Development of a program system for managing vending machines

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Abstract—**Due to the lack of comprehensive software products for monitoring sales in vending machines and analyzing sales data, the subject of this paper is to develop an IT-solution for vendings which includes the ability to remotely monitor the status of vending machines, make contactless purchases and receipts of goods in the vending, and automatically analyze data of purchases in order to identify trends in consumer demand. To develop the system, cloud technologies and client-server architecture, built with the use of the Raspberry PI controller in the vending, are used. The result, which is achieved through the development of a comprehensive system for vending machines with the implementation of a contactless sales algorithm for vending machines with the possibility of reserving goods, can have many commercial applications.**

Keywords—*vending, smart vending, vending management system, vending BI, Raspberry PI.*

I. Introduction

Due to the ease of operation of vending machines and popularity of their use by consumers, the vending business is spread worldwide as a convenient and less demanding way to trade, provide goods and services, leading to an increase in the number of machines and vending networks formation, which creates a demand for the development of automated system for management operations of vending networks.

Moreover, in the situation of maintaining social distance due to the current epidemiological situation, the use of vending machines with an implemented contactless purchase technology is one of the possible solutions for organizing remote receipt of products and services.

The necessity to develop and implement program system for vendings determines the relevance of the work and is associated with the following reasons:

- Insufficient quality of management decisions due to the lack of ability to collect sales data from vending machines, automatically analyze sales information and create analytical reports.

- Significant operational and time costs owing to the lack of a replenishment system which can be based on data collected from a system of electronic document management and reporting.

- Meaningful support costs for vending machines because there is no opportunity to get remote access to them and get actual information about them.

According to the papers [1]-[10] the project is relevant as there is no comprehensive software product that can continuously monitor and control sales in vending networks, make decisions about sales optimization and make contactless sales.

Development and implementation of system for analyzing sales and managing vending machines is the main aim of the project.

To achieve the described goal, it is necessary to analyze information related to this subject area, design a software system for managing vending machines and analyzing sales data and develop the program system and test it.

II. Processes in vending business to automate

This section describes business processes which can be automated in vending systems and the concept of IT-solution for vendings which is going to be developed.

Considering the work of vending machines and the business associated with them, there are six main business processes that can be fully or partially automated, including:

- purchase of goods,

- delivery of goods,

- monitoring the assortment of vending machines,
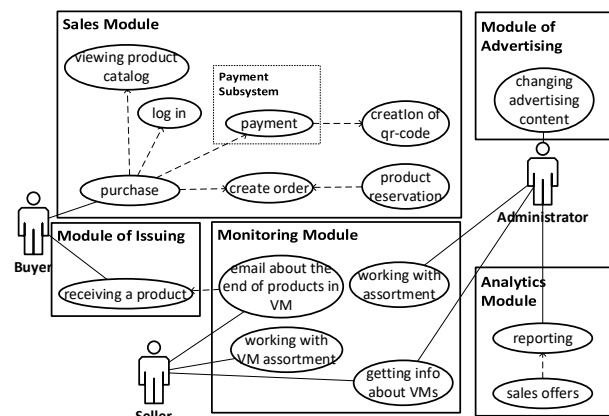
- sales analysis and reporting,

Fig. 1. Processes in vending business which can be automated

- monitoring the status of vending machines,

- and displaying advertising content.

Taking into account the automation of the processes of the vending business highlighted above, the description of the modules of the concept model of the system is shown in the Fig. 1.

The Sales Module includes placing an order, creating a customer basket, reserving a product in a specific vending, and paying for the order. The Module of issuing realizes the process of receiving the order. These modules are intended for such a user of the system as the Buyer.

The Analytics Module is designed for the salesperson (Seller) and the system manager (Administrator), while the Module of Advertising and the Analytics Module are created only for the Administrator because changing advertising content and creating analytical reports are available only for the owner of the vending business.

Receiving an email with a notification of the necessity to replenish the product in the vending in the Monitoring Module expands the precedent of receiving the product and is associated with Sellers' vending service work. For the Seller, working with the vending assortment and getting information about vending machines are also provided in the Monitoring Module. The Module of Monitoring also includes working with the assortment for the system manager.

According to the selected business processes, the considered approaches to building vending systems and existing IT-solutions should relate to the field of software systems related to inventory management, namely retail management systems and vendor management software.

III. EXISTING APPROACHES AND IT-SOLUTIONS FOR VENDINGS

This section compares existing approaches to solving problems of automation of selected processes and IT-projects implemented in retail chains in terms of functions performed and architecture, justifies the choice of software solution implementation based on the assessment and comparison of analogues.

There are plenty of papers which describe various software systems and approaches to creating program systems for automation of vending business, but all these works can be divided into groups depending on the architectural solution and the hardware used (which directly affects the functionality of the entire system).

Most of the works under consideration [1]-[3], [5]-[9], [10]-[11], [12] focus on the use of cloud technologies and IoT. Since the goal of the project is to create a comprehensive software product for managing the vending business, which includes such functionality as contactless purchase, product reservation, analysis of sales data, storage of transaction data, remote access to vendings, display of advertising content, the works under consideration are evaluated in terms of the selected functionality and hardware that implements this functionality.

The paper [4] presents the realization of the program system for vending machines based on IoT and web technologies which are used for organizing mobile micropayments based on the NFC technology. Hardware of the system consists of a simple microcontroller Arduino which is enabled to interact with Vending Machine Controller. The same hardware is used in [8]. The described solution for the vending system is focused on the implementation of sales, while the current system is concentrated on continuously monitoring and control sales in vending networks, making decisions about sales optimization, analyzing sales data, and making contactless sales using QR-codes to issue goods with the possibility of reserving the product when purchasing in any vending machine that has this product.

The main difference between [1]-[3], [6]-[10] and the software system described in the article [5] is the ability to buy more than one product in the vending at one time, which expands the capabilities of the vending machine. Moreover, the described program control system in [5] is extensible for the implementation of IoT technologies by using the concept Fuzzy Logic Controller, which is based on the following components: an IoT gateway device, a vending machine input/output expansion board and peripherals of vending machines.

Using cloud based Service Component Architecture (SCA) runtime service which is integrated with vending machine system in order to increase system efficiency is the main idea of the work [6]. To develop the program system which consist of four components – "Vending Machine System Management Module", "Financial Management Module", "Logistics Management Module" and "Vending Machine Module" [6], the architecture for vending machine system of Platform as a Service (PaaS) is used. The architecture of current project is going to be developed as PaaS.

The functionality of the systems which are described in works [1]-[7], [9], [10], [12] is almost the same. IT-solutions realize an opportunity to control sales information and the information about the vending, while such functions as contactless purchase, product reservation, analysis of sales data and display of advertising content are not implemented in the described projects or implemented only partially.

New opportunities in vending systems such as implemented payment system based on using SMS, "early warning system" (EWS) [8] to signal the battery status and monitoring sales system, which is developed as an Android application to control sales data continuously, are described in the work [8]. The developed vending system consists of an Arduino controller, SMS Gateway module "Wavecome", battery and input interface. Even though the described system has significant benefits like an ability to monitor sales 24 hours a day and battery status, to support cashless payments, used SMS as the main way of connection in vending system may increase cost of using vending system as each message that is sent has a fixed cost and the number of such messages in the system tends to be substantial.

Usage of Electronic Product Code (EPC) and IoT is implemented in the vending system, and the concept of such implementation is illustrated in the article [10]. Furthermore, the paper describes the design of the data of vendings which based on encapsulation format of the data. Data encapsulation format, described in the work, could be developed in the current project, as such form of presentation data is a unified standard for vending machine.

Furthermore, sending data in JSON format to form connection between hardware and software, from vending machine to the webserver is the main idea presented in the paper [7]. Using HTTP Protocol to send data to server is another idea of this work and also is described in the IT-solutions [1]-[3], [6], [10]. The realized integration of the monitoring system for vendings with webserver can be considered as an analog of the current system.

Two works [12], [12] illustrate the process of developing not the entire system, but its parts. Implementation of system which can identify such customer characteristics like age and gender based on CNN networks and used in vending machines

to analyze customer's preferences is described in the work [12]. Integration of AI technologies in a vending sale system opens the possibility to find out groups of consumers and their purchasing behavior and based on their preferences sell corresponding products in vending machines. The block of sales analysis of the current project may be extended by using the customer recognition model which can be based on the model described in the article.

The article [12] presents a method to organize replenishment in vending machines in real-time based on mathematical model which includes five characteristics: selling price, product cost, traveling cost and quantity of the product, daily forecast demand of the product and time interval of replenishment of vending machines. The described real-time replenishment system (RRS) is effective to decrease transport cost for filing vending machine, so the described idea of the replenishment system for vendings could be taken

into consideration in the current project to reduce transport costs.

While other described works [1]-[6], [8]-[10] are focused on the software and hardware and the architecture of the program system for vending machines, the significant part of this work [11] is dedicated to the development of an interface solution for vendings, which includes the product retrieval system based on a chute system. The vending system includes a fingerprint recognition system and a alarm system, which make the machine safe, and the advertising platform for vendings' owners to attract new consumers. The developed system is not designed to form vending networks, form sales reports and make contactless orders, but it has an ability to broadcast advertising content which is a promising source of profit.

The works which are described and analyzed above are presented in Table I for clarity.

TABLE I.   REVIEW OF EXISTING APPROACHES SOLVING PROBLEMS OF AUTOMATION OF SELECTED BUSINESS PROCESSES AND IT-PROJECTS IMPLEMENTED IN RETAIL CHAINS FROM THE POINT OF VIEW OF THE FUNCTIONS PERFORMED

Approach/IT-Solution	Requirements							Architecture
	Contactless Purchase	Product Reservation	Replenishment Module	Analysis of Sales Data	Storage of Transaction Data	Remote Access to Vending	Display of Advertising Content	
[1] Vend-Track	+/-	-	+	+	+	+	-	Client-server
[2] Cantaloupe	+/-	-	+	+	+	+	-	Cloud computing
[3] VMS – Cloud Based Vending Management System and Vending BI	+/-	-	+	+	+	+	-	Cloud computing
[4] A. Solano, …, "Smart vending machines in the era of internet of things"	+/-	-	-	-	+	+	-	Cloud computing
[5] E. Murena, …, "Design of a control system for a vending machine"	+/-	-	+	-	+	+	-	Client-server
[6] F. Lin, …, "Service Component Architecture for Vending Machine System in Cloud Computing Infrastructure"	+/-	-	+	+	+	+	-	Cloud computing
[8] S. Arifin, …, "Smart vending machine based on SMS gateway for general transactions"	+/-	-	+	+	+	+	-	Client-server based on SMS Gateway Module
[9] S. Tegeltija, …, "Universal IoT Vending Machine Management Platform"	+/-	-	-	-	+	+	-	Client-server
[10] Z. Qing and Y. Pu, "Research and application on vending machine data integration based on EPC system"	+/-	-	-	+	+	+	-	Client-server
[11] V. Sibanda, …, "Design of a high-tech vending machine"	-	-	+	-	+	+	+	Client-server

After analyzing the existing solutions for the automation of the dedicated business processes (see Table I), it is clear that none of the existing solutions fully automates the described business processes, but the architectural solutions illustrated in existing works (client-server architecture, web-service development, integration with cloud technologies) could be taken as the basis for the current system and described in details in the next part of the work.

IV. DESIGNING A SOFTWARE SYSTEM FOR MANAGING VENDING MACHINES AND ANALYZING SALES DATA

To develop the system for managing vending machines and analyzing sales data it is necessary to design the architecture of the IT-solution, chose methods and tools to realize the whole system, describe main program modules in details using sequence diagrams.

The concept of the system architecture, which includes the connections between the software and hardware parts of the system, and the main processes of the program such as buying and receiving goods in the vending are discussed in this part of the paper.

A. Vending controllers review and selection

As part of the current work, the vending machine and software are being developed to sell products that are located on the spirals of the vending machine. It is suggested to use servomotors (servos) to put the spirals in motion. Using a spiral architecture as a vending distribution device allows you to accurately position the product in the vending, and linking to the servos allows you to calculate the time for scrolling the spiral to deliver the product.

As a vending controller, it is proposed to use a single-board computer, rather than a microcontroller, due to the need to solve several tasks simultaneously on such a controller, which is not possible when using a microcontroller.

As a single-board computer, the following options can be used, the characteristics of which are given in Table II.

TABLE II. OVERVIEW OF SINGLE-BOARD COMPUTERS

Name	Raspberry Pi 3 model B+	Hackboard 2	Rock Pi4	NanoPi R4S	NVIDIA Jetson Nano 2GB	Asus Tinker Board
Price	≈ $38	$99	$49	$45	$54	≈ $86
CPU	Broadcom BCM 2837B0	Intel Celeron N4020	Hex Core Rockchip RK3399	Rockchip RK3399	Quad-core ARM A57	Rockchip RK3288
RAM	1 GB	4 GB	1 GB	1 GB	2 GB	2 GB
MicroSD	+	+	+	+	+	+
OS	Linux	Linux, Windows 10 Pro	Debian, Ubuntu	Linux	Linux	Debian, Kodi
USB	4 USB 2.0	3 USB 3.0	2 USB 3.0, 2 USB 2.0	2 USB 3.0 Type-A, USB 2.0	2 USB 2.0, USB 3.0	4 USB 2.0
GPIO	40-pin GPIO	40-pin GPIO	40-pin GPIO	2*5 pin connector with SPI and l2C	40-pin GPIO	40-pin GPIO
Wireless connection	Wi-Fi, Ethernet (RJ-45) Bluetooth 4.2	Wi-Fi-module Intel dual-band AC95060 Bluetooth 5.1	Wi-FI 802.11 ac, Bluetooth 5.0	2 Gigabit Ethernet ports	802.11 ac wireless, gigabit ethernet port	802.11 b/g/n Bluetooth 4.0
Display	HDMI 2.0 DSI Port for Raspberry Pi Touch Display	Intel UHD Graphics 600 with 4K HDMI 2.1 output	HDMI 2.0	-	HDMI	HDMI 2.0 with support for resolutions up to 4K Display Serial Interface (MIPI DSI) with HD resolution support
Camera	CSI Port for Raspberry Pi Camera	-	2 MIPI CSI for cameras or display, support for cameras up to 8 MP	-	CSI port for the camera	CSI port for the camera
Size	85 × 56 mm	120 x 80 mm	85 x 54 mm	66 x 66 mm	100 x 80 x 29 mm	85,6 × 54 mm

According to the Table II, the best option in terms of price and features is a single-board computer Raspberry Pi 3 model B+, since for use in vending machines for a single-board computer, it is enough to have RAM equal to 1 GB, the ability to install microSD cards for installing Linux OS and a software solution for vending, as well as to have ports for display and camera, support wireless communication, which are typical for this hardware solution of minimal cost, therefore, this single-board computer is proposed to be used in the development of the system.

B. Development of an architectural solution for a software system

The system is based on the principle of client-server architecture, since this type of architecture is the simplest and most commonly used in the development of software for vending machines, according to a comparative analysis of existing approaches for the development of software for vending machines and software products used in vending networks (see Table I).

The client is a vending (software developed in the Python programming language and installed in the vending for the controller based on Raspberry Pi 3 Model B+) that exchanges information with the server (based on ASP.NET Core Framework) via HTTP requests (see Fig. 2). The whole system is going to be developed using the Visual Studio 2019 (a tool for developing).

Information about sales, products, and vending is planned to be stored in a database (MS SQL Server is going to be used) hosted like a server in cloud storage, which requires access to the Internet network from the vending itself. A query constructor based on the execution of parameterized

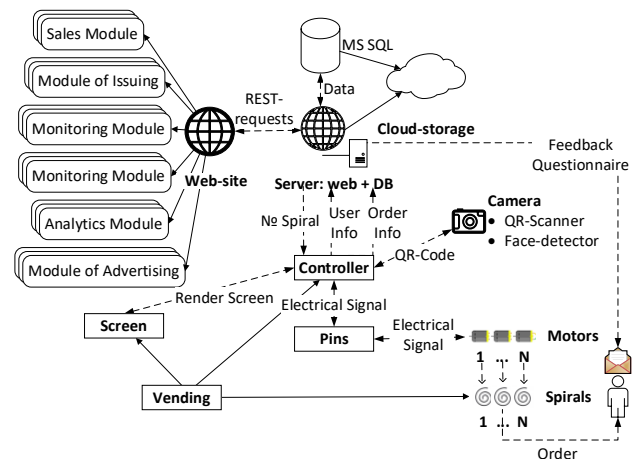sql-queries to the database is going to be developed to analyze sales data.

Fig. 2. System architecture

C. Description of the processes of buying and receiving goods in the vending

Buying and receiving goods in the vending are the main processes which need to be automated.

To ensure contactless sales, moving away from the hardware dependence on the payment system, payment is provided on a third-party site. Payment on the site allows implementation of the ability to purchase and reserve goods in a specific vending (see Fig. 3).

Thus, the purchase of goods is completely made on the site: the customer creates a basket, pays for the order, makes a reservation of goods if necessary, information about the order is stored in the database. Based on the order ID, a QR-code is generated, which is sent to the customer at the email address specified on the website (see Fig. 3).
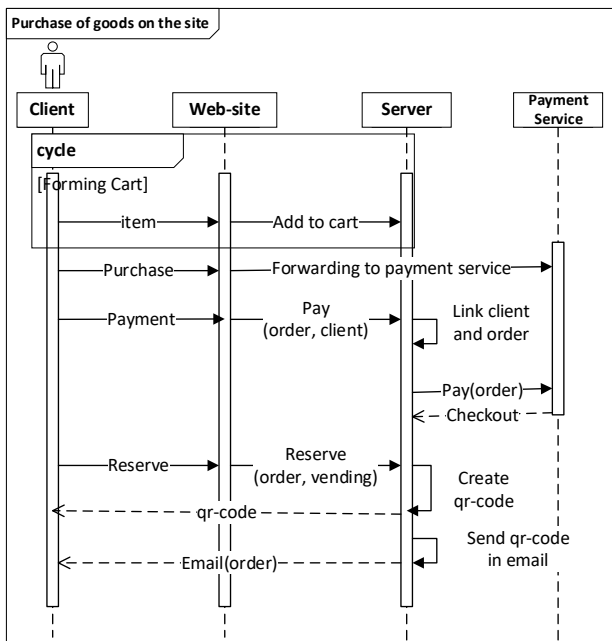

Fig. 3. Purchase of goods on the site with the possibility of reservation for receiving in a specific vending

After making a purchase of goods on the site, the customer must pick up the purchased goods in the vending. As a result of making changes to the process of purchasing goods from the vending, which include contactless sales and reserving products in the order in vendings through the web site with the formation of a QR-code to receive ordered items, changes are required to the process of receiving goods (see Fig. 4).
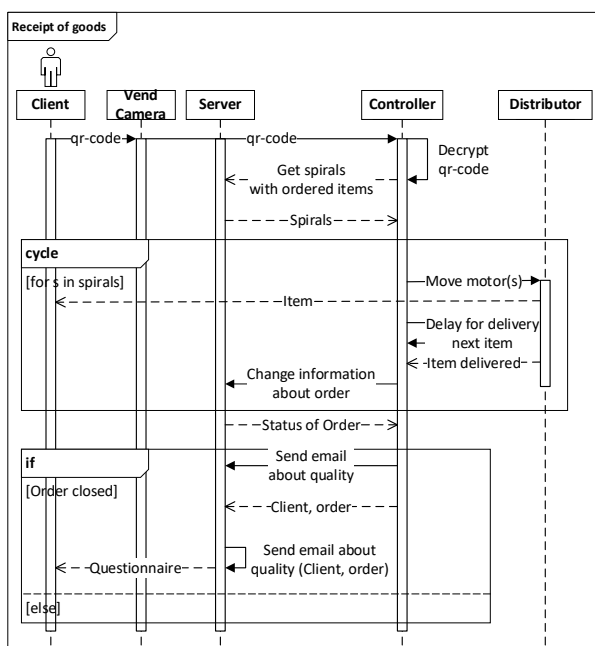

Fig. 4. Receipt of goods by scanning the qr code in the vending

To receive the goods, the customer brings the QR-code to the vending machine camera, the vending machine controller reads the order information and sends a GET request to the server to get information about the order, to get information about the spirals on which the purchased goods are located. After the request is completed, a list of spirals is received, a servomotor is set in motion for each of the received spirals, the product falls from the spiral, the customer can pick up the product. After the product is delivered by the vending, a POST request is made to change the order information. If all the products of the order are received, the order status changes (the order is closed), a small questionnaire is sent to the customer's mailing address to assess the quality of the services provided and the purchased goods. The information about the estimates is stored in the database for further use in sales analysis.

V. RESULTS

As part of the current work, an analysis of literature resources; comparative analysis of software solutions and approaches to the implementation of vending machine management systems; main functional requirements for the software product presented using the use case diagram and sequence diagrams; methods and tools to develop the IT-solution were identified.

In the near future, the system modules will be programmed based on the designed architecture. These modules will later be combined into a single system for managing vending machines.

VI. CONCLUSIONS

The project is focused on the development of a software product for managing vending machines based on the principles of client-server architecture, cloud technologies.

The significance of the work lies in the practical application of the software product in the vending business as a tool for effective sales organization (using of contactless purchase technologies to ensure the safety and convenience, making informed decisions about the replenishment of the vending, collecting and analyzing sales data in order to identify customer preferences). The proposed method of contactless purchase through the site (the creation of a QR-code for receiving goods in the vending) and the possibility of reserving goods in a particular vending are features of this work that are not considered in other similar systems for vendings and approaches for their design [1]-[12].

The proposed solution expands the capabilities of the vending business and can be considered in future works as a part of the implementation of the system of interaction with various smart devices.

REFERENCES

[1] "My Vend Track - Vending Management Software", Myvendtrack.com, 2020. [Online]. Available: https://myvendtrack.com/. [Accessed: 16- Dec- 2020].

[2] "The unattended retail platform you need to optimize your entire business.", USA Technologies, 2020. [Online]. Available: https://www.usatech.com/. [Accessed: 16- Dec- 2020].

[3] "VMS – Cloud Based Vending Management System and Vending BI - OTI Europa ASEC S.A", OTI Europa ASEC S.A, 2020. [Online]. Available: https://otieuropa.com/en/vms/. [Accessed: 16- Dec- 2020].

[4] Solano A., Duro N., Dormido R. and González P., Smart vending machines in the era of internet of things. *Future Generation Computer Systems*, 2017, vol. 76, pp. 215-220.

[5] Murena E., Sibanda V., Sibanda S. and Mpofu K., Design of a control system for a vending machine, *Procedia CIRP*, 2020, vol. 91, pp. 758-763.

[6] Lin F., Lee Y., Hsu C., Chen K. and Weng T., Service Component Architecture for Vending Machine System in Cloud Computing Infrastructure, In: *2009 IEEE International Conference on e-Business Engineering*, 2009, pp. 591-595.

[7] Asyhari M. W., Sigit R. and Sukaridhoto S., Vending Machine Monitoring System Integrated with Webserver, In: *2019 International Electronics Symposium (IES)*, 2019, pp. 556-559.

[8] Arifin S. et al., Smart vending machine based on SMS gateway for general transactions, In: *2017 15th International Conference on Quality in Research (QiR) : International Symposium on Electrical and Computer Engineering*, 2017, pp. 34-39.

[9] Tegeltija S., Tejic B., Senk I., Tarjan L. and Ostojic G., Universal IoT Vending Machine Management Platform, In: *2020 19th International Symposium INFOTEH-JAHORINA (INFOTEH)*, 2020, pp. 1-5.

[10] Qing Z. and Pu Y., Research and application on vending machine data integration based on EPC system, In: *2011 International Conference on Consumer Electronics, Communications and Networks (CECNet)*, 2011, pp. 4304-4306.

[11] Sibanda V., Munetsi L., Mpofu K., Murena E. and Trimble J., Design of a high-tech vending machine, *Procedia CIRP*, 2020, vol. 91, pp. 678-683.

[12] Hsu C., Lin Y., Shiue Y. and Sun C., New Generation Artificial Intelligent Vending Machine System based on LoRaWan IOT Network, In: *2019 IEEE International Conference on Consumer Electronics - Taiwan (ICCE-TW)*, 2019,. pp. 1-2

[13] Poon T., Choy K., Cheng C. and Lao S., A real-time replenishment system for vending machine industry, In: *2010 8th IEEE International Conference on Industrial Informatics*, 2010, pp. 209-213.