Universal IoT Vending Machine Management Platform

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Abstract— **With the advances of technology, vending machines have evolved from simple devices that sell individual products and provide simple services to complex devices where product and service offerings are tailored to each individual user. Following the increasing need to use a large amount of information in real-time (optimization of supply, timely updating of machines, monitoring the status of vending machines, etc), an increasing number of vending machines are connecting to the Internet and represent the IoT devices in the IoT ecosystem. In this paper, a solution for a universal IoT platform for managing vending machines is proposed. Emphasis is placed on the implementation of the control unit with an additional module for interaction with the users.**

Keywords-IoT; platform; management; vending machine;

I. INTRODUCTION

Vending machines include all automated machines and devices intended for sale of different types of products and the provision of different services [1]. The first vending machines were intended for the sale of one type of product (beverages, snacks, cigarettes, newspapers, etc.) as well as the payment of one service (purchase of tickets for transportation, photo booths, vehicle washing, etc.) [2]. Vending machines are mostly installed in busy places (shopping malls, bus and train stations, airports, schools, university campuses, companies) [3]. Unlike most outlets, the vending machines offer the most sought after products and services available to customers 24 hours a day, 7 days a week. Vending machines allow users to easily and quickly purchase a product or pay for a service without waiting in line. Facilitated and accelerated payment at vending machines has been made possible by the application of an increasing number of cashless payment systems [4], [5]. All this has led to the fact that vending machines have gained a lot of popularity among users over many decades of use on the market. On the other hand, the high popularity of vending machines among users brings a very large profit to their owners [6].

Due to the mutual benefit for users and owners, vending machines have been refined throughout history. With the advances of technology, vending machines have evolved from simple devices that sell individual products and provide simple services to complex devices where product and service offerings are tailored to each individual user. The simpler vending machines have ready-made products for sale (snacks, sweets, soda, soft drinks, sandwiches, water, spirits, etc.), while slightly more sophisticated vending machines offer customers the preparation of cold and hot beverages as desired, such as various types of coffee, tea, and refreshments. The most advanced vending machines prepare consumers with more complex food products, such as vending machines making fries, ice creams, etc. Depending on the offered products and services, as well as depending on the place of installation, vending machines can be of different sizes and shapes and can be placed both individually and in larger clusters. Fig. 1 shows an example of clustered vending machines for selling snacks, cold and hot drinks [7].

Figure 1. An example of clustered vending machines

In recent years, in order to sell products and provide services that are not offered by traditional vending machines, such as the sale of souvenirs, gold, cars, jewelry, vending machines for 3D printing service, etc, specialized vending machines have been developed [8]. Lately, vending machines for the sale of agricultural products, i.e. fresh fruit and vegetables, eggs, milk, and dairy products, have been increasingly found [8]. The application of new technologies has enabled vending machines to be equipped with large screens for user interaction (dynamic UI change) as well as to display advertisements and products/services information offered on vending machines. There are also vending machines with built-in cameras and image processing systems with implemented artificial intelligence algorithms that, in addition to the security aspect, allow users to identify the age/gender of users and thus tailor information to vending machine users as well as optimize supply on vending machines [9]. Following the increasing need to use a large amount of information in real-time (optimization of supply, timely updating of machines,

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monitoring the status of vending machines, etc), an increasing number of vending machines are connecting to the Internet and represent one of the IoT (Internet of Things) devices in the IoT ecosystem [10], [11].

The vast majority of vending machine manufacturers make their own dedicated control units for managing vending machines and very often especially for one type or series of vending machines. The dedicated control unit integrated into the vending machine communicates with all sensors (buttons, switches, temperature sensors, keyboards, etc), actuators (motors that drive spirals or belts that eject products to customers, refrigeration unit compressors, etc), devices for payment (cash and non-cash) and auxiliary devices (information displays). Since there are many older vending machines on the market that have mechanical assemblies in good condition, there is a possibility to repair the machines and continue their lifespan as new machines. Today it is very difficult, and for some vending machines even practically impossible to obtain control units (vending machines older than 10 - 15 years) and therefore it is not easy to repair them. With this drawback, the technology used ten years ago cannot introduce the innovations that are being implemented today in new vending machines (cashless payment systems, remote monitoring and management, etc).

Recently, there has been a trend in the development of new control units that enable the replacement of existing control units of vending machines with new control units. The new control units are being implemented by combining them with computers running vending machine firmware. New control units enable the implementation of new technologies in old vending machines (IoT concept, optimization of product and service offerings, remote monitoring, predictive maintenance, etc.) [12]. The disadvantage of these devices is that all control functions are implemented in one microcontroller unit which slows down the process of operation and complicates the implementation of vending machine management software. To connect different machine types, the wiring in the vending machine needs to be modified. Encouraged by these shortcomings and the trend to develop more complex drivers (running on computers running vending machines), this paper presents the development of a universal platform that, through appropriate minimal changes to the software and hardware level of a vending machine, can be used at multiple types of different vending machines. The very introduction of computers opens great opportunities for a vending machine to become an IoT device and offers many more opportunities to both end-users and vending machine owners. With the new universal platform for managing the operation of vending machines presented in this paper, we get:

- a simpler, faster and less costly process of repairing vending machines
- use the same or similar software on different kinds and types of vending machines,
- enabling the use of new payment systems on vending machines.

The realized control unit has the possibility of easy integration into both new vending machines and existing vending machines. It can in parallel connect to an existing control unit and be configured to only collect vending machine status information.

II. Conceptual Solution

Initially, dedicated control units that were independent units were used to manage vending machines. These control units are easier to manage vending machines and they executed simpler control algorithms. As more vending machines need to implement more complex control algorithms, to effectively manage vending machines due to the need to manage multiple actuators, monitor information from multiple sensors, communicate with more advanced cash and cashless payment systems, new types of control units for managing vending machines have been implemented. The new vending machine control units (VMCUs) have been implemented as an interface between the hardware components of vending machines on one side and computers running more complex control algorithms. Fig. 2 shows a block diagram of the new vending machine control units.

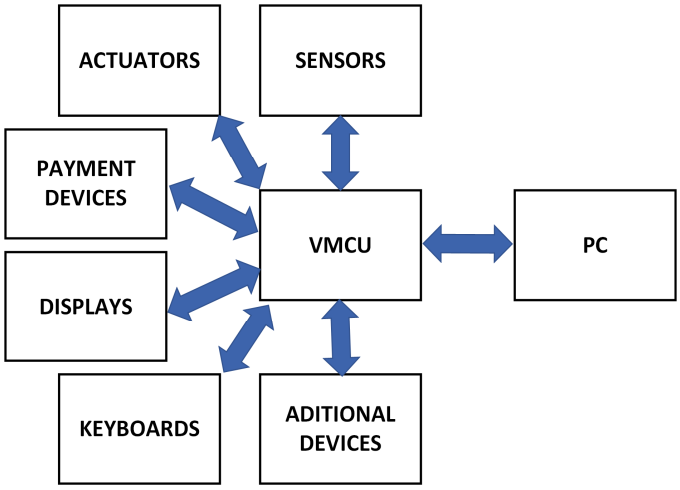

Figure 2. A block diagram of the new control units

The disadvantage of this way of implementing new control units is that it is very difficult to implement them into existing vending machines. Major changes to hardware (wiring) and existing software components are required to be implemented. Another disadvantage was that all hardware components of the vending machine were connected to the new control units of the vending machine, which was a bottleneck. The management application running on the computer sent commands to the vending machine control unit, which forwarded the received commands to the hardware components of the vending machine, and then followed up all the results of the tasks as well as information gathered from the vending machine sensors to the application on the computer. Newer vending machines are equipped with a large number of actuators, sensors as well as cash and cashless payment devices, often blocking the flow of information, slowing down the work and at some moments and unreliable operation of these control units. To solve the problem of overloading vending machine control units, the platform implemented in this paper is designed to divide the vending machine hardware

system into multiple independent entities in order to unload the control unit. The basis of the universal IoT platform for managing vending machines consist of:

- A computer with a vending machine management application,
- Communication module for communication between computer and monitoring center,
- Payment devices,
- Implemented vending machine control unit and user interaction module.

Fig. 3 shows a block diagram of a conceptual design of a universal IoT platform for managing vending machines.

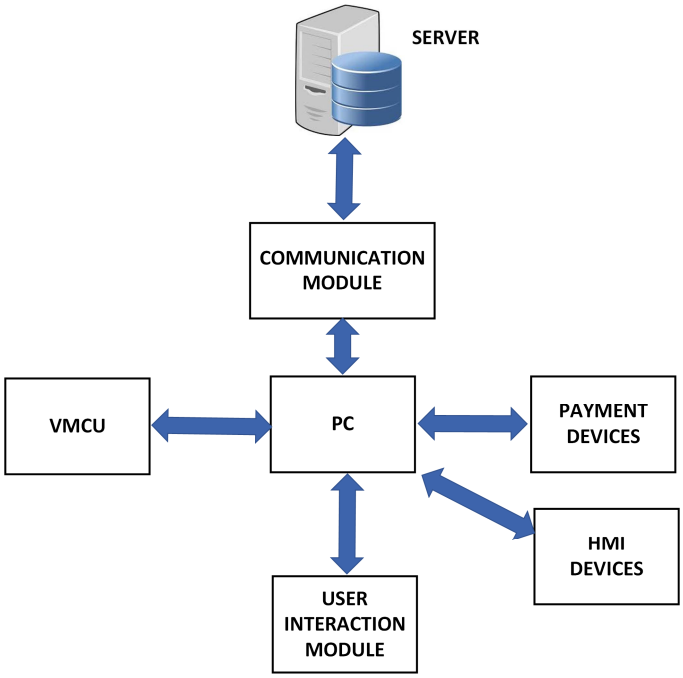

Figure 3. A block diagram of a conceptual design of a universal IoT platform for managing vending machines

One separate unit is a computer running complex control algorithms for managing a vending machine. The second independent unit is the control unit that manages the basic hardware components of the vending machine and manages the actuators (coil motors, belt drives, refrigeration system compressor, etc), collects information from the sensors and, where necessary, makes certain simpler independent applications on the computer algorithms for controlling a vending machine (e.g. maintaining a set temperature in the cooling section, etc). The payment devices are separated as a separate unit and connect to the computer via USB, RS232 or Ethernet communication interfaces. This is necessary because most new devices for cash or cashless payment, for security reasons, require the implementation of complex algorithms for data exchange. Implementing these algorithms on an application on your computer frees the vending machine control unit. Auxiliary displays, keyboards, and accessories are all connected to the computer.

III. THE REALIZED CONTROL UNIT

The realized control unit consists of 5 units: the control microcontroller, the communication module for communication with the computer, the output module, the input module, and the module for controlling the power supply of hardware components of the vending machine. In Fig. 4 the block diagram of the realized control unit is shown.

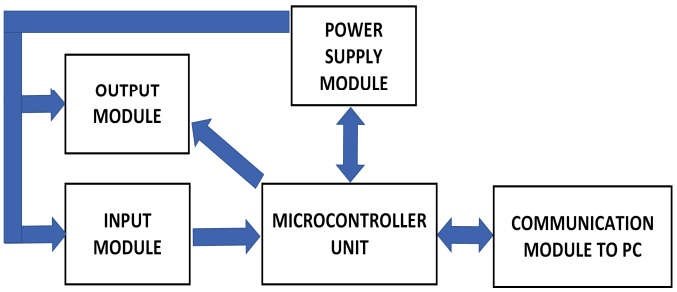

Figure 4. The block diagram of the realized vending machine control unit

The control microcontroller controls the operation of the executive bodies of vending machines and collects information from all sensors built into the vending machine. Based on the received commands from the application on the vending machine computer, the control microcontroller manages the work of the executive organs of the vending machine. The results of the commands execution and the information collected from the sensors embedded in the vending machine are forwarded to the application on the vending machine computer. The Atmel ATMEGA128 microcontroller was chosen as the control microcontroller because of the need for many digital inputs and outputs, analog inputs and communication interfaces for communication with the computer. The communication module for communication with the computer is based on the application of USB or RS232 communication interfaces.

A simple and secure protocol has been implemented for communication between the control unit and the application on the vending machine computer. Data exchange can be synchronous and asynchronous. Synchronous data exchange takes place by sending a command to the control unit on the computer, and the control unit responds with acknowledgment of the command receipt and status of command execution. In the case of asynchronous data exchange, the control unit sends a message to the application on the computer that a certain event of interest (open door, detection of the products in the delivery tray, presence of the cash box, etc.) has occurred and in this case, there is no response from the application that the message has been received. The commands are formed in the form of:

StartMsg_CodeCommand_Data_Checksum_EndMsg

and are sent as a series of bytes.

The output module was implemented using P and N channel MOSFETs, which control the operation of all the executive organs of the vending machine (motors, electromagnets, relays, vending machine lighting, etc.). Due to the need to adjust the voltage levels of the signal, safe operation as well as the need to increase the resistance to

electromagnetic interference, the entire output module is galvanically separated from the control microcontroller using an optocoupler. Each digital output can control voltages in the range of 12 to 24 V DC and can be loaded up to 6 A of output current at maximum.

The input module is designed to be able to process information from the digital (switches, optical and mechanical sensors of product presence, temperature sensors, etc.) and from analog sensors (temperature sensors, ultrasonic sensors of product presence, etc.). The input module, for the same reasons as the output module, is galvanically separated from the control microcontroller.

The module for controlling the power supply of the hardware components of a vending machine consists of two submodules. The first submodule manages and controls the power supply of all hardware components of the vending machine itself (executives, sensors, and payment devices). If necessary, it can switch off the power supply to the hardware components of the vending machine for a specified period of time and restore it. The second submodule monitors and powers the computer of the vending machine. In the event of a communication failure between the vending machine control unit and the application on the computer (freezing the OS computer or the management application), this submodule may interrupt the power supply to the computer for a period and reestablish. With this, the redundancy of the system is obtained so that in the event of communication interruption between the computers of the vending machine and the remote monitoring system (center), the machine itself can be switched off and on again, i.e. initializes all systems in order to establish the proper operation of the system. In Fig. 5 realized vending machine control unit is shown.

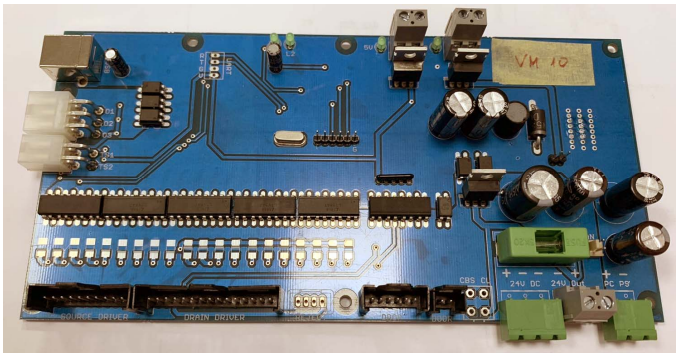

Figure 5. The realized vending machine control unit

In order to enable complete reparation of old vending machines with as little as possible the addition of new components to interact with the user (display of information and assigning commands by the user), a module for interaction with the customer has been developed. This module consists of a microcontroller, a computer communication module, an LCD display interface (usually 16x2 characters) and digital inputs/outputs for reading typed commands via the keyboard (most commonly a 3x4 keypad). Fig. 6 shows a block diagram of the module for interaction with the users.

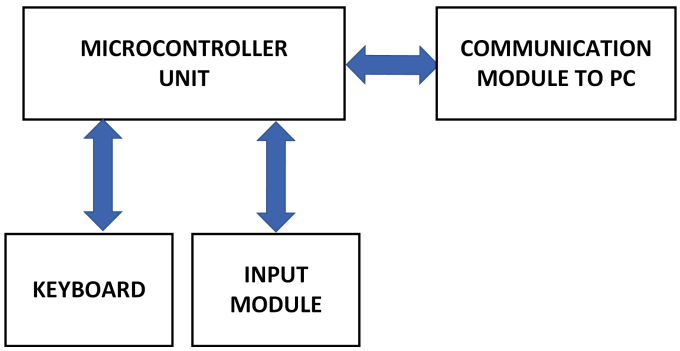

Figure 6. A block diagram of the module for interaction with the users

As this module does not require large memory space for the implementation of the control algorithm, there is no need for many inputs and outputs, for this reason, the Atmel ATMEGA 16 microcontroller was selected. It uses a 4-bit interface to communicate between the microcontroller and the LCD. The LCD shows all the necessary information to the vending machine user in order to purchase the product or pay for the service on the vending machine. In Fig. 7 realized module for interaction with the users is shown.

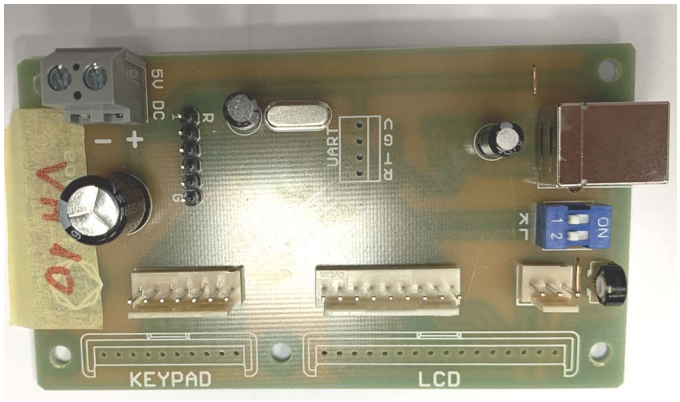

Figure 7. Realized module for interaction with the users

All described modules that have a control microcontroller (control unit, user interaction module) can update the implemented control algorithm using a bootloader via USB / RS232 communication.

IV. CONCLUSION

This paper proposes a solution to a universal IoT platform for managing vending machines. Emphasis is placed on the implementation of the control unit with an additional module for interaction with the user and their detailed description is given. The advantages of the control unit described in this paper are multiple. The implemented control unit enables easy and inexpensive implementation, both in new vending machines and in existing vending machines. Through the ability to update the control unit management algorithm, new functionalities can be subsequently added easily without changing hardware components or leaving trained workers to vending machines. The disadvantage of the implemented

platform is that it is necessary to make a minimum correction on the wiring of the existing machines and configure the control algorithm of the control unit to accommodate the different existing vending machines. The implemented solution was in the test phase on five vending machines and for now, gives satisfactory results with a negligible number of work failures in relation to the total time of use.

The implementation of the remote control center and the communication interface between the vending machine and the remote control service is left for future work. Through the implementation of remote control center, different algorithms will be implemented that will enable: management of vending machines; monitoring and optimization of products and services offered in the vending machines; tracking the status of the products in vending machines (monitoring and evaluation of shelf-life); planning and assistance on maintenance and servicing of the vending machines; sending notifications in the event of lower stock or expiry duration of products, in the event of failure in vending machine operations, etc. In the future work it is planned to test in detail the realized control unit on a larger number of vending machines. After the implementation of the remote control center and the communication interface between the vending machine and the remote control center, detailed testing of the entire universal IoT platform for managing vending machines is planned.

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