Pairing BPM and IoT For Sensor Error Discovery and Recovery Automation

Srđan Popov*, Miroslav Zarić*, Đorđe Ćosić*
* University of Novi Sad, Faculty of Technical Sciences
srdjanpopov@uns.ac.rs, miroslavzaric@uns.ac.rs, djordjecosic@uns.ac.rs

***Abstract*— Business process management (BPM) systems are becoming increasingly data-driven. At the same time IoT (Internet-of-Things) sensing devices are generating large quantities of data. Some of this data represents information about critical events. These events may be used to trigger and drive some automated BPM response procedures to minimize negative effect of critical event or to repair potential damage presented by those events. In this paper, we are proposing pairing of BPM driven application and IoT for sensor error discovery and recovery automation.**

I Introduction

The onset of the age of Internet of Things (IoT) has brought unprecedented possibilities regarding data collection and analysis, and promises ability to significantly improve critical functions in many different activities. The possibilities to use new devices connected to the Internet (ranging from simple sensors to smart devices or complex devices capable not only of sensing but also of actuating certain work), and to use data gathered from these devices and interacting with them is bringing ever larger impact on economy. This change has lately been denoted as 4th industrial revolution. New applications, taking advantage of vast amount of data created by IoT devices are created at increasingly fast rate. The usage scenarios of IoT may range from simple applications aimed for personal use (tracking fitness activities, or monitoring vital signs of chronically ill patients), applications aimed for improving day-to-day activities of larger population (like applications using sensor data to manage public transport congestions), to applications that may have wider scope of use.

Similarly, business process management (BPM) oriented applications have also gained strong acceptance in a variety of business solutions in recent years. BPM applications were initially focused on streamlining traditional interactive business processes by defining clear and understandable process models and orchestrating activities to improve the process efficiency. However, automated business processes, containing primarily automatically performed tasks, have become important tool for achieving various integration scenarios between different software systems. Optimizing emergency management by formalizing emergency response procedures by BPMN, and deploying them to appropriate systems has been in focus of several research papers such as [1,2].

Since business process models may be designed to allow a process instance to be invoked by different external events (timers, signals, messages), pairing the IoT devices, as a source of critical events, with automated business processes is promising faster reaction to events received from the IoT devices.

II The Health of the Sensor

Substantial number of IoT devices are still different types of Internet connected sensor devices, often situated in remote places. Those sensors provide valuable data that are processed for further value added services. Their malfunction, especially when not noticed and corrected in reasonable time, can lead to unreliable or incomplete data series, deficient data analysis, difficulties in making business decisions and other negative effects for systems relying on analysis of those data.

Therefore, IoT sensors, regarded as critical devices to a specific business case, require good maintenance and prompt resolution of potential problems. A trend has been developing [3,4] to merge automated BPM systems with IoT based systems to provide new ways of using data generated by IoT sensor devices, or to bring faster response to detected erroneous situations. If IoT devices are used as integral part of any emergency management system [1,2] the health of the IoT sensor device and its availability must be monitored.

In this paper, we concentrate on using data that specific sensors are providing to determine the health of the sensor device itself, and to trigger appropriate maintenance procedures to prevent their failure, or to minimize the downtime of such a device.

III A Case Study – Environmental Sensors for Agricultural Use

The WAHASTRAT project [5] has developed a network of 8 automated monitoring stations (designated as WH1 – WH8) to provide information about environment variables: soil moisture, speed and wind direction, air temperature, air humidity and atmospheric precipitation. The data from these monitoring stations are collected and analyzed to provide information specifically about water shortage and drought conditions. Currently a new, cross border project is under consideration - to increase the number of sensors (monitoring stations) and to provide data exchange between countries in order to get better coverage and overall understanding of weather patterns in the region and their impact on agriculture.

Availability of data provided by these sensors is invaluable to modern agriculture, and may be used to make informed decisions about irrigation needs during drought periods, or drainage needs and capability of soil to absorb excess water during the prolonged periods of rain.

This information is currently used to assess the risk to agricultural production. All these assessments are also gaining ground as a base for whole base of new business cases, for example about type of plants appropriate for given location, or about new insurance packages and premium calculation for crop insurance.

A. Monitoring station and data acquisition

The monitoring stations are recording the environmental data. Acquired data are stored locally and transferred to a concentrator (server application) in 1h intervals. Local storage represents a buffer with up to 211 address locations of 10-bit data).

Recorded data is exported to the application server over the network connection. Monitoring stations are connected to the internet over the 3G network, using the standard SIM cards, and appropriate built-in 3G modems.

Data from the monitoring stations, essentially sensor logs, are provided in several formats (Comma Separated Values – CSV, Microsoft Excel format – XSL, as well as XML formatted data) to support interoperability. Current setup of the system commonly use CSV format since its relative simplicity. Full data set provided by a monitoring station contains following:

- Soil Moisture 1
- Soil Moisture 2
- Soil Moisture 3
- Soil Moisture 4
- Soil Moisture 5
- Soil Moisture 6
- Battery 1
- Air Humidity 1
- Air Temperature 1
- Precipitation 1
- Wind Speed 1
- Wind Direction 1

Power supply is primarily provided from the solar panels used to charge accumulator batteries.

B. Data Processing

Communication is initiated from the monitoring station to the designated server. The application server provides web service access point and is also running an application for data processing. This application analyzes data, form time-series data, performs statistical calculations and provide data visualization. Data analysis and visualization is provided through a program module utilizing R language [8].

Typical tabular representation of parsed data is given in Fig.1. Overview of all data from one monitoring station and data visualization is given in Fig. 2.

C. Missing Data and Battery Status Data

The system currently does not take any special action to automatically react to a situation when certain log file is missing.

WH2 ×

Filter

	Datum	Vreme	Uređaj	ID.vrednosti	Vrednost
1	10.3.2016	8:18:59	2	SM1	32.811
2	10.3.2016	8:18:59	2	SM2	32.811
3	10.3.2016	8:18:59	2	SM3	32.323
4	10.3.2016	8:18:59	2	SM4	30.871
5	10.3.2016	8:18:59	2	SM5	30.871
6	10.3.2016	8:18:59	2	SM6	34.751
7	10.3.2016	8:18:59	2	BT1	79.671
8	10.3.2016	8:18:59	2	AH1	95.000
9	10.3.2016	8:18:59	2	AT1	6.110
10	10.3.2016	8:18:59	2	PP1	0.000
11	10.3.2016	8:18:59	2	WS1	1.170
12	10.3.2016	8:18:59	2	WD1	272.000
13	10.3.2016	7:19:57	2	SM1	32.811
14	10.3.2016	7:19:57	2	SM2	32.811
15	10.3.2016	7:19:57	2	SM3	32.323
16	10.3.2016	7:19:57	2	SM4	30.871
17	10.3.2016	7:19:57	2	SM5	30.871
18	10.3.2016	7:19:57	2	SM6	34.263
19	10.3.2016	7:19:57	2	BT1	74.320
20	10.3.2016	7:19:57	2	AH1	95.000

Showing 1 to 20 of 238,390 entries

Figure 1. Tabular representation of acquired data with timestamps, sensor IDs and values.

As already mentioned, in addition to the environmental data, a data about battery state is also transmitted. Although recorded, and visualized, as shown in Fig 2 (dark red line) no automatic action is taken if battery data shows that battery is near flattening out. If data received is not examined by operator on a daily basis, the monitoring station failure can go unnoticed for some time. If some monitor station is unable to transmit its data over prolonged period of time, data loss is imminent.

There are several possible reasons for monitor station not to be able to transmit its data:

- loss of power supply due to accumulator battery failure, or simply because solar panels are obstructed by leaves or dust,
- 3G interface (modem) failure, either by software failure, hardware failure, or simple oversight such as unpaid telecommunication bills,
- physical damage.

Although for the last one there is no simple solution, in some cases timely alert can provide enough time to react to avoid data loss, and to keep monitoring station up and running.

Battery level data are of special value, since they may show trending, which may be detected by data analysis algorithm, compared to some predefined threshold, and if certain conditions are met, a timely alert, before battery levels falls below critical level, may be created.

Furthermore, if a predefined number of logs are not received from a certain monitoring station, server can detect missing data, and again create an alert. Since monitoring stations are usually on remote spots, this will give appropriate, and timely warning to authorized person to inspect the monitoring station, hopefully, prior to its failure.

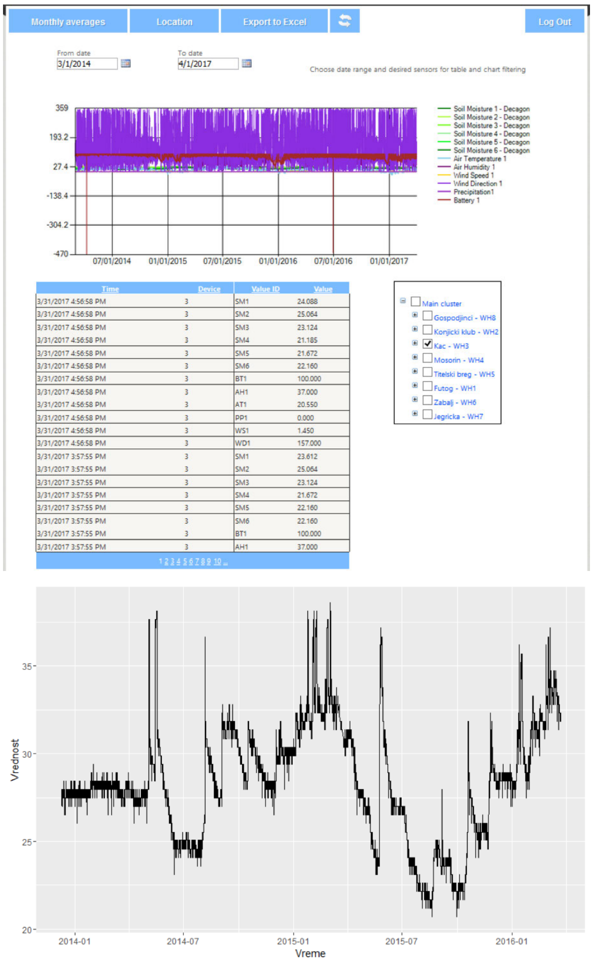

Figure 2. Visualization of data from a certain monitoring station (above - group view, below - data from a single sensor).

IV ENHANCING SERVER APPLICATION WITH BPM BASED ERROR RESPONSE

We are proposing to extend the current setup on the application server, in such a way that it provides not only acquired data statistical analysis and data visualization, but to proactively react and support maintenance operations for monitoring stations.

As any recovery procedure requires some actions to be performed in given sequence, a process model approach is a reasonable choice. BPM applications are making transition from typically interactive processes to more data-driven processes in recent years [6]. Approaches of joining BPM based systems with IoT are increasingly gaining ground [6, 7]. Pairing of BPM data-driven application with data from IoT devices (monitoring stations in our case) is likely to be beneficial for overall functionality of the system.

As a first phase, we are developing a BPMN model of appropriate response procedure. In order to support trigger signal creation, adaptations of R language algorithms were also needed. The adaptations cover the detection of battery low power state, as well as detecting the missing data from monitoring stations.

If events representing error or warning are detected during the data analysis, a signal is created to trigger the execution of semi-automated recovery process. Such a process is modeled, deployed and when necessary upgraded by using process aware software solution such as BPM processing engines.

In initial implementation, we are aiming at automated alerting of authorized persons to check the health of monitoring station. Since current monitoring stations are not capable of receiving commands online. In a more advanced implementation, with monitoring station supporting bidirectional communications, a process could be polling the monitoring station to try to retrieve additional data or to gain more insight about monitoring station health status. Since an upgrade of the monitoring station is envisioned, the response procedure is already developed to support the polling, although the service task is currently unimplemented. The basic model of automated response process is given in Fig. 3.

When a signal to start recovery is received, data is rechecked to determine the type of the problem. Currently no monitoring station supports remote command mode, so after the type of error is determined, a notification to person responsible for the monitoring station maintenance will be sent. Notification will contain error details. By examining

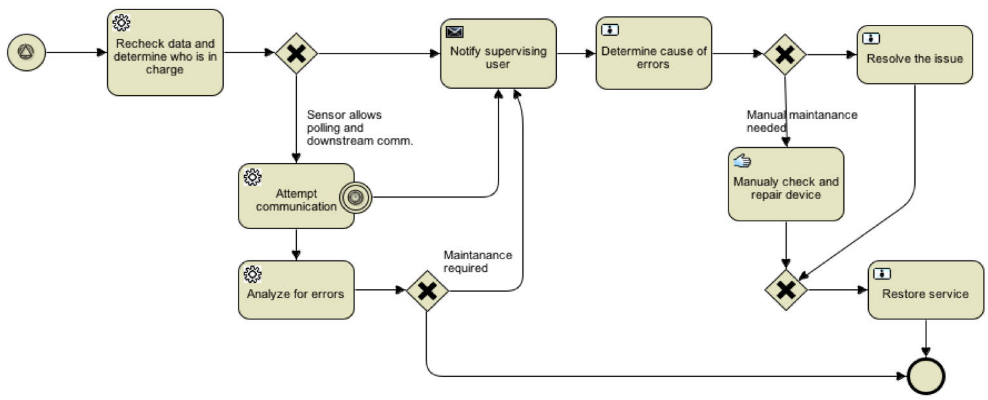

Figure 3. Proposed (semi)automated error discovery and recovery process.

the error details, the authorized user can decide whether the manual inspection and the visit to the monitoring station is necessary or the issue may be resolved in some other way. After the issue is resolved, the normal service of monitoring station may be restored.

If a problem has occurred on a monitoring station that will support remote commands (as none currently does), the attempt to contact the monitoring station will be made. For this purpose, a service task invoking the communication is added to the process.

Since monitoring station may in fact already have failed, the communication task is timed, and if no response is received in given time, authorized user action is again needed. If communication is successful, and monitoring station is responding, the newly received data is analyzed to determine whether further action is needed.

V CONCLUSIONS AND FURTHER WORK

In our paper, we have focused on a problem of detecting a failure of an automated environmental monitoring station used for acquiring data primarily about soil humidity. There is an operational network of such monitoring stations. Monitoring stations are acquiring data for several years, and these data are regularly analyzed. However, detection of monitoring station failure has not been properly addressed. Although failures of monitoring stations have been fairly rare, they do happen from time to time. Sometimes such a failure may have been prevented if some corrective actions have been taken.

By adapting the data analysis algorithm, we can detect critical events and use them to trigger automatic execution of modeled response procedure. In the simplest implementation, the recovery procedure will notify authorized personnel, responsible for the given monitoring station, to check the health of monitoring station. In this case we are getting faster response, when compared to standard review and detection of the problem from the plotted graphs.

If a monitoring stations are upgraded, and bidirectional communication is made possible, some form of automated recovery may be attempted directly from the recovery process.

BPMN is well known and adopted process modeling language, and there are several commercial and open source process engines that supports deployment and execution of processes described in BPMN. In this case, use of process model driven system as an implementation platform gives an extra flexibility, making it possible to adapt current base model to further, more sophisticated, needs. Similar approach may be used for any kind of sensor as long as error conditions may be derived from data obtained from the sensor itself (or from the absence of that data).

REFERENCES

[1] Norwegian Emergency Management Process By Using Business Process Modeling Notation, V. Nunavath and A. Prinz, *8th IADIS International Conference Information Systems, Madeira, Portugal, 2015*

[2] Design Patterns for Emergency Management Processes, T. Ludík and T. Pitner, *Proceedings of 11th IFIP WG 5.11 International Symposium, ISESS 2015,* IFIP *Advances in Information and Communication Technology, vol 448, pp 434-444, Melbourne, VIC, Australia, 2015.*

[3] BPM and IoT: Transformation at the Digital Interface to the Physical World, *BPM Whitepaper* [http://bpm.com/resources/featured-whitepapers/1081-bpm-and-iot-transformation-at-the-digital-interface-to-the-physical-world]

[4] Integrating the Internet of Things with Business Process Management: A Process-aware Framework for Smart Objects, G. Merroni, *CEUR WORKSHOP PROCEEDING,* 2015

[5] Water shortage hazard and adaptive water management strategies in the Hungarian-Serbian cross-border region [https://wahastrat.vizugy.hu]

[6] IoT-BPM Case Study, [http://www.pnmsoft.com/wp-content/uploads/2016/02/IoT-BPM-case-study.pdf]

[7] Internet of Things-aware Process Modeling: Integrating IoT Devices as Business Process Resources, S. Meyer, A. Ruppen, C. Magerkurth, *25th International Conference, CAiSE 2013, Valencia, Spain, June 17-21, 2013. Proceedings*

[8] The R Project for Statistical Computing, [https://www.r-project.org/] accessed in april 2017.