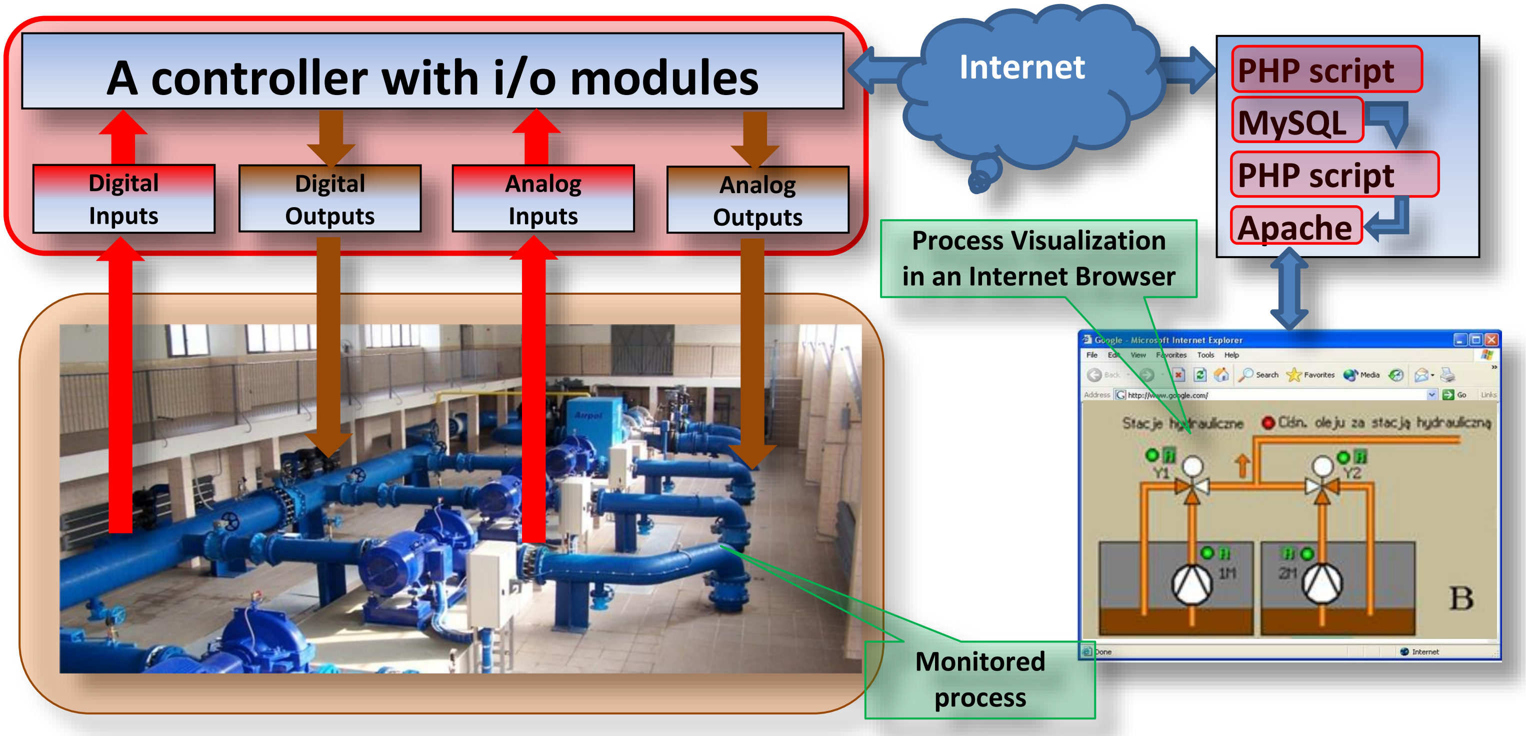
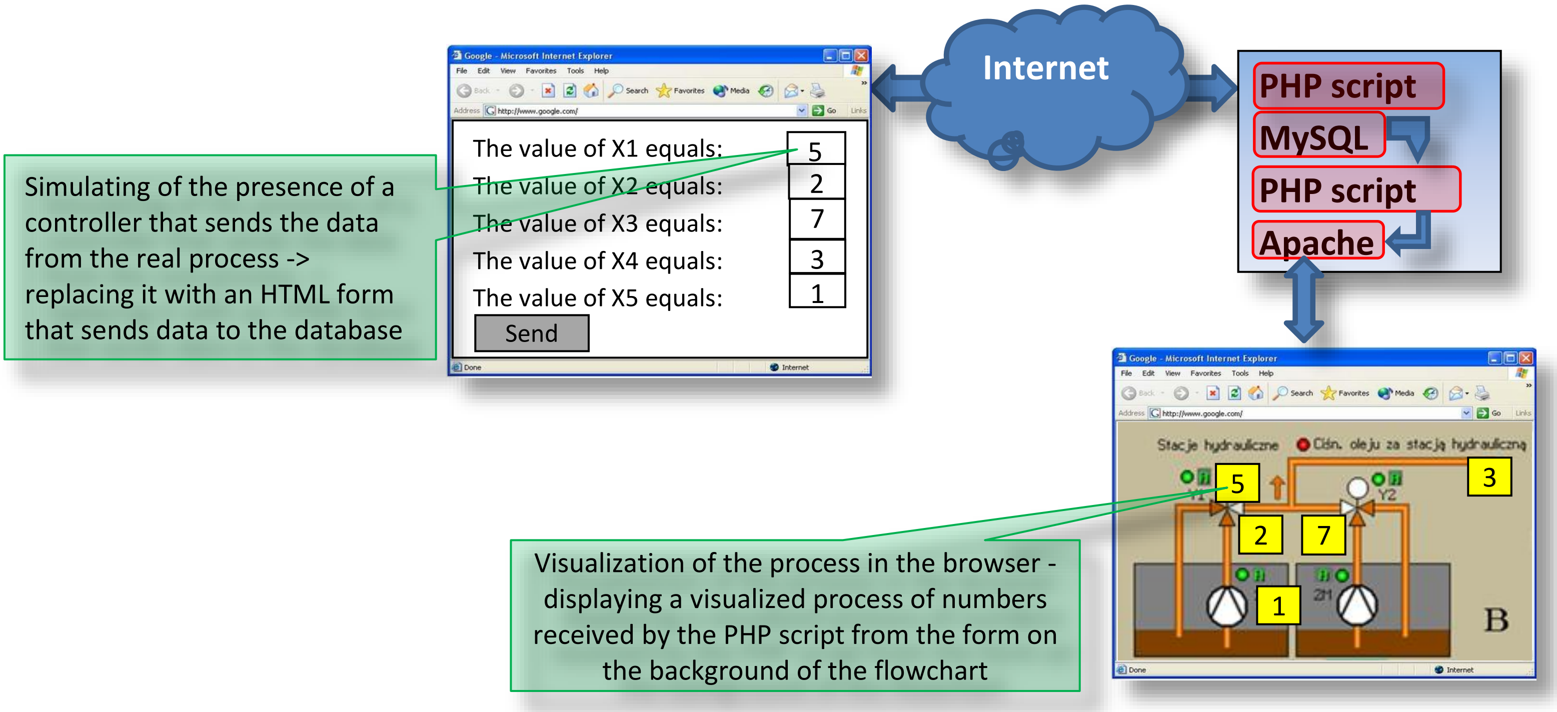
Exercise 4. SCADA *(Supervisory Control And Data Acquisition)*, IoT *(Internet of Things)*

Very often there is a need to register, visualize and manage various processes, for instance production, building automation, logistic processes, movement of the people, vehicles, goods, etc. Such systems consist of one, several or even several dozen controllers that monitor the status of the managed process and they generate control signals based on the status of these processes, GPS position and other parameters as well as the control algorithm, schedule, etc. These controllers usually communicate with the SCADA supervisory system (https://en.wikipedia.org/wiki/SCADA), through the network LAN, WAN. The cheapest implementation of such a controller is Arduino with Ethernet Shield or Raspberry Pi. The simplified block diagram of such a system using the PHP / MySQL technology is presented below. In this system, the controller with the Ethernet interface transfers data from and to the monitored process, via the WAN, to the MySQL database on the hosting server, through the appropriate PHP script. The server processes data and generates appropriate control signals, which it then sends to the controller. IoT - https://en.wikipedia.org/wiki/Internet_of_things.


A controller with i/o modules
Digital Inputs
Digital Outputs
Analog Inputs
Analog Outputs
Internet
PHP script
MySQL
PHP script
Apache
Process Visualization in an Internet Browser
Monitored process
Google - Microsoft Internet Explorer
Stacje hydrauliczne
Ciśn. oleju za stacją hydrauliczną
Y1
Y2
1M
2M
B

The creation of the whole above system, including the controller monitoring a process, exceeds the time frame of individual laboratory classes. Therefore, the task will be simplified, the controller will be replaced with a web browser application with a form for inserting data. The simplified system block diagram is shown below.


The value of X1 equals: 5
The value of X2 equals: 2
The value of X3 equals: 7
The value of X4 equals: 3
The value of X5 equals: 1
Send

Internet
PHP script
MySQL
PHP script
Apache
Google - Microsoft Internet Explorer
Stacje hydrauliczne
Ciśn. oleju za stacją hydrauliczną
5
3
2
7
1
B

Simulating of the presence of a controller that sends the data from the real process -> replacing it with an HTML form that sends data to the database

Visualization of the process in the browser - displaying a visualized process of numbers received by the PHP script from the form on the background of the flowchart

How to create a program

Note: the exercise consists of many elements, so the teacher can check them quickly, if you create a main file with properly commented links to scripts showing the implementation of individual task sub-points.

1. Create two simple web applications using HTML5, CSS3, PHP, MySQL, JavaScript:
   a. The first application should work, for example, in the Google Chrome browser
      i. to enable sending data simulating a controlled process to the MySQL database table on the server, via a PHP script (in commercial solutions these data are generated by PLC controllers),
      ii. in the first phase of the exercise implementation this application may look like an application that has replaced the controller in the system block drawing presented above.

   b. The second application should work in a different browser, e.g. Mozilla Firefox
      i. it should perform visualization of the work of the controlled system based on data from the database,
      ii. it should reload the contents to allow you to observe changes in the database, which always follow the introduction of new data through the form in the second browser window, in the simplest case it can be done by cyclic page reloads: <head> <meta http-equiv = "refresh" content = "10" /> </ head>

2. The visualization will include mandatory graphs of analog data received from the database. The charts must look professional, so you should choose the appropriate scripts carefully. In the Internet resources you can find a lot of simple, as well as more complex, free of charge scripts, which allow you to create charts, based on a number of available data, including:

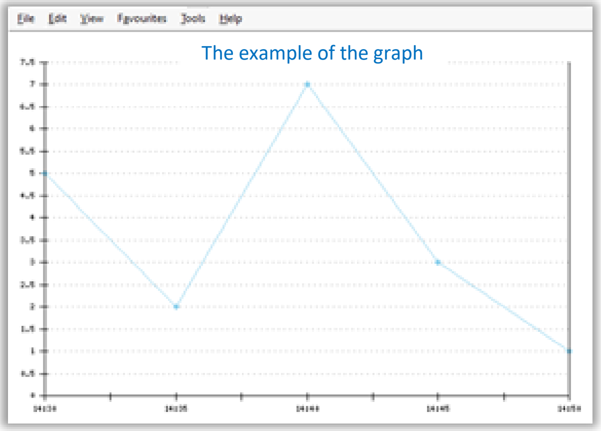
a.	phplot	http://sourceforge.net/projects/phplot
b.	libchart	https://naku.dohcrew.com/libchart/pages/introduction/
c.	jpGraph	http://jpgraph.net
d.	phpchart	http://phpchart.com
e.	XML/SWF Charts	http://www.maani.us/xml_charts

3. In order for the charts to be dynamically generated on your server - download from the Internet and put the files of the selected script for creating charts in the server's home directory.
   If you have decided to use phplot:
   a. From that portal http://sourceforge.net/projects/phplot download the packed package of files and extract the phplot.php script from it and put it on your hosting, in the same directory in which you will put the chart generating file,
   b. On the portal http://phplot.sourceforge.net/phplotdocs there is the information needed to install and use correctly the presented scripts, there is also a long list of examples for reviewing the available charts.

4. Create a file in the server's directory that contains the code to specify the data and parameters of the sample chart:

```
<?php
require_once 'phplot.php';
$plot = new PHPlot();
$data = array(array('14:30',0,5), array('14:35',1,2), array('14:40',2,7), array('14:45',3,3), array('14:50',4,1));
$plot->SetDataValues($data);
$plot->SetDataType('data-data');
$plot->SetTitle('The example of the graph');            // optional title of the graph
$plot->DrawGraph();
?>
```

5. Test the operation of the script, the graph should be displayed. If it is not displayed - it is probably because of missing the phplot.php file on the server in the directory of the running script.



6. Then go to phpMyAdmin and create a table **measurements** with 7 columns: primary key id, five integer data with names X1, X2, X3, X4, X5 and datetime (default setting CURRENT_TIMESTAMP)

   measurements (id, X1, X2, X3, X4, X5, datetime)

7. Create a form that allows you to transfer data (X1, X2, X3, X4, X5) to the MySQL database.
   In the first phase of the task, this form may look like an application that has replaced the controller in the block drawing.

8. Create a PHP script that will receive data from the form and insert it into the table **measurements** using the SQL UPDATE command - there will be only one record in that table - containing the data from the last sent form content.

9. Replace fixed data in the data specification of table elements using variables $X1, $X2, $X3, $X4, $X5 and modify the application in such a way that the chart is drawn on the basis of data from the MySQL database table, i.e. running the script - connect to the database and retrieve data from the table to the variables $X1, $X2, $X3, $X4, $X5, and then use them to call the script that draws the chart. Test whether the chart is drawn based on data sent from the form. After each transfer of the contents of the form containing different numbers to the database, they should appear in the chart.

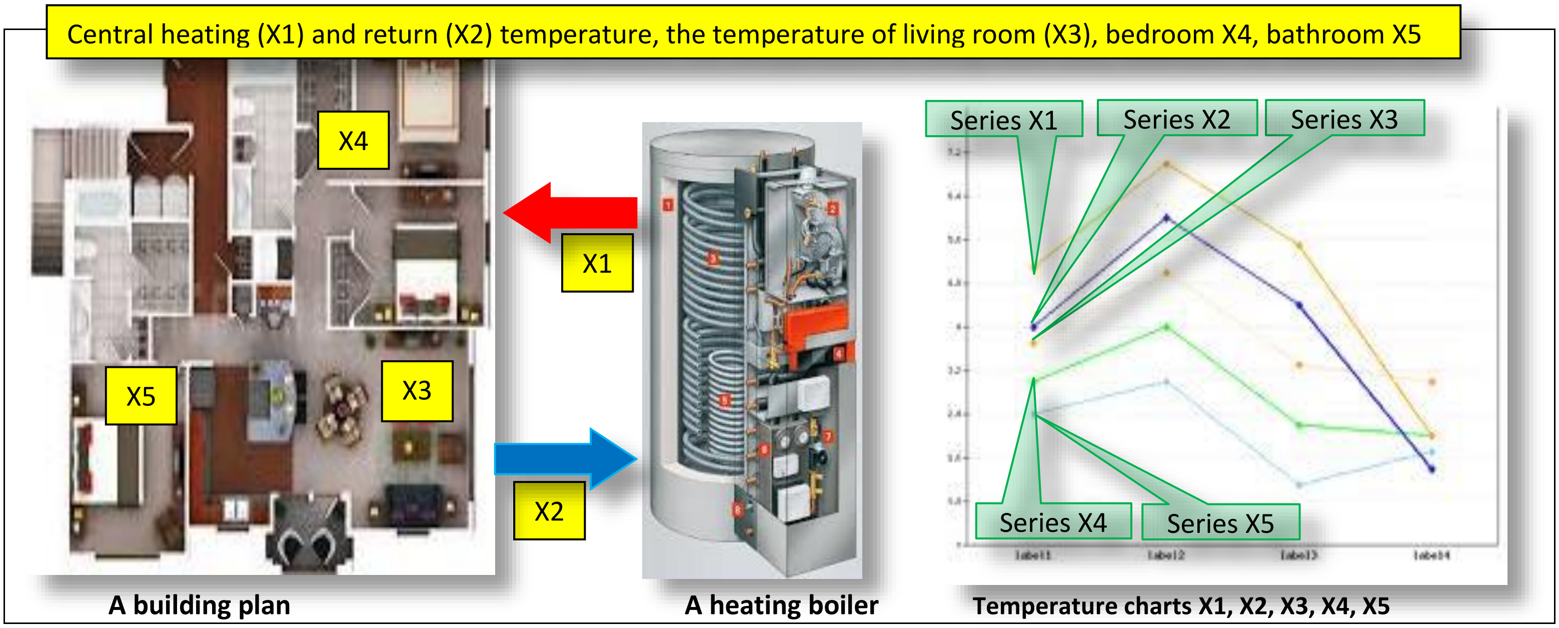
```
$data = array( array('Title',0,$X1),array('',1,$X2),array('',2,$X3),array('',3,$X4), array('',3,$X5),);
```

10. Please modify the script that receives the data from the form, please use INSERT command instead of UPDATE command. The reason to do it is to enable displaying all the data entered by the forms. For example, if the first form contains data 2,4,6,8,10, and the next form contains data 3, 5, 7, 9, 11, then it will be observed that the values of subsequent variables $X1, $X2, $X3, $X4, $X5 increased by 1 Celsius degree.

11. Modify the script that draws the chart as shown in the figure below. i.e. the graph should not only show the content of one form, i.e. the last 5 digits entered - as in the previous examples. This time the idea is to display all the data collected in the table, which were entered into the variables $X1, $X2, $X3, $X4, $X5 from submitted forms. The following figure shows a graph of five variables $X1, $X2, $X3, $X4, $X5. This chart, as you can see, has been plotted on the basis of the contents of the four submitted forms, because each data series consists of four points.
    If you do not know how to modify the chart plotting script - look again at http://phplot.sourceforge.net/phplotdocs, which presents the information necessary to make the right use the script to display several data series.
    If you have decided to use a different script - look for hints in the documentation of this script.

12. Create the beginning of the SCADA program:
    a. Put in the background of the page an example of the apartment layout and a picture illustrating the boiler (CSS3)
    b. Current temperatures must be displayed on the page near the places to which they are assigned.
    c. Put on the right side a graph of 5 waveforms taking into account the current values (they will be displayed depending on the configuration of the script at the beginning or the end of the graph) and historical data. ATTENTION: the graph is to present data from the table to which INSERT data was inserted for a certain time, thanks to which it will be possible to check what temperature was at a certain moment in the past.

The browser window


Central heating (X1) and return (X2) temperature, the temperature of living room (X3), bedroom X4, bathroom X5
X4
X5
X3
X1
X2
Series X1
Series X2
Series X3
Series X4
Series X5
label1
label2
label3
label4

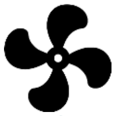
A building plan

A heating boiler

Temperature charts X1, X2, X3, X4, X5

13. Please expand your SCADA program with individual elements specific to your project
    a. Obligatory elements of the visualization are 5 temperature sensors for the mentioned areas.
    b. The following visual elements are optional: static and animated (gif) icons symbolizing work or failure of the ventilation, air conditioning, heating, access control system, burglary and assault signaling, fire alarm, flooding sensor, gas leak sensor, CO2 sensor, CO sensor, etc.
    Sample icons for these systems are at the end of the task.
    You can use them when using static icons, but all animated gifs should be downloaded from the Internet.\
    c. You do not need to insert all of the mentioned sensors, select a set of 2 additional visualization elements and place them on the visualization plan and extend them with a form that allows you to simulate the operation of the controller, which transmits the status of various sensors to the server, so that we can observe the Internet not only temperature distribution in the building, but also to find out whether ventilation, air conditioning, heating, whether the alarm is set, whether it is on fire or whether the flat is flooded or if the level of natural gas, CO2 or CO is too high.
    d. Depending on the data, static or animated icons should be displayed in the database, e.g. if ventilation is switched on 100% - a fast moving fan is displayed in the right place of visualization, if at 50% - then slower if ventilation is switched off - then a static icon is displayed.
    e. For ventilation, it is possible to take three states: 0%, 50%, 100%, for many other elements two states are enough: e.g. fire sensor - detected fire (eg animated flame) and no fire (eg static icon of a fire extinguisher).
    f. There are the links to indicators with buttons from Google, which strongly support visualization technology.
    https://developers.google.com/chart/interactive/docs/examples
    https://developers.google.com/chart/interactive/docs/gallery/gauge

Icon examples


Ventilation

Cooling

Heating

Access control system

Burglary and assault signaling

Fire alarm system

Fire alarm system Ready

Water sensor alarm

Propan-butan gas alarm

CO$_2$ gas alarm

CO gas alarm