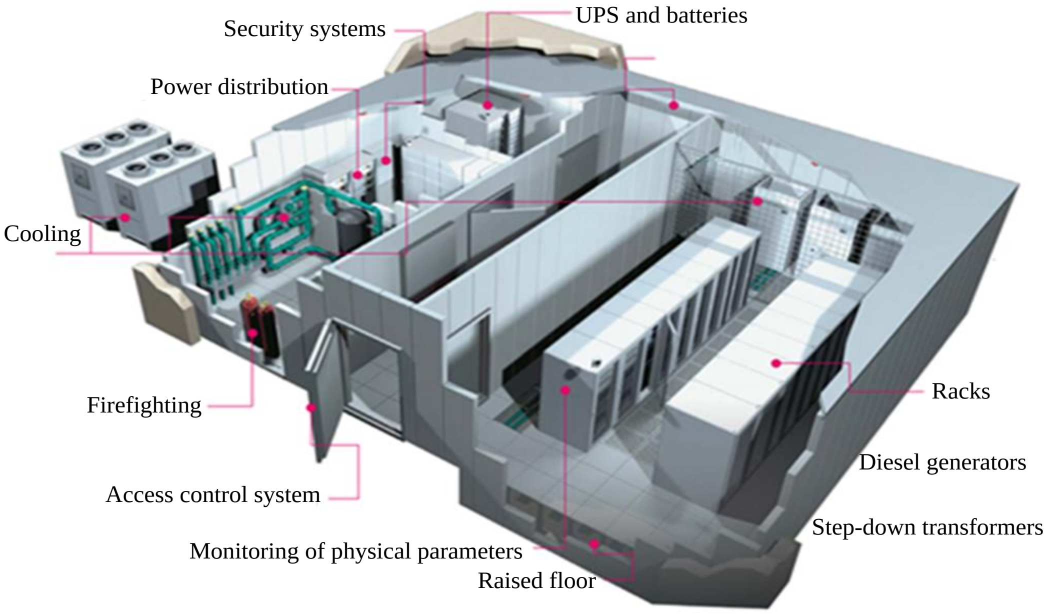

Fig. 3. Main components of the data center [7]

For instance, tree-type representation of data relationships is one of the most common approaches in computer science enabling to simplify information search, display and manage hierarchical data, solve issues of debugging and code optimization, etc. A common application is to build a decision tree for a specific issue.

A number of advantages of tree-type relationship visualization can be specified:

- User-friendly classification model.
- Displaying relationships in areas where it is difficult for an expert to formalize his/her knowledge.
- Quick perception of information.
- Perception of information in a non-parametric form.

Therefore, trees represent a convenient tool in decision support systems in such areas as manufacturing, banking and medicine.

The importance of this visualization method for manufacturing will increase along with transition to the Industry 4.0 concept focused on the use of cyber-physical subsystems (CPS).

For instance, in their paper, Eidelwein et al. [8] addressed the issue of achieving modularization based on the Theory of Constraints (TOC) thinking process. The authors understand modularization as creation of an integrated product or system consisting of subsystems called modules which can be designed independently, but are integrated and operate jointly. The authors demonstrated the possibility of using the TOC tools, the current- and future-reality tree, to solve the issues of companies based on modularization ideas.

The Industry 4.0 concept focuses on integration of a person, an object and a system, and is aimed at arranging gradual and continuous improvement of production systems necessary to increase production flexibility, it is reasonable to consider the possibilities of visualizing processes using the tree-type representation of relationships. In such visualization systems, relationships can be built both between process parameters and between process parameters, on one side, and process or production efficiency estimates, on the other side. Problem concepts and effects provided for by the TOC may be involved in such relationships.

III. Application of the Developed System: an Example

The developed system was used to monitor data center parameters. The data center is an engineering structure to house and maintain IT systems, computer and telecommunications equipment [10]. The main components of a data center are data processing and storage systems, active network equipment and engineering systems. It hosts computational platforms, as well as a data storage system, data transmission system, power supply and electric lighting system, air conditioning system, structured cable system, cable channel system, raised floor, suspended ceiling, integrated security system, means of physical protection of computing systems and telecommunications equipment, early fire detection and gaseous fire suppression systems (Fig. 3). Fig. 4 shows an equipment layout in the Compass Plus Ltd data center.

The developed system monitors metrics used in assessment of computer resources. The metric is a standard for measuring computer resources. The following metrics were used during monitoring:

- central processor unit (CPU) utilization rate showing the percentage of the processor's current utilization;
- memory usage — the percentage of the total server memory's utilization (shown as the percentage of the total available physical memory);

- disk I/O — a metric showing the number of read and write operations on the server (shown in MB per second);

Adding other metrics to the mnemonic diagram of the process is impractical because it results in a visual overload of its individual parts.

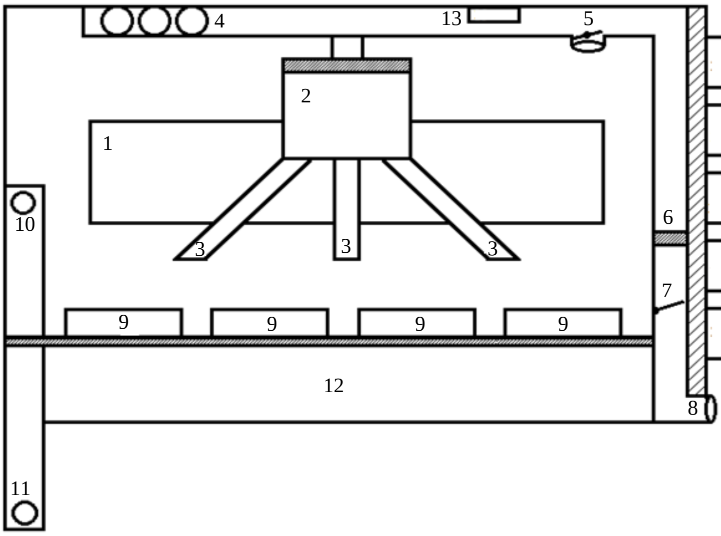

Fig. 4. Equipment layout in the Compass Plus Ltd data center: 1 — equipment racks; 2 — channel air-conditioner with an air supply system; 3 — distributing air duct; 4 — air supply duct; 5, 7 — butterfly valves; 6 — fine filter; 8 — air supply unit; 9 — split system; 10 — fire-fighting air extraction system inlet; 11 — fire-fighting air extraction system outlet; 12 — display room; 13 — air conditioning control panel; 14 — external air conditioner units

- disk usage — a metric showing the current disk space utilization;
- bandwidth — a metric showing the amount of incoming and outgoing traffic;
- primary processes — a metric showing processes that consume the most CPU or memory resources;
- data center hardware temperature sensors.

Fig. 5 shows an example of metrics visualization in the form of a mnemonic diagram. It displays seven temperature sensors as the temperature in a data center should not exceed 26° to avoid equipment overheating.

The color-coded indication shows that the temperature measured by T5 sensor starts exceeding the set value. T2, T3 and T4 sensors indicate normal conditions, the temperature is below 26°, and the temperatures measures by T1, T6 and T7 sensors have reached a critical level of 26° but returned to the normal state.

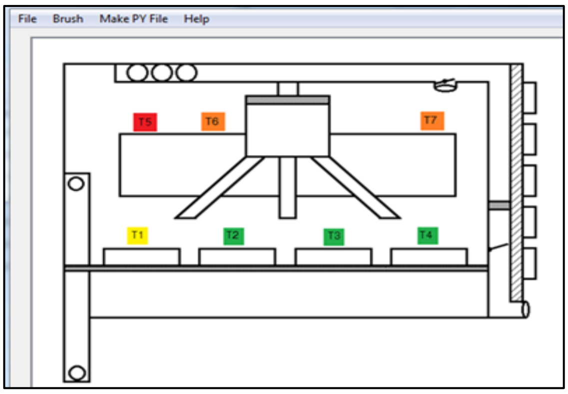

Fig. 5. Data center metrics visualization in the form of a mnemonic diagram: an example

When preparing the tree-type visualization, it is advisable to consider some features of data center operation. Data centers represent large energy consumers. In current conditions, data centers are responsible for over 1% of world energy consumption [11]. For comparison, the entire global industry consumes about 27% of energy produced [12]. It is believed that an increase in the temperature maintained in data centers by one degree can reduce energy consumption by 2–5%. Normally, the set temperature in a data center is 20–22°C.

According to the study performed by Kosenko [13], most servers and active network equipment switch off when the temperature of incoming air reaches 60°C. Calculation of the air heating rate in a data center in case of air conditioning system failure is individual. According to approximate estimates, in a data center with energy consumption of 100 kW, the air temperature will change from 22°C to critical 60°C in about 4–5 minutes.

In this case, a visualization diagram focusing on perception of causes behind data center temperature changes can be suggested (Fig. 6).

Stable power and humidity located at the tree bottom are critical for system operation and should be kept within the specified values. The growth of traffic increases the load on processor and memory, which, in turn, loads the disks. An increase in memory, processor, and disk load leads to a rise in temperature which is a critical parameter in the considered visualization approach.

Fig. 7 shows tree-type visualization which may be more convenient for perception. In the figure, the tree roots show parameters of humidity and equipment energy consumption, the trunk shows data transmission indicators and the branches show equipment utilization parameters and the environment state.

Indicators 21 and 27 demonstrate a power surge (indicator 21). Metric 46 demonstrates that the data reception rates are normal. Metrics 67 and 22 show the volume of memory utilized. Those parameters are normal. Metrics 76 and 32 are responsible for CPU and disk subsystem utilization. Those parameters are also in normal conditions. Parameter 16 is responsible for data center temperature conditions.

Its color indicates nonaccepted values. Considering the occurred power surge and the fact that other parameters are currently normal, an emergency may have occurred. It is advisable to go to the screen with the mnemonic diagram and determine the location of the corresponding sensor.

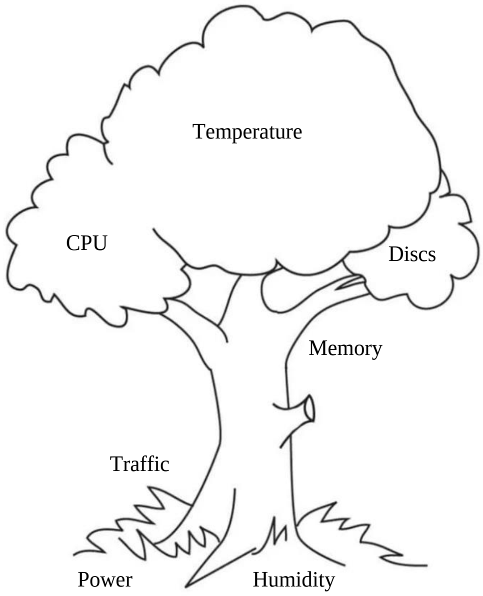

Fig. 6. Visualization diagram focused on perception of causes behind data center temperature changes

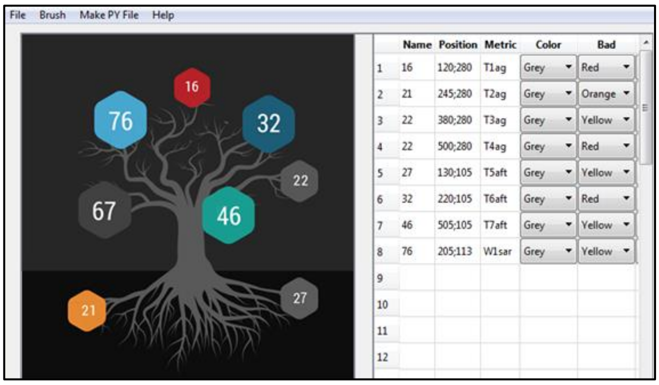

Fig. 7. Tree-type visualization of data center metrics: an example

IV. Conclusion

The described visualization options complement each other. Temperature monitoring is reasonable with the use of a mnemonic diagram to quickly determine the location of a problematic device. Other metrics should be monitored with account for interrelations between parameters, e.g. based on tree-type representation.

In this regard, it is advisable to further develop the design tools for mobile visualization systems, enabling to configure diagrams, defining interactions between parameters or their groups based on measurements of various concepts, at the first stage, and then, at the second stage, to quickly obtain a variety of mobile visualization options using templates of typical methods. Such visualization options can be context-based with regard to solving certain monitoring tasks.

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