

## DIY „hands-on-remote“ experiment in physics with Arduino

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**Abstract**—The goal of this workshop is to present new possibilities in simple creation of remote laboratories – either with the professional ISES system but also using easily accessible hardware like Arduino boards. Our aim is to show that a remote experiment is simple enough even for beginners or non-programmers. It is not only within the domain of science laboratories, but can be created in a DIY environment. Even visitors can build a simple remote experiment or demonstration and publish it within 10 minutes on the local network or Internet! We will present a new type of a school experiment – “hands-on-remote” experiment which is both hands-on and remote. As a professional solution, we will introduce the ISES-LAN and ISES-WIN measurement devices that contain a full-featured PC with Windows 10 and internet connectivity. We recommend the participants to bring their own notebook or Arduino board, which they will be able to convert to a remote experiment during the demonstration. Beginners need only an Arduino Uno board with simple sensors and our freely downloadable “Remduino Lab SDK”. We recommend the workshop to anyone – even a complete beginners to Arduino or remote experiments.

**Keywords**—Remote laboratory, hands-on laboratory, hands-on-remote laboratory, Arduino, ISES

## 1 INTRODUCTION

Many authors often discuss the disadvantages of real remote laboratories, and prefer performing hands-on experiments. Contributors nowadays mostly focus on remote lab management systems (RLMS), clouds [1], [2] massive open online labs or courses (MOOLs/MOOCs) [3] etc., but no new remote experiments have been created recently!

What is the progress in the development and dissemination of remote labs? Why is the number of real remote labs so low? We can identify several possible reasons: Remote laboratories are too expensive, they require permanent service and it is hard to create them. After 2010 many of the existing remote experiments started to disappear. Universities started to actively block access with passwords and made their remote experiments accessible to their own students only.

## 2 GOALS OF THE WORKSHOP

1. Presentation of a new type of remote experiment – “hands-on-remote” experiment.
2. Presentation of professional systems ISES-LAN and ISES-WIN as a hardware platform for such experiments.
3. Demonstration of an alternative, low-cost and easily accessible approach for creation of experiments with Arduino boards and the “Remduino Lab SDK”.
4. Participants will be able to assemble their own remote experiment using Arduino (we encourage them to use their own notebooks for the installation of the remote experiment software, we will provide the necessary Arduino boards).
5. All participants will also be able to monitor and control the experiments using their own mobile devices (BYOD).
6. There will be around 5 simple experiments already prepared in advance.

Our aim is to show that a remote experiment is simple enough even for beginners or non-programmers. It is not only within the domain of science laboratories, but can be created in a DIY environment. Workshop participants can build a simple remote experiment or demonstration and publish it within 10 minutes on the local network or Internet! Simultaneously we want to introduce a new form of school experiment - “hands-on-remote” that is both remote and hands-on.

In such experiment, students themselves may create their own experimental setup or just observe the one prepared by their teacher. Afterwards they can operate it remotely with their mobile devices (BYOD). Finally students may access the experiment from the classroom, school building, and perhaps from their homes after school.

We tried to build remote experiments based on a very popular and easily accessible Arduino platform. Experiments built on Arduino platform have already been published. [4], [5], [6]. The simplest solution has used only Arduino board with a LAN shield. Further experiments have used Arduino and Raspberry boards. Our approach uses Arduino Uno board only as an A/D or D/A converter, connected to a PC via USB port.

The control and data pre-processing is carried out in our new software kit “Remduino Lab SDK”, which will be the main part of our workshop.

This software kit consists of approx. 20 freely distributable JavaScript components (widgets) with commented source code. Widgets are highly configurable and provide many well documented options and allow to build a complex measurement and control interface with data and video transfer. The kit is a result of a long-term gradual development. At first, our software kits were relatively complex and specialized. Only very qualified users were able to use them, so for all applications in schools and other institutions, we had to develop the appropriate software ourselves. Later we managed to gradually simplify the software so that it could be used as a development kit. Users can simply “glue” together an experiment interface from prepared components like Input, Output, Record, Export or Video Transfer.

We have been developing remote laboratories for more than 15 years. We consider ourselves to be pioneers in the remote experiment field (our first remote experiment went online in 2002 and is still available). During the workshop, we will also present the current state of our iSES laboratory, where we currently run 18 experiments on ISES-PCI board (see <http://www.ises.info/index.php/en/laboratory>) [7]. For references on ISES see [8], [9], [10] and [11].

### **3 “HANDS-ON-REMOTE” EXPERIMENT WITH iSES SYSTEM**

#### ***Hardware:***

Modular system iSES (internet School Experimental Studio) communicates with different measurement platforms. The newest system **ISES-LAN** and **ISES-WIN** (see Figure 1 and 2) includes a PC with Windows 10 operating system (not Arduino, not Raspberry Pi etc.). Both feature 2x analog input, 1x analog output channel, 5x digital outputs/inputs with sampling frequency of 100 kHz. Software “iSES Remote Lab SDK“ can handle up to 4 ISES-LAN or ISES-WIN units..

The ISES system has 20 modules and sensors for Physics, Chemistry and Biology for remote or local experiments: input modules/sensors (temperature, voltmeter, ammeter...), output modules/sensors (relay, repro, booster, etc.). For more details and technical parameters about ISES modules see [www.ises.info](http://www.ises.info).



**Fig. 1.** New measurement system ISES-WIN



**Fig. 2.** New measurement system ISES-LAN

***Software:***

Server-side part of a remote experiment consists of experimental hardware connected to a dedicated computer that runs the MeasureServer and optionally the ImageServer applications. The MeasureServer provides two-way communication with the hardware, while ImageServer distributes the video stream captured by the webcam. Since the real-time data transfer is realized using the WebSocket technology, a web server has to be also installed and running. In the most of our experimental setups, the web server runs on the same dedicated computer and provides both user interface in

a form of a webpage and relays the WebSocket connection to the MeasureServer. Clients connect to the experiment using regular web browsers.

To create a user interface of an experiment we have prepared the library of approx. 20 JavaScript components (widgets) - "iSES Remote Lab SDK". This library is freely distributable under Creative Commons license. Individual widgets are highly configurable and provide many thoroughly documented options, which allow even non-programmers to build a complex measurement and control interface with data and video transfer. Among built-in features, users have access to a real-time spline interpolation, simple processing, export of data in various formats, graphical output and other sophisticated functionality. Widgets use standard web elements, so any web developer can readily modify the default design and fit them to the appropriate page as needed.

***"Hands-on-remote" easy experiments with iSES:***

For non-experienced experiment designers using the iSES platform we have prepared a "Lite iSES Remote Lab SDK" where we provide a collection of pre-made simple experiments like remote analog record of one quantity (e.g. temperature), remote analog control of one channel (e.g. current booster), remote digital inputs and outputs, time dependence of two or more quantities, XY dependence of input and output quantities, data record, data export, webcam stream etc. The examples have the simplest possible code and mostly use default settings for all components. These simple examples can be arbitrarily merged and combined, so even beginners are able to rapidly develop complex interfaces. They can immediately control their own remote experiments via mobile phones or tablets. Professional complete experiments are available at [12].

## **4 "HANDS-ON-REMOTE" EXPERIMENT WITH ARDUINO PLATFORM**

***Hardware:***

For simple "hands-on remote" experiment we propose to use Arduino-Uno board only as an A/D and D/A converter that is connected via USB port to a PC with the Windows OS (see Figure 3).

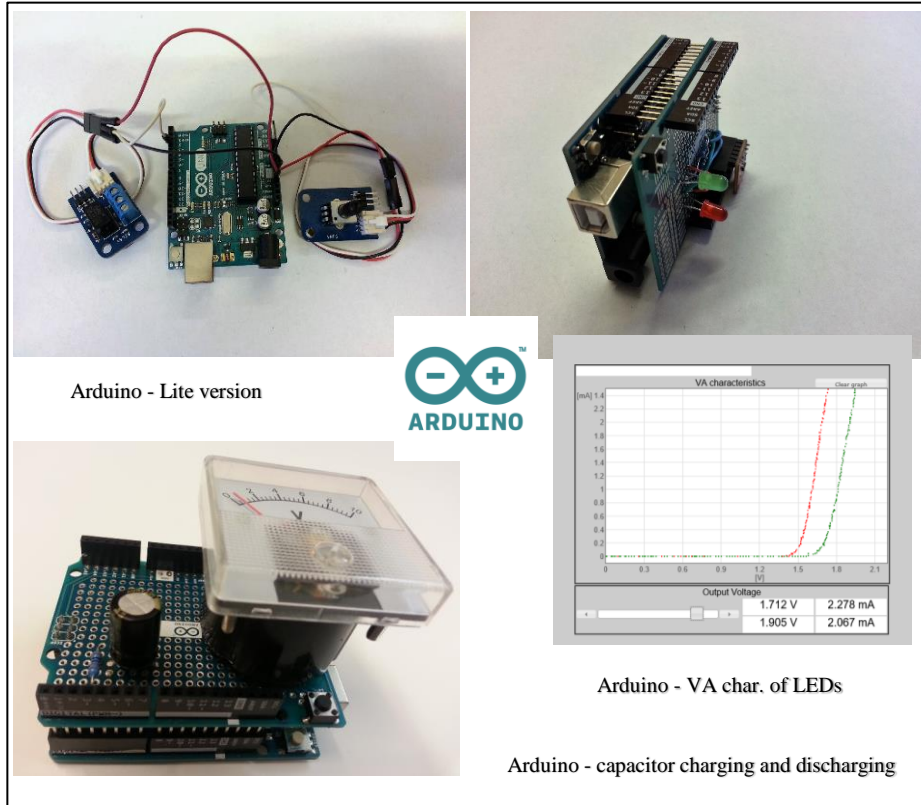


Fig. 3. Arduino and “Remduino Lab SDK”

**Software:**

Lite version of “Remduino Lab SDK” supports the measurement on the input pin A0 (e.g. for temperature sensor) and the control of one digital output pin D3 (e.g. for a relay). Lite version of “Remduino Lab SDK” will be freely accessible at the demonstration. Visitors will be able to try out and take away the software of the presented experiments for later use. Full version of the kit supports all different Arduino boards with all pins read/write access. Both versions provide input of data, output of data, data record and export function (e.g. to MS Excel).

**“Hands-on-remote” easy experiments with Arduino:**

Examples from the freeware “Remduino Lab SDK - lite version” will be presented on example projects like the volt-ampere characteristics of LEDs, capacitor charging and discharging, mass-on-spring oscillations or a simple automatization project “heating and cooling”.

We have very first experience with the proposed approach at a secondary school. The “Remduino Lab SDK” software kit has been used in several Physics lessons. The teacher presents a “*hands-on-remote*” experiment in the classroom, students can immediately operate it as “*near-remote*” during the lesson from the school building. For this purpose it is possible to limit the access to the experiment to a specific group of students or to the school intranet. After school, the students can easily access the experiment as “*far-remote*”, try it out again as a review of the lesson, or download and process their own experimental data to complete a “remote-experiment homework”.

## 5 CONCLUSIONS

Our “Hands-on-remote” laboratories might resemble e.g. a LabVIEW Remote Front Panel that enables to simply turn a local experiment into a remote one. LabVIEW Remote Front Panel, however, requires full installation of the LabVIEW Run-time Engine (large installation files, limited rights for installations in students’ labs, lack of support by the majority of web browsers or mobile devices like smartphones) [13]. Moreover, LabVIEW is a commercial paid product, therefore it’s less suitable to beginners and non-programmers.

Our new “hands-on-remote” experiments do not require any additional installations, remote experiment can be published and shared in approx. 10 minutes. Hands-on-remote experiments are accessible via smartphones and other mobile devices. Finally, lite version of the “Remduino Lab SDK” is freely downloadable. In our original approach to remote experimenting (hands-on-remote) a student experiences all important phases: 1. Initial setup of hands-on experiment (local), 2. creation of the control web-page (local), which is in its nature also immediately remote, 3. “near-remote” control of the experiment from a classroom and 4. “far-remote” access to a real hands-on-remote experiment.

We hope that this new type of remote experiment “hands-on-remote” to be presented for the first time at REV2018 conference might become a turning point in the remote experimenting field. It addresses both crucial advantages and disadvantages of real hands-on and remote laboratories.

We expect that this approach might sparkle the motivation inside potential new experiment creators. We believe that remote experiments with Arduino and the “Remduino Lab SDK” might become the dreamed Massive Open Online Labs (MOOLs), which are used by many participants and feature a greater number of real remote experiments.

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