

## REMLABGRAB – Data Providing System for Remote Laboratories Extensions Building

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### **Abstract**

*This paper represents a new era for the REMLABNET system, which is approaching new possibilities and the use of Remote Laboratories (RLs). The new, improved system brings the possibility of access to various platforms for building RLs, but also a reduction in the costs associated with building a computer-controlled experiment. The paper presents the REMLABGRAB (RLG) cloud platform for the provision of remote laboratories using the new concept of Remote Laboratory as a Service (RLaaS). The platform is primarily focused on simplifying the control of RLs individuals and allows superusers access not only to data, but also to the overall control of the laboratory at the level of Measure Server (MS). The main goal of RLG is to facilitate programming activities for those who want to add any added value to all these educational tools, such as artificial intelligence (AI), any form of virtual reality (VR) or feedback systems (FS).*

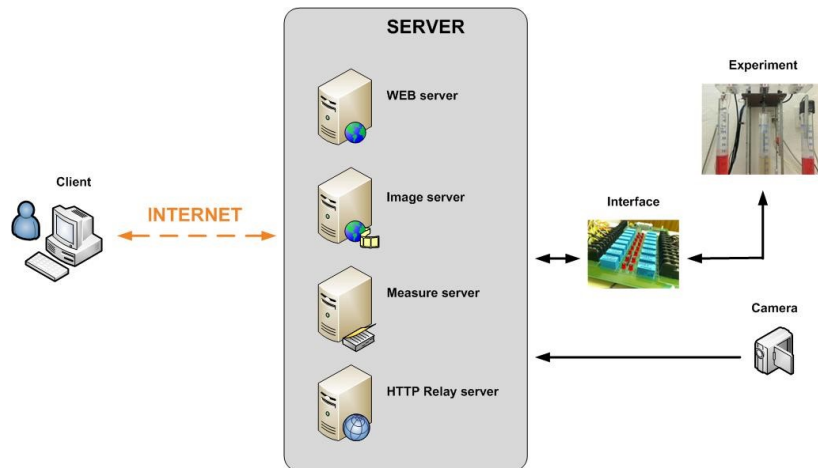
**Key words:** cloud, computing, virtual, platform, datacenter, service, remote labs, thin client

**JEL Classification:** L86, D85, L63

### **1. Introduction**

The REMLABNET consortium started a new era of building remote laboratories (RLs), which was caused both by the problem of budget cuts and by the Covid19 pandemic. During the pandemic, of course, students and the entire pedagogical community got into the online world, where it is mostly to this day, and the teaching of natural sciences in particular had to be moved from the laboratory exclusively to the theoretical level of online lectures. With the help of RLs, we try to prevent this as much as possible, and we present our students with new methods by which they can experiment and acquire the necessary skills. It is proven that students simply acquire knowledge if they can be perceived by multiple senses. Jan Amos Komenský already developed this principle theoretically and practically when he wrote: *"Let it be the golden rule for learners that everything be served in all possible senses. Namely, things visible to the eyes, audible hearing, audible smell, palatable tastes and palpable touch, and if some things can be perceived simultaneously by several senses, let them be administered simultaneously to several"* [1].

The logical structure for the remote laboratory is very simple and is shown in Figure 1, where we see the standard laboratory equipment (right), the interface for communication with a computer or server and a video camera. The main communication server (computer) follows, where the data from the experiment are encoded on a standard website and distributed to the client (left).



**Figure 1 – Basic system structure block diagram [02]**

According to the name of the consortium, our complex system is called REMLABNET [03], which has already undergone many modifications, proposals and strategies, but is now built to be able to accommodate experiments based on other architectures than the Internet School Experimental System (ISES). [04] for example: Electrochemical cell [05], Energy in RLC [06], Incline [07], Electromagnetic induction [08], Radiation [09], Wave laboratory [10], described too in [11].

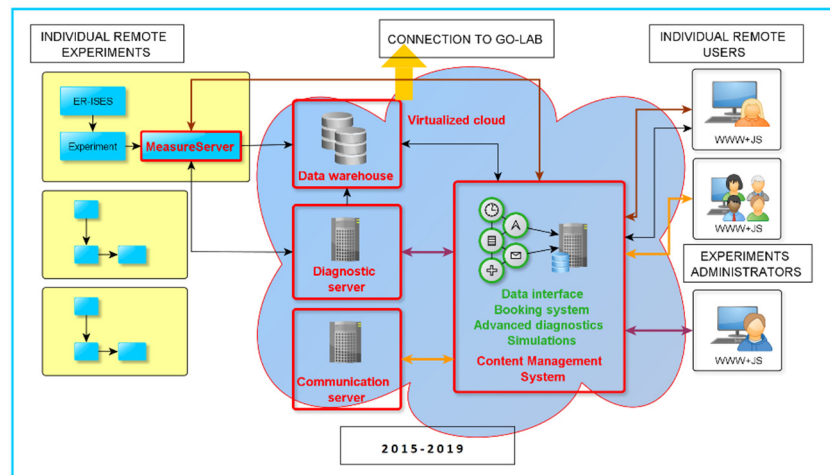
All remote laboratories are located in RLMS REMLABNET, where they are supervised and monitored for operation [12]. Some of the mentioned RLs are equipped with built-in and synchronized simulations [13]. A simple diagram of the REMLABNET network is shown in Figure 2 with the following sections [14]:

- **Data warehouse (DW)** - is a part of the system for data storage and analysis.
- **Reservation and administration server** - part of the content management system (CMS) - generates a service enabling individual remote reservation of the experiment for a given period of time.
- **Communication server** - another part of CMS is a system designed for information transfer and communication in real time, interaction and cooperation in the teaching and learning process with RE.
- **Virtualized Cloud** - The Virtualized DTC contains physical and virtual servers that serve a variety of services, including web services, file services, and more.

On top of this were recently added following servers:

- Diagnostic server – of I and II level [15],
- Embedded simulations server[16].

All this component parts of RMLS were placed on the cloud of Trnava University in Trnava [17].



**Figure 2 – Block scheme of REMLABNET with cloud embedded [18]**

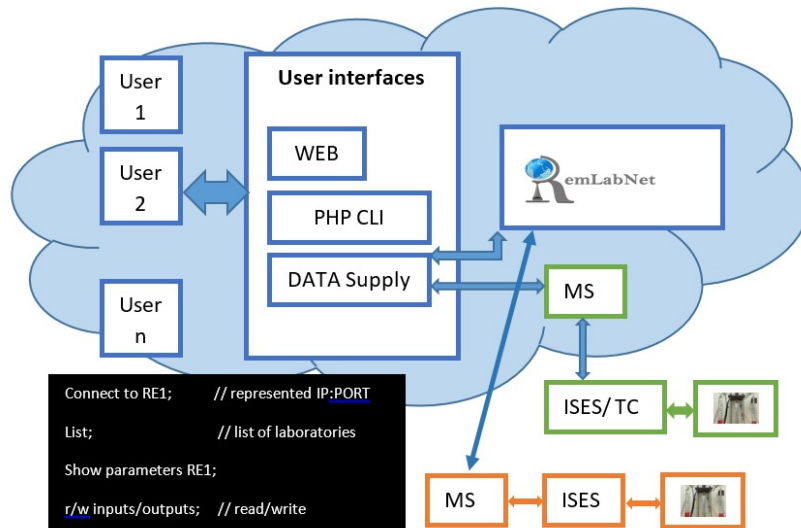
Of course, we consider the ISES system to be the most progressive method developed by our collaborator doc. Lustig at Charles University in Prague [19], but circumstances and times have progressed. We necessarily had to reach for new methods that we will use in the development of RLs. One such method is to replace ordinary PCs used to involve each expert. We have made great strides in this area in the deployment of thin client technology.

Another of the new methods in the use of RLs technology is our new concept of API style interface, which we are called REMLABGRAB (RLG).

***RLG concept***

RLG basically serves for easy access to all bidirectional data between the supervising client and the RL management server. This differs from a regular client that only has access to selected data. The supervising client thus has access to all data corresponding to the correct function of the RL, but can also change the functioning of the RL.

Simple scheme of RLG is in Figure 3 including ISES RL blocks and Measure Server (MS) unit (in orange). Of course, the block called ISES, for us no longer means not only ISES technology, but we are also able to involve other technologies for building RLs, which include, for example, the use of experiments based on Arduino or Raspberry PI [20]. In principle, REMLABNET enters the RLG system with all RLs, followed by the basic unit DATA Supply, whose function is to provide all cumulative RL data from the REMLABNET communication server by parsing. The PHP CLI block is used to directly create PHP communication commands. The WEB block is used to set up a communication website for client supervision, which contains a list of RLs (Figure 4) and items of inputs, outputs, IPs and camera addresses for individual RLs (Figure 5).



**Figure 3 – RLG main idea**

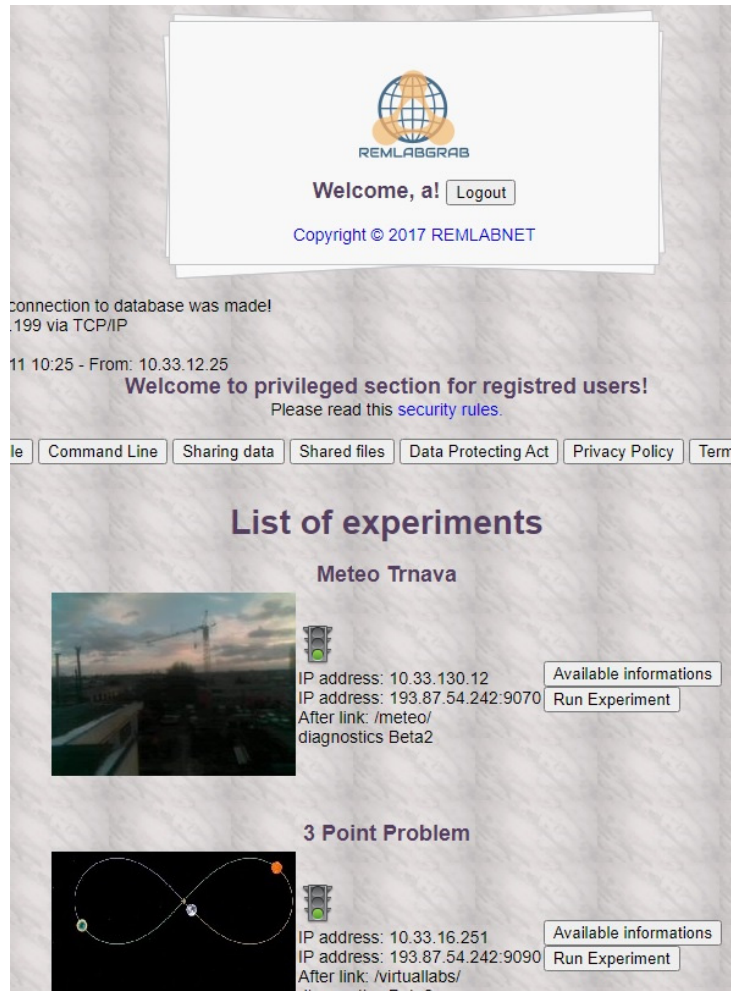
The function of the unit of RLG is following:

1. Supervising client must choose the RL in question
2. Communication with RL must be established in order to generate RL data
3. Supervising client can now control RL and may make full use of the data and functioning of RL

Supervising client thus can read the data from measure server of RL addressed with given IP address and corresponding PORT(Figure 4). Visible in Figure traffic light indicates the availability of RL.

In the list Figure 4 we can see the access IP addresses. Of course, the private IP address is used exclusively inside the cloud. This allows access, for example, from another RL that needs to use the information contained here. Such an example can be, for example, the external light intensity from RL Meteo Trnava for RL Photovoltaics, where the use of photovoltaic cells is compared.

Another IP address with a port is public, to which an authorized superuser (supervising client) connects in order to gain direct access to the laboratory.



**Figure 4 – RLG, list of experiments with example Meteo Trnava RLS**

In general the supervising client gains general data comprising inputs, outputs, camera address or else, what is need to work for each RLS. Example of possible data for electromagnetic induction is in Figure 5.

Basically, RLG serves for an easy access to all bidirectional data flux between supervising personnel and the RL. Supervising personnel has the approach to all the data, corresponding to proper functioning of a RL, but also possesses the possibility for changing its functioning. In schematical representation (Figure 6), are represented two kinds of connectivity, one by measuring client via REMLABNET (green line) and one via REMLABGRAB by the supervising personnel (orange line).

Here is an example of using RLG for the Electromagnetic induction experiment (Figure 7), values of parameters adjusted to measurement:

Controlling voltage on electromotor:

$$indukce\_napeti = \{0, 2, 4, 6, 8, 10\} V$$

Number of coils at time:

$$indukce\_sim\_windings\_count = 18 \text{ coil (for } 0 - 13.484 \text{ s)}$$

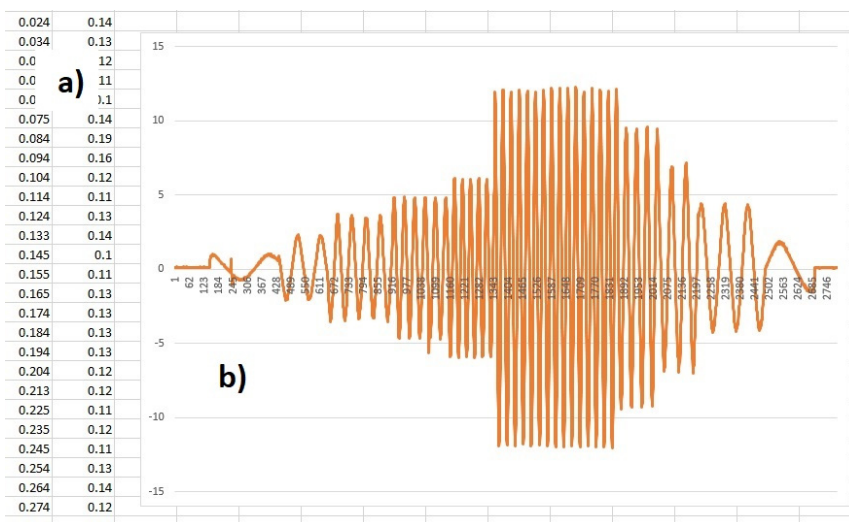
$$indukce\_sim\_windings\_count = 36 \text{ coil (for } 13.484 - 27.8 \text{ s)}$$

ELECTROMAGNETIC INDUCTION		
Available informations		
<b>1. INPUTS</b>		
indukce_motor	[-10000 to 10000]	(1/1000V)
indukce_sim_frequency	[0 to 7]	(Hz)
indukce_sim_windings_count	[1 to 50]	(--)
indukce_sim_magnetic_flux	[0.1 to 1.2]	(Wb)
<b>2. OUTPUTS</b>		
indukce_motor	[-10000 to 10000]	(1/1000V)
indukce_napeti	[-10 to 10]	(V)
indukce_sim_napeti	[-10 to 10]	(V)
indukce_sim_frequency	[0 to 7]	(Hz)
indukce_sim_windings_count	[1 to 50]	(--)
indukce_sim_magnetic_flux	[0.1 to 1.2]	(Wb)
<b>3. IP ADDRESS</b>		
195.178.94.35:8889-		
<b>4. CAMERA</b>		
IP address 10.33.179.2:8899		

Figure 5 – Available information for Electromagnetic induction laboratory, each laboratory have own information like this one



Figure 6 - REMLABNET and REMLABGRAB: Possible connections in our system of RLs: clients via REMLABNET for the measurements on RLs (green line) and supervising personnel via REMLABGRAB to inspect measurements and control data (orange line)



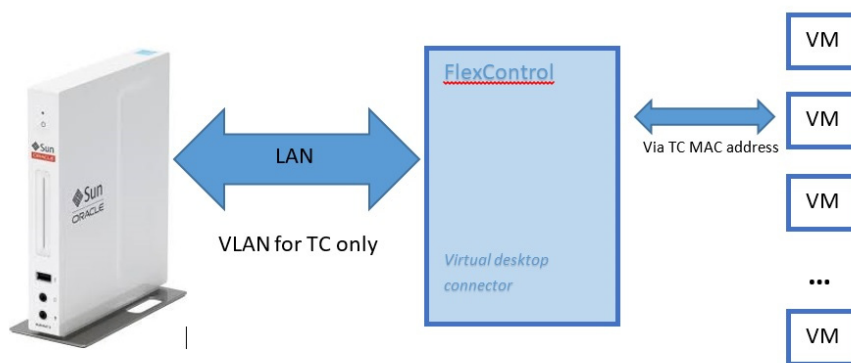
**Figure 7 - Measurement of „Electromagnetic induction“ via REMLABGRAB – a) part of the measured data, b) the graph of the measured induced electromotive voltage for controlling voltage on driving motor {0, 2, 4, 6, 8, 10, 9, 7, 5, 3 }**

***RLG Thin client***

To describe Figure 3 completely, it is well to mention that in connection with building of the interface RLG we used a new idea of exploitation of thin client (TC) communication unit, transferring all the functions of controlling server of RL to the cloud. This is depicted already in Figure 3 (in green). The TCs used in REMLABNET have also undergone many changes. The old version used TC company Sun Microsystems/Oracle, but here was many disadvantages. The new version of Huawei allowed us to access the source code, so we were able to modify the communication structure and get the most suitable use for REMLABNET / REMLABGRAB from the TC (Figure 8) used. The major advantage of this approach rests in the possibility to transfer all controlling and steering SW to a cloud. Simultaneously there is a possibility to multiplex many virtual clients (VM), with one physical HW, resulting in substantial, financial asses (Figure 9).



**Figure 8 – Thin clients used in REMLABNET (new version of TC - left, old version of TC - right)**



**Figure 9 - Architecture of TC in RLG, with Flexcontrol API**

### ***RLG contributions***

The main assets of a new interface of RLG is by providing new cloud service, Remote Laboratory as a Service (RLaaS) for our clients, teachers, students and any interested in RLGs of Science via Internet. We will inform about the services within REMLABNET in new contributions, because Cloud Computing of REMLABNET is under global reconstruction and we are moving to new, more modern solutions. However, new solutions always bring with them new demands on the computer / digital literacy of clients and therefore it is often necessary to educate them [21] and guide them. Ideally, if this is already happening within the schools where they are gaining education. With a new possibility to use TC technology the possibility is open to for create experimental basis of massive remote laboratories. On top of this substantial functional reduction results with the possibility of increase number of clients working with one experimental physical HW.

At this point, it is necessary to note that in the world of RLGs there is still no similar management system and no one has yet implemented it with the system we have used and proved to be. The use of TC in connection with cloud services brings many advantages. This brought us a considerable saving of financial costs and a huge saving of RLGs administration time. As we mentioned, RLGs have a great deal of credit for allowing our students to do laboratory exercises. Of course, the students of Trnava University are not the only ones who approach our laboratories. First of all, they are all students of our REMLABNET consortium, which consists of three universities: Charles University in Prague, Tomas Bata University in Zlín and, of course, Trnava University in Trnava. However, especially during the Covid 19 pandemic, the laboratories were visited by others. Our records include universities and high schools from all over Slovakia, Czechia, but also Spain, Italy and Austria.

## **2. Conclusions**

We can formulate following conclusions for introduction of REMLABGRAB module:

1. Accessibility of complex data of every RLG in REMLABNET system
2. Possibility of building extra sophisticated modules for RLG bringing additional application
3. Possibility of REMLABNET monitoring and its simplified supervising
4. General possibility of easy laboratories maintenance computer oriented school



We do not yet know what the future will bring us, but the REMLABNET system is constantly being improved and built on solid foundations by ISES systems. New methods of solving RLs bring new problems, but also new experiences and knowledge that we can use for continuous improvement.

What we can say and estimate is that the near future of using remote laboratories will only be bigger. On the one hand, the Covid 19 pandemic has influenced this, and on the other hand, it has been shown that RLs not only greatly help to save costs for organizations, but also keep students more interested in experimental knowledge. Times have changed and today's generation lives online. So why not take advantage of their weakness for the online world and show them something useful?

### ***Acknowledgement***

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