EXPERIMENTAL PLATFORM FOR SIMULATION AND ANALYSIS OF SYSTEMS STATES AND FAULT DIAGNOSIS IN INDUSTRIAL AND LOGISTICS SYSTEMS

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Abstract. The present paper describes the development of advanced experimental platform, designated for modelling, simulation and analysis of technologic operations, systems states, and fault diagnosis realized in real and/or simulated industrial and logistics facilities. The developed experimental platform can be applied in research and development studies as well as in teaching activities performed by PhD-students, PostDoc-students and other academic staff in Technical University of Sofia, Bulgaria.

Keywords: experimental platform, simulation and analysis of systems states, fault diagnosis, reliability enhancement

1. Introduction

The successful completion of some really sophisticated activities of s*imulation and analysis of information needed for optimal and/or adaptive control realized in industrial and logistic facilities* requires *development and implementation of specific* ***Experimental Platforms*** [1, 3, 4].

The general purpose for the creation of such specific experimental platforms must always be ***object-oriented*** [2, 3, 4], i.e., these platforms should be capable to provide the following capacities:

- ***to create*** various kinds of *initial data bases*, containing the necessary (specific) information, that must be used in control and fault diagnosis;
- ***to simulate*** various technologic operations, technical conditions and systems states;
- ***to develop*** various representative process models***;***
- ***to detect and isolate*** faults and failures;
- ***to overcome*** some possible measuring errors.

The present paper describes the development of advanced experimental platform, designated for process modeling, simulation and analysis of information generated during the operation of control mechanisms in real and/or simulated industrial or logistic centers.

The created Experimental Platform is applied in research and development activities, as well as in teaching programs realized by PhD-students, assistants and professors in Technical University of Sofia (and more specifically at the Department of Mechanical Engineering, the French Faculty of Electrical Engineering, Automation, Electronics and Informatics, the Laboratory of Reliability and Diagnosis, etc.).

2. Design and development of the experimental platform

The main goal in designing the experimental platform is to achieve ***ease of use***, ***fast and optimal control, scalability and adequate maintenance.***

The controller board that is capable to satisfy all these requirements was selected to be Velleman K8055 USB I/O.

The general structure of the experimental platform is shown at Figure 1.

The main modules of the developed platform respectively are:

- Velleman k8055 boards (I thru IV);
- Brushed DC Motors (I thru IV);
- Stepper Motors;
- Incremental Encoders (sensors);
- Distance Measuring Sensor Units;
- Driver boards for the brushed DC motors;
- Driver boards for the Stepper Motors;
- Signal Generating Board (SGB);
- USB HUB;
- Stack light;
- Stack light driver circuit;
- 12V DC PSU;
- PVC base plate.

The four Velleman K8055 USB I/O boards (Figure 2) compose the core of the platform's control system. Each controller is equipped with a powerful 48 MHz PIC18F24J50, USB serial connection, five digital inputs (0 = ground, 1 = open), two analogue inputs with attenuation and amplification options, eight logical open collector outputs and two analog dual (PWM/0-5 V) outputs. The architecture of the k8055 provides a capability for four boards to be simultaneously addressed on a single USB bus by a single computer.

The incremental encoders are selected to be Kubler 2400 units, with maximal impulse frequency of 160 kHz, 12,000 rpm max, and standard TTL outputs.

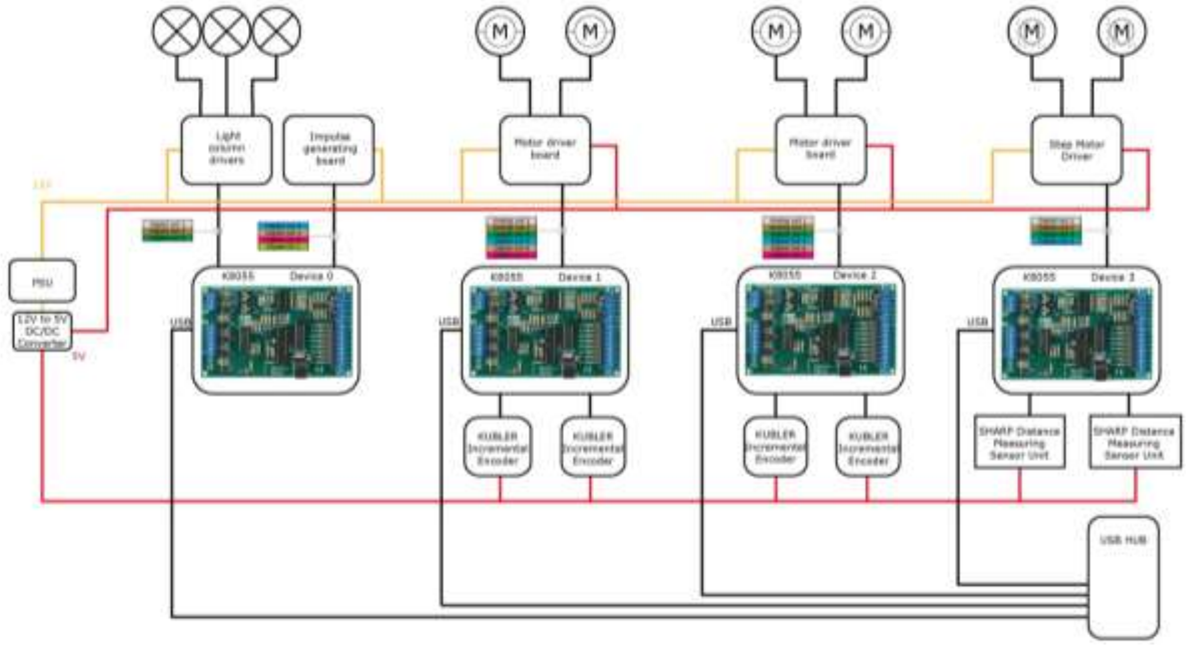

Figure 1. General structure of the developed experimental platform

Figure 2. Velleman K8055 controller board

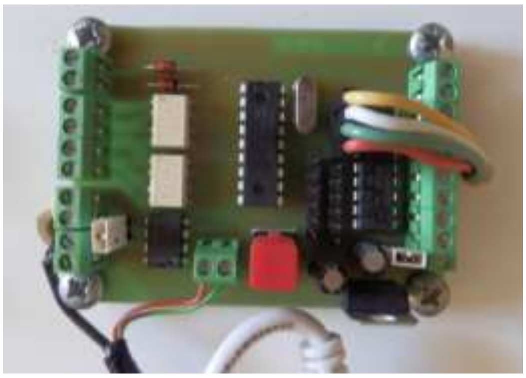

Figure 3. PIC16F88 Signal generating board

The Distance Measuring Sensor Units are SHARP GP2Y0A21YK0F units with distance measuring range from 5 to 80 cm and respectively are capable to generate an analogue output voltage of +0.5 V (~80 cm distance) to +3.5 V(~5 cm distance) depending on the proximity of the object.

The Signal generating board (SGB), Figure 3, is based on a powerful 20 MHz PIC16F88 microprocessor. It has eight open collector outputs (50V/500mA), two opto-isolated (2.5 kV) digital inputs that are AC/DC capable, one analog input (0÷5 V) and is accessible by a RS485 and TTL ports. The SGB is connected to the USB hub via TTL/USB interface and is accessible for boot-loading via Colt PIC boot-loader.

The Stepper Motors are Allegro A4988 with DMOS-based driver boards. The highly integrated chips feature a motor driver, a logic level translator and an over-current/over-temperature protection. It is compact and easy to use. The control signals are two-directions and step-featured.

The DC Motors are Infineon Technologies BTS 7960 based drivers. The power stage of the chips is a half- bridge. Two of them are used per motor, making a total of eight at the platform. The extra features are: logic level inputs, diagnosis with current sense, slow rate adjustment, dead time generation and protection against over-temperature, over-voltage, under-voltage, over-current and short circuit. The control signals are two-directions and PWM for speed control.

The driver for the stack light is a simple switch, based on an IRF541 transistor, Figure 4.

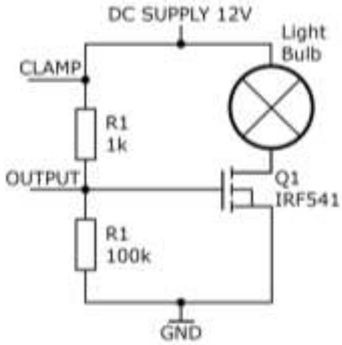

Figure 4. Switch circuit based on an IRF541 transistor

The power supply of the complete experimental platform (including with all its components) is based on a Mean Well 320 W PSU. The model RSP-320-12 provides 12 V (orange line) to all components of the experimental platform. The power supply features a built-in overload, over-voltage and over-temperature protection and provides excellent load regulation.

However, some of the electronic logic circuits as well as the sensors require a 5 V supply (red line) so a small 12 V to 5 V DC/DC converter based on a LM2596 PWM regulator is used for the purpose. It provides more than ample power for all 5 V circuits.

3. Control of the Experimental Platform – element connections and logic

The Analogue Outputs of the Velleman boards posses a simple Digital to Analogue Converter. This feature provides the use of 8-bit values that can be translated into voltage. In fact, this means that each value corresponds to a specific voltage. The value 0 corresponds to a minimum output voltage (0 Volt) and the value 255 corresponds to a maximum output voltage (+5 V). A value of 'X' lying in between these borders can be translated into voltage by the following formula: $U_o = 0.0196 \times X$ (byte in DEC format). The minimum step is 19.6 mV.

The Digital Input Channels 1 and 2 of each Velleman board are equipped with 16-bit pulse counters, so that a pulse counting functions can be realized. These functions are also accessible via the included DLL library; they are fully hardware based and operate all the time. Therefore, the load from the USB lines can be reduced and respectively, the control functions can be improved.

The four Velleman boards are connected via USB bus and all the system components are connected to the Velleman boards. Each board is assigned to some particular functions. The boards also have different addresses so, the PC software and DLL library can differentiate between boards on reads and address them separately on writes.

3.1. Velleman board I (Device 0)

The board is connected to the Stack Light driver using Digital Outputs 1 to 3, outputting a high TTL lights up the corresponding light.

Also this board is connected to the SGB via Digital Outputs 4 to 6. The SGB is pre-programmed with three modes of impulse generation but can also be reprogrammed quite easily using the JALv2 language and the supplied boot-loader. Each 3-bit combination output on the Velleman board triggers a different mode on the SGB. The output of the SGB is connected to Device 0's Digital Input 1 and the impulse counter on that channel can monitor the generated signals.

3.2. Velleman boards II and III (Device 1 & 2)

These boards are connected with the DC Motor drivers via 1 Analog output and 2 Digital outputs for each motor. The Analog outputs used in PWM mode control the speed of the motors, while the digital outputs control the direction and can be used as an electric brake if engaged simultaneously.

Digital1	Digital2	Motor Status
0	0	Stop
0	1	Clock-wise (CW)
1	0	Counter-clock-wise (CCW)
1	1	Stop

Motor Control via 2 digital signals

Device 1 and 2 use the impulse counters on Digital channels 1 and 2 to store the values measured by the Incremental Encoders, which are mechanically linked to the brushed DC motors.

3.3. Velleman board IV (Device 3)

The board is used to control the Stepper Motor Drivers as well as to measure the voltage coming from the Distance Measuring Sensor Units. The Stepper motors are controlled in a similar way to the DC motors with two Digital values – one for directions the other one for stepping. One generated impulse drives the motor with one step.

Digital1	Digital2	Motor Status
0	0	Stop
0		Clock-wise (CW)
1		Counter-clock-wise (CCW)
1	1	Stop

Step Motor Control via 2 digital signals

The Distance Measuring Sensor Units are connected to the Analogue Inputs of the board, and the ADC translates the voltage generated during the measurements into an 8-bit value. This value is later translated into distance in software by the means of a lookup table, linking the voltage to centimetres.

The real status of the developed Experimental Platform (entirely completed and ready for experiments) is shown at Figure 5.

Figure 5. The developed experimental platform – entirely completed and ready for experiments

4. Example of a simulated system

Once the system is already set up some representative examples for simulation of real industrial cases can be realized (of course with a certain degree of abstraction). ***The simulated industrial complex represents a logistics facility for automated (robotized) parking***, Figure 6.

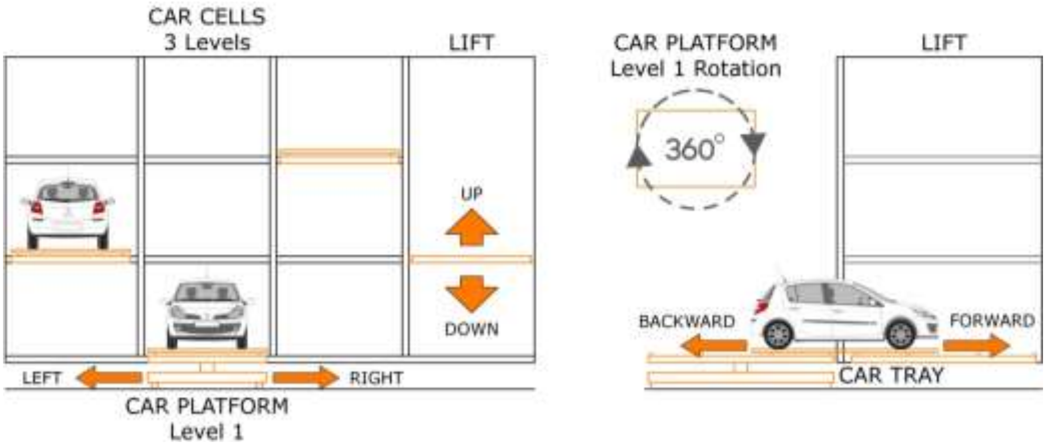

Figure 6. Various processes in a simulated automatic (robotized) parking system

The automated (i.e., the robotized) parking system consists of 3×3 car cells and a vertical lift.

The car parking system possesses one Entrance and one Exit point [5, 6]. Each row of cells has a servicing platform that moves left to right along the row of cell and the vertical lift [5, 6].

Each car platform has a mechanism to push/pull a specially developed car tray forward or backward [5]. The bottom car platform (on level 1) has a rotating 360° tray that can rotate the stored car, so that the car can exit the parking correctly [5].

For the simulation purposes it is necessary to associate a particular element of the Experimental Platform to a specific part of the simulated complex. For example, one of the DC Motors (i.e., 1 to 3) can be associated to each car platform. Respectively, the DC Motor 4 can be associated to the 360º rotation. The car tray moving forward and backward on the lift can be associated to the Step Motor 1. The car lift-movement (respectively for up and down) can be associated to the Step Motor 2. Therefore specific control algorithms for depositing and retrieving cars can be developed, and their structure is shown respectively at Figures 7 and 8.

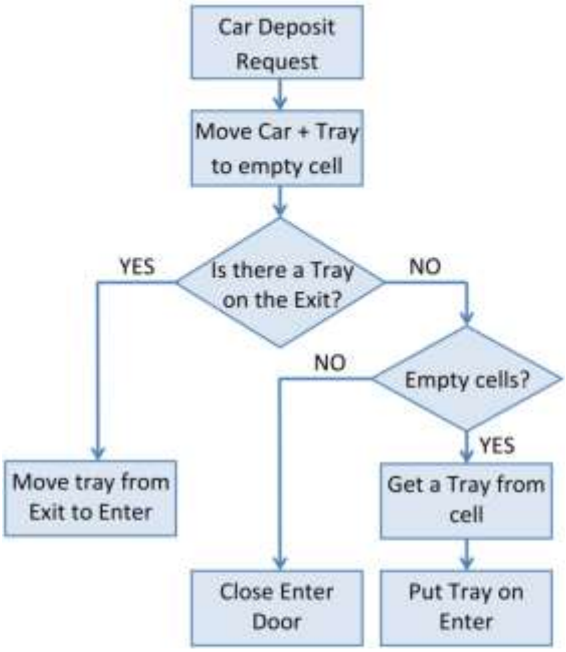

Figure 7. Parking Control algorithm for depositing the cars

The so-developed algorithms can easily be coded (for example in Matlab), and the specific code can be executed in order to control the Experimental Platform.

5. Conclusions

5.1. The so-developed experimental platform is capable to meet the predefined requirements, i.e.

- ***Ease of use***: the simple communication via USB to the controlling PC allows an immediate use of many scripting languages. The code can be written and executed on the controlling PC without the need of complex pre-loading procedures;
- ***Fast control***: the Velleman's main PIC processors provide reliable and fast communication from the Operating PC to the platform elements;
- ***Scalability***: after connecting all the elements of the platform, the Velleman controllers still possess unused inputs and outputs that can be later used to extend the platform with the addition of different new modules;
- ***Simple Maintenance***: the fact that the platform control is distributed over four separate controllers makes the maintenance relatively easy, but also allowing the entire functionality of the other modules of the platform in case of a malfunction in one of the controller boards.

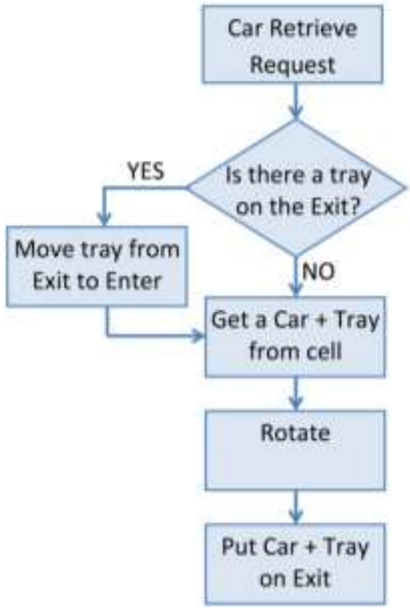

Figure 8. Parking Control algorithm for retrieving the cars

5.2. An entire mainframe of an advanced experimental platform designated for process modeling, simulation and analysis of information and technical conditions during the development of control mechanisms in real and/or simulated industrial or logistic centers was designed and realized. The developed experimental platform is entirely completed and ready to fulfill laboratory experiments in the area of operational reliability, simulation and modeling of systems technical states, pattern recognition, etc.

5.3. Examples of operational algorithms were created and can respectively be coded, so that a test of the experimental platform's capabilities in simulated cases can be realized.

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