

DISTRIBUTED SYSTEM FOR AUTOMATIC EXECUTION OF EXPERIMENTS

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Abstract: This paper describes system for automatic execution and measurement of experiments and first obtained results by it. System is based on distributed control systems built on standard software and hardware automation components. First results was obtained in measure input data for experimental identify of mathematical model of portal crane. To obtain mathematical model is the first step in process of design real network control system to control portal crane. System for automatic execution of experiments will be used to make sufficient amount of experiments to verify designed network control system on real system.

Keywords: distributed control system, automatic experiment execution, data acquisition, indentify system, portal crane

1. INTRODUCTION

Our work in the field of network control systems deals with methodics of design, modeling, simulating and realization of network control systems. Realisation and experimental verifying of NCS is important part of this work because of occurrence of random behavior that is caused by using communication network. This approach occurs in differences between which-ever 2 experiments performed under same conditions. Optimal results are obtained by using statistical methods that uses amount of experiments performed under the same conditions (Laciňák, 2005). In the simulation there is no problem to make experiment many times and capture each experiment for post-processing. Now, when we realise experiments at real systems, it is need to provide the same conditions and collect data from experiments. For this reason the distributed system for automatic execution and measurement of experiments was created.

2. FUNCTIONS OF THE SYSTEM

Basic function of whole system is to automatically execute experiments without operator intervention, when it is need to make tenths or hundreds of experiments, which require amount of time. This function is done by PLC. Second function of system is to automatically collect amount of data from experiment and prepare it for processing, eventually make process in a moment the experiment is done. This function is provided by matlab scripts. Third function is monitoring whole system and collect current data to database to process and statistic evaluate process. Last function is visualization interface to command whole system with ability to configure executing of experiments. Strong attribute is possibility of extension of the system to make intervention in control system each experiment, which makes base for system to be ready for verify new methods and approaches.

3. SYSTEM STRUCTURE

Structure of system is divided to 3 levels according to Jasenovec (2006). First level is technology level, which contains standard automation components. This level provides direct local control of hardware equipment of tested real system or model. In our case hardware base is represented by model of bridge crane. Second level, SCADA/HMI level provides operator interface to control execution of experiments. Information level is used to monitor whole system, collection data from experiments and about its conditions. Structure of whole system is shown at Figure 1.

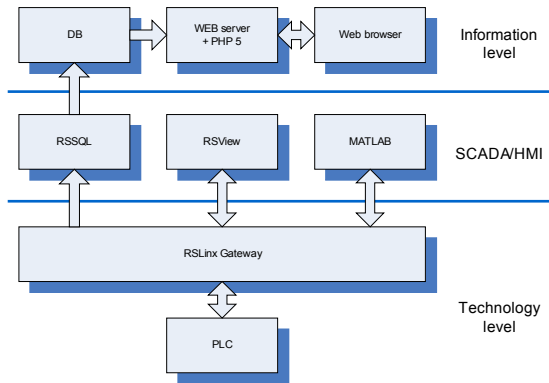


Fig. 1. Structure of whole distributed system divided to 3 levels.

Note that large part of the data are in raw format, so the values are in engineering units obtained direct from PLC in its scale when unit is not presented. This convention will be used in whole paper.

3.1 Technology level

Technology level is based on programmable logic controller (PLC), which locally controls real system. Control system also consists of 4 frequency converters with asynchronous motors, which drives portal crane, incremental rotary counters to determine position of portal elements, sensors for endpoints and some inspection tensometers.

Table 1 Selection of parameters from PLC control interface

| Parameter | PLC Address |
|------------------------------------|-------------|
| T_m Measurement time | N7:23 |
| f_{vz} Sample frequency | N7:24 |
| C_v Count of samples/measurement | N7:7 |
| T_e Experiment time | N7:21 |
| T_d Delay between experiments | N7:22 |
| C_e Number of experiments done | N7:12 |
| U_o Measured output of system | N7:6 |
| RB Run experiments | B3:0/1 |
| EB Activation of single experiment | B3:0/2 |
| IB Impulse/step switch | B3:0/7 |
| DB Allow to transfer data to PC | B3:0/5 |
| V_o Actuating value | N7:43 |

PLC executes program, which obtains data block for executing experiments. Special interface is defined in PLC to obtain data from distributed system to experiments, because of PLC program can be unique based on real system. Interface is standard in automation systems, but block of memory is reserved to obtain experiment parameters and other system data. Main parameters of the interface are listed in Table 1.

PLC runs experiment after experiment while start bit B3:0/1 is set. Bit is set or reset from user interface at SCADA/HMI level. Single experiment can be executed by setting bit B3:0/5, which is reset by PLC after experiment is done. Experiment parameters can be generated by user through user interface or can be generated in PLC. In second case PLC also controls limits of output value, while it has integral character. Actuating value to system is switched by B3:0/7 bit and it can be made like step or impulse.

Collecting of the input and output data is processed at this level, where PLC is storing desired parameters to reserved data blocks in its internal memory. In our case input data are 3 input signals to control movement in 3 axis of manipulator. Outputs from system are 3 positions or speeds measured on separate axis of movement. Oscillation in bridge and crane crab directions are also stored to independent data block. Each measured parameter has one data block reserved. Maximum length of each block is 255 samples, our data blocks were limited to 50 samples. List of parameters collected and corresponding data blocks are in Table 2.

Table 2 Data blocks for values collecting

| Parameter | PLC buffer 1 | PLC buffer 2 |
|-----------------------------------|--------------|--------------|
| Position, bridge direction, out1 | N14:1,L50 | N34:1,L50 |
| Position, crab direction, out2 | N16:1,L50 | N36:1,L50 |
| Elevation, out3 | N17:1,L50 | N37:1,L50 |
| Swing out, bridge direction, out4 | N18:1,L50 | N38:1,L50 |
| Swing out, crab direction, out5 | N19:1,L50 | N39:1,L50 |
| Input for bridge direction, in1 | N20:1,L50 | N30:1,L50 |
| Input for crab direction, in2 | N22:1,L50 | N32:1,L50 |
| Input for elevation, in3 | N23:1,L50 | N33:1,L50 |

Communication between technology level and SCADA/HMI level is done by gateway PC running RSLinx Gateway. RSLinx is product of Rockwell Software (RS), communication program that is dedicated to communicate between PLC or other automation devices and RS or other automation software products (Rockwell Software).

3.2 SCADA/HMI level

This level is running RSView 32 application, that visualize actual status of distributed experiment system, status of actual experiment running and provides interface to command system by operator. SCADA/HMI level also running RSSQL, which realise collecting of experiment and current data and storing of it to database at information level.

RSView 32. RSView 32 is running application with 3 windows. Main window provides overall view at experiment system with showing of all parameters and running experiments. Graphical elements are arranged as a string of process elements, from configuration through execution to measure experimental data. Main visualization window is shown at Figure 2.

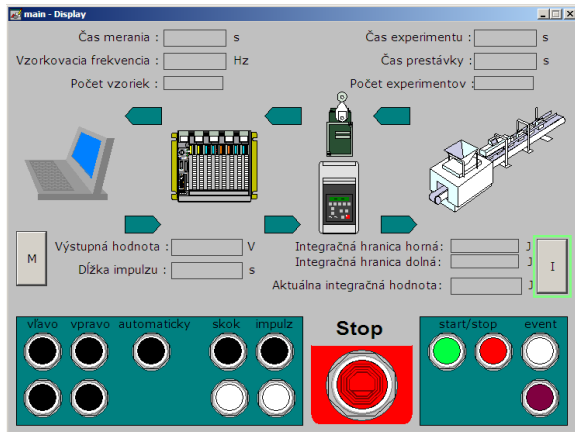


Fig. 2. Main visualization window.

Main window contains parameters *Time of measurement* and *Sample frequency* that generates count of measured samples in data block. There are placed at left up corner of the window. At the right up corner are placed parameters *Time of experiment*, *Time of delay* (between experiments) and *Count of experiments* completed. Low left corner places parameters for generating input signal to the system, namely *Output amplitude* and *Width of input impulse*. Low right corner shows actual settings of parameters for integral output of system. Bottom fields of main window contains control buttons, right side button for exit program, run single experiment and start/stop of automatic experiment execution. By buttons in left field user is able to change direction of input signal, switch between step or impulse form of signal and turn automatic experiment generator on.

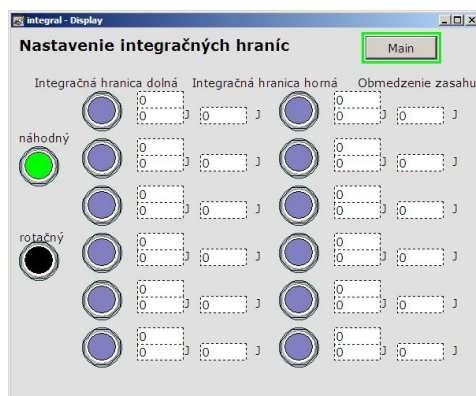


Fig. 3. Additional visualization window for setting integral limits and generator style.

Two windows shown at Figures 3 and 4 are additional, one of this provides setting parameters for automatic random generator, specifically upper and

lower limit and style of generating actuating signal. Window provides setting of the amplitude limits for each of inputs too. Second additional window is intended to manual actuation of a real system. Because of various count of inputs of the system, maximum count of 6 inputs can be manually controlled by this system.

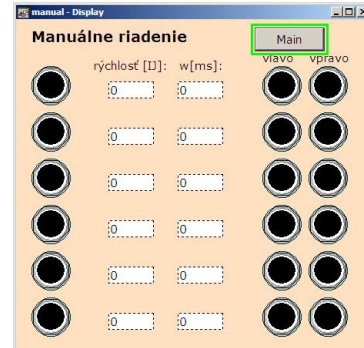


Fig. 4. Additional visualization windows for manual control of 6-input system.

Matlab. Matlab script is most powerful part of system, because of possibility to flexible changing its function in the system. Script can read measured data from PLC by standard DDE protocol, store it to different format files on PC and also can contains optional function provided by Matlab.

Two different scripts were created in to collect data in this system. Both of them are running on local PC and it has the same simple user interface that is shown at Figure 4. In top field of interface window is place to show actually downloaded data, in bottom are control buttons.

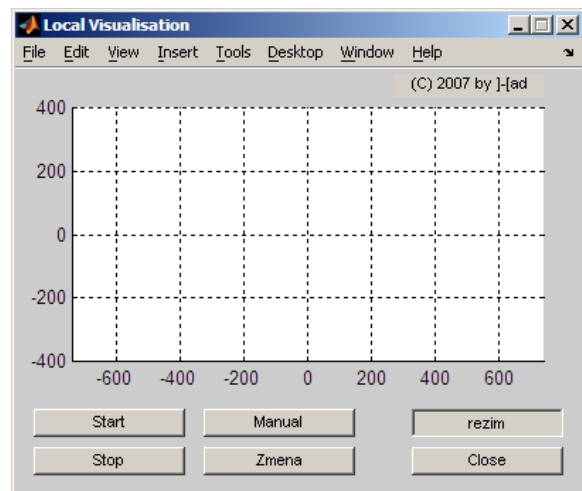


Fig. 5. Similar user interface of matlab scripts

First script is named *local_visual.m*, it is intended to download data from each experiment and store it to different files. Second script is written in *continual.m* file and it downloads data continuously with writing it to single file using method of 2 buffers described later in this section.

Script after first launch initiates DDE hotlink to bit B3:0/5, which allows run script, when value of bit is

changed. Script after launching downloads measured data from the experiment when it is done. Downloaded data are then stored to dat file in ASCII format. Because of downloading time is too much, it was need to find solution, how to collect data with relative high sampling frequency (10Hz) in real time. Problem was solved by using 2 buffers in PLC, where the first buffer is used to measure data, when second is readed by matlab script. After the first buffer is filled, download of the second buffer is done and the buffers can be switched in their functions. Buffers are joined to continuous block by Matlab script.

RSSQL. RSSQL is transaction manager by Rockwell Software and provides data transfers from PLC to some database. There are 2 connectors and 1 transaction configured inside RSSQL. First connector is technology and defines type of connection into PLC and parameters of transfer. Second connector connects RSSQL to MySQL database through system ODBC resource. Transaction defined in RSSQL ensure data transfer between technology and database connectors by which collecting of data and storing it to database is done. Database contains 3 tables with description that will be in table 3 in next section.

3.3 Information level

Information level is based on some kind of database system, which stores all collected data of whole system. Data are evaluated by standard database tools or by information systems. In our case we uses MySQL database to store basic current data. Database tables structures are shown in Table 3.

Table 3 Description of the database tables

| field | type | description |
|--------------------------|----------|-------------------------------|
| table status | | |
| id | int(11) | status id |
| cas | datetime | record time |
| mode | smallint | mode of collecting of data |
| inX | int | system input, 6x |
| outX | double | system output, 6x |
| run_bit | tinyint | experiment run |
| table experiments | | |
| id | int | result id |
| cas | datetime | start time |
| inXon | tinyint | inputs enable |
| te | int | experiment duration |
| fname | int | number of correspondeing file |
| ampX | int | amplitude, 6x |
| widX | int | width of impulse, 6x |

Fig. 6. Interface for configuring output from database.

Information level also contains standard web server with support for PHP5, which serves web pages of simple information system to view database data via standard web browser. Interface of information system provides input of parameters to system how it have to show data from database. It offers graphical and table output. Interface with setting parameters is shown at Figure 6. User is able to select table, type of graph, which parameters is he want to show and range of data used to generate output. Example output generated by information system is shown at Figure 7.



Fig. 7. Example of graphical output generated by Graph generator.

3.4 Real system

Real system used for test described system is model of bridge crane. Structure of model is shown at Figure 8.

Basic parameters of bridge crane are:

- nominal load capacity 100 kg
- elevation 2m
- range of bridge 2m
- length of bridge travel 4m
- speed of bridge 0-30 m/min
- speed of crane crab 0-30 m/min
- speed of elevation 0-15 m/min

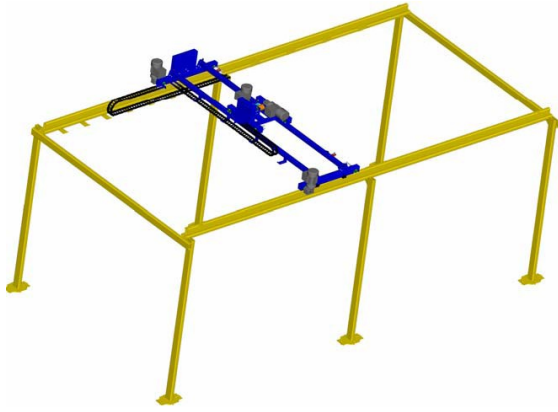


Fig. 8: Construction of bridge crane model.

Bridge crane construction consist of bridge travel placed on stand construction. Bridge of the crane goes on travel by 4 wheels and it is constructed of 2 girders and 2 transoms, crane crab travel are carried by girders. Crane crab carries uplift mechanism with simple reel hook hanging and also rides on 4 wheels (Ritók and Bigoš, 2004).

All movements (bridge, crane crab and elevation direction) are measured by incremental rotary counters, actuating is provided by 4 motors driven by frequency drives. Endpoints of all tracks are handled by limit switches nesides lowest position of elevation. Structure of whole control system is shown at Figure 9 (Hami, 2006).

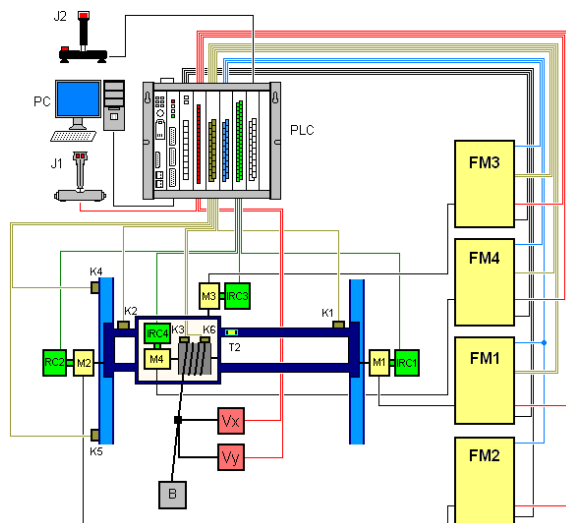


Fig. 9. Structure of control system based on Allen-Bradley PLC 5/25.

4. RESULTS OBTAINED BY SYSTEM

4.1 Initial conditions

Results presented in this paper was obtained under conditions described in this section. First, the most important is the fact that position of crane elements have integral character, therego it was used automatic generation of inputs to experiments with integral limits.

Parameters used in visualization interface were set like this:

- time of measurement = 5s
- sampling frequency = 10Hz
- experiment time = 6s
- delay time = 10s
- output value = 10 -
- impulse width = 0.5s
- low integral limit = 5000
- high integral limit = 16000

Next, experiments was executed only in bridge direction of the crane, experiments was generated automatic and periodical between integral limits, which means that direction of system input is left until actual position is not reached low limit where direction is changed to right. After the position reach right limit, direction of movement is changed to left again.

4.2 Measured data

Two measurements will be presented now.

First, 56 independent experiments were made in the experiment based measurements done with this distributed system. Measured data from 2 selected experiments are shown at Figure 10.

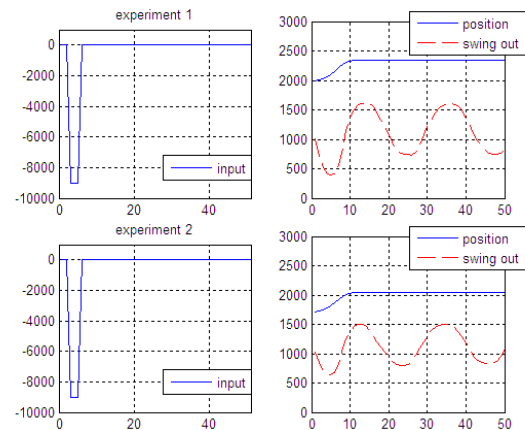


Fig. 10. Two experiments data are shown at this figure. Input values to crane crab direction movement drive is shown at the left graphs, right graphs shows output response, position of the crane crab and swing out of load.

Experiment results shown at Figure 10. are different, because of different initial conditions of each experiment.

Second measurement approach is to continually collect data to Matlab and to store it in one file. It is required to have continuous set of data in some cases. Some measurements using this approach were also performed. A selection of data measured are shown at Figure 11. because of measurement times was some minutes to tenths of minutes that generates thousands of samples per file at sampling frequency of 10Hz.

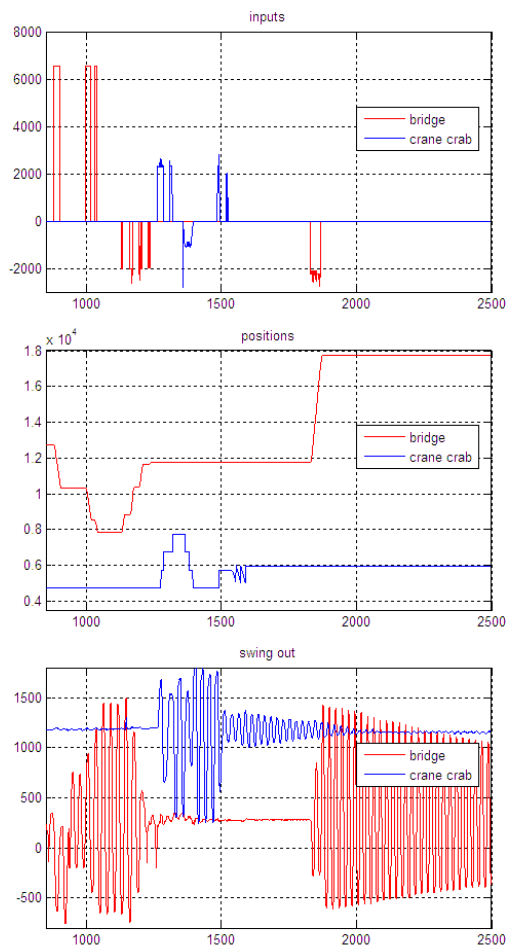


Fig. 11. Sample of input values to drives in bridge and crane crab directions are shown at the top graph, corresponding responses, rather the position at the middle and swing out at the bottom graph.

4.3 Contents of the database tables

Database holds after first measurements 1985 records in table *status* and 56 records in table *experimenty*. In Table 4 are listed some records from table *experimenty* with parameters of experiment.

Table 4. First 4 experiments stored in table *experimenty*

| id | cas | amp1 | wid1 |
|----|---------------------|------|------|
| 1 | 2007-09-05 13:24:15 | 10 | 50 |
| 2 | 2007-09-05 13:24:32 | 10 | 50 |
| 3 | 2007-09-05 13:24:43 | 10 | 70 |
| 4 | 2007-09-05 13:25:19 | 10 | 70 |

Sample of contents generated to graph representation by Graph generator is shown at figure 12. Graph shows relation between time and output1, which is a position of bridge. At the left side of graph we can see time of cyclic executing of experiments, right side shows behaviour during calibration.



Fig. 12. Sample from the contents of table *status* generated by Graph generator.

5. CONCLUSIONS

Described system for automatic execution of experiments, measuring of system inputs and output response, collecting of data to PC and possibility to easy view and process data is good tool to make process of testing and tuning new methods and theories automatic and fast. It is useful and so it will be used in each step of experimental part of our work in the field of network control systems. It will be also used to obtain more accurately mathematical model of bridge crane by experimental identification and to make sufficient amount of experiments to verify designed network control system on real system. This tool will be used to research in the field of lifetime of the bridge crane travels too.

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