Towards Augmented Reality in Power Engineering

Ioana Opriş, Sorina Costinaş, *Senior Member IEEE*, Cristina Sorana Ionescu, Daniela Elena Gogoașe Nistoran
University POLITEHNICA of Bucharest
ioana.opris@upb.ro, sorina.costinas@upb.ro, cristina.ionescu@upb.ro, daniela.nistoran@upb.ro

***Abstract*- The paper explores the main directions in which the augmented reality and the Web can change the approach in power engineering and significantly improving it. These innovations facilitate, in a user-friendly way, the availability of real-time data, fast processed information, assistance and guidance at any time and in any place along the entire energy chain. A step-by-step implementation of AR applications is recommended to allow the human adaptation time to the new technology, the evaluation of results and the choosing of best future development. For the beginning, simple AR application should be introduced in student laboratories, on smartphones.**

***Keywords*: augmented reality, emerging technologies, internet, power engineering, education**

I. INTRODUCTION

Augmented reality (AR) is a technique of reducing the gap between the virtual and the real world. The real and the virtual are mixed to create a new, augmented, reality. Within AR, the real world around us interacts in real time with virtual objects created by a computer program. AR is possible due to the development of the display technologies. One can enter the AR environment by looking through a special device – tablet, smart-phone, display or special glasses – that has a connection to a computer. The task of the computer is to bring over and mix the virtual component with the (real) surroundings. The augmentation is usually a visual one, but it can be applied also to other human senses, for example by using sounds, smells or tactile features [1, 2, 3].

Inside an augmented world, the interconnections between information, individuals and things is growing and deepening. One may feel like the future is awaiting for him/her with an overall-web-invisible link between everything, everyone, everywhere, real and virtual. Static and dynamic programmable interconnections are available, even beyond the Earth [4]. There is a high interest of children and adults for the AR technology and a willingness to use it [5].

The objective of this paper is to present the main directions in which the AR and the Web could significantly improve the field of power engineering in the near future, for activities such as design, operation, maintenance, training and education. Aiming for an efficient and sound implementation of AR, a start-point for the implementation is proposed, in the most opened field and for the most opened users: the lab work within higher education.

II. AUGMENTED REALITY

A useful and wise manner to get better knowledge and control on processes that occur in the energy field is to make them easily studied. Therefore, different modeling and simulation techniques were developed to obtain virtual results, similar to the real ones. Mathematical models are successfully used in the field of power plants as an aid for training, design, verification, diagnosis, operation, optimization and management [6, 7, 8, 9].

At present, the technological achievements in the field of electronics and computing, along with the use of Internet, opened the way for the development of smart equipments. The main capabilities of smart equipments are bidirectional communication, computing and networking [10]. Today, smart metering and smart systems are more and more present in the energy field, as means to increase the energy efficiency and reliability along the entire energy chain. As a result of introducing and using such systems, a high amount of real-time information may be available in different places, in real time [11, 12].

To usefully benefit from the entire amount of information, one must find a convenient way to make it readily available, anywhere, anytime. For now, AR proved itself to be a good solution to achieve this task.

Within AR, the real environment and the additional (computed) information from the virtual reality are shown all together, as if they were both real (Fig.1).

A tracking system is used to follow the real image and position of the user to be able to superpose the virtual image over the real one.

In a computer, the AR is created by combining the real world with virtual objects. The real world can be shown, but enriched with some 2D or 3D virtual objects. The virtual objects can be realistic or fictional, depending on the final objective. These virtual images interact in real-time with the real images, as they would have the same origin [1].

To see an augmented reality of a specific environment, a special display is used: a Head-mounted Display, a Hand-held Display or Spatial Display [3, 13]. The display superimposes the virtual objects over the focused environment, so that an augmented reality is seen [2]. There are several games that use augmented reality, the most successful being Pokémon Go.

ISBN: 978-1-5090-5160-1/17/$31.00 ©2017 IEEE

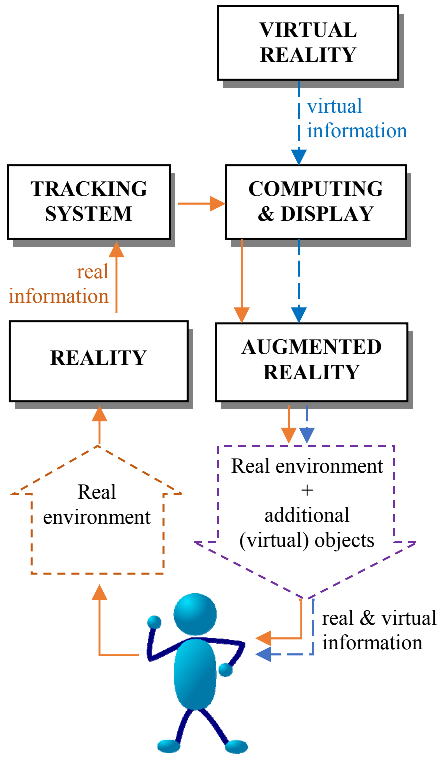

Fig. 1. Augmented Reality Concept.

The most affordable and frequent option is to use a Hand-held Display, e.g. a tablet or a smart phone. These allow the ease of communication and use of AR, making it more user-friendly [14].

Such a new possibility of extending the reality changes the approach of the entire energy chain - generation, transport and distribution, supply, and energy use. At any level of the chain, AR can bring real-time information in a convenient way, allowing a power-friendly approach to the energy domain. The access to real-time energy data at different levels enables a more efficient operation of the entire energy chain. Generation and use can be better controlled and optimized, the problems can be detected and solved more easily, allowing operational savings and an effective network management of energy systems. The overall benefit of using advanced systems in power engineering would be higher energy efficiency and reduced greenhouse gas emissions [15].

III. Possible Applications of Augmented Reality in Power Engineering

The most important benefit of using AR in the power engineering field is to complement the information that is available in a specific place with additional information (knowledge) brought through the virtual world, in the right place and at the right moment.

AR may bring closer separate fields of power engineering (Fig. 2) – like design, operation, maintenance, education and training etc. – by giving the possibility to easily address and exchange real time useful information. Moreover, AR can bring specialists from different fields closer, enabling their dialogue and understanding. For example, the constructor and end-user can discuss on a 3D augmented image instead of a 2D construction plan.

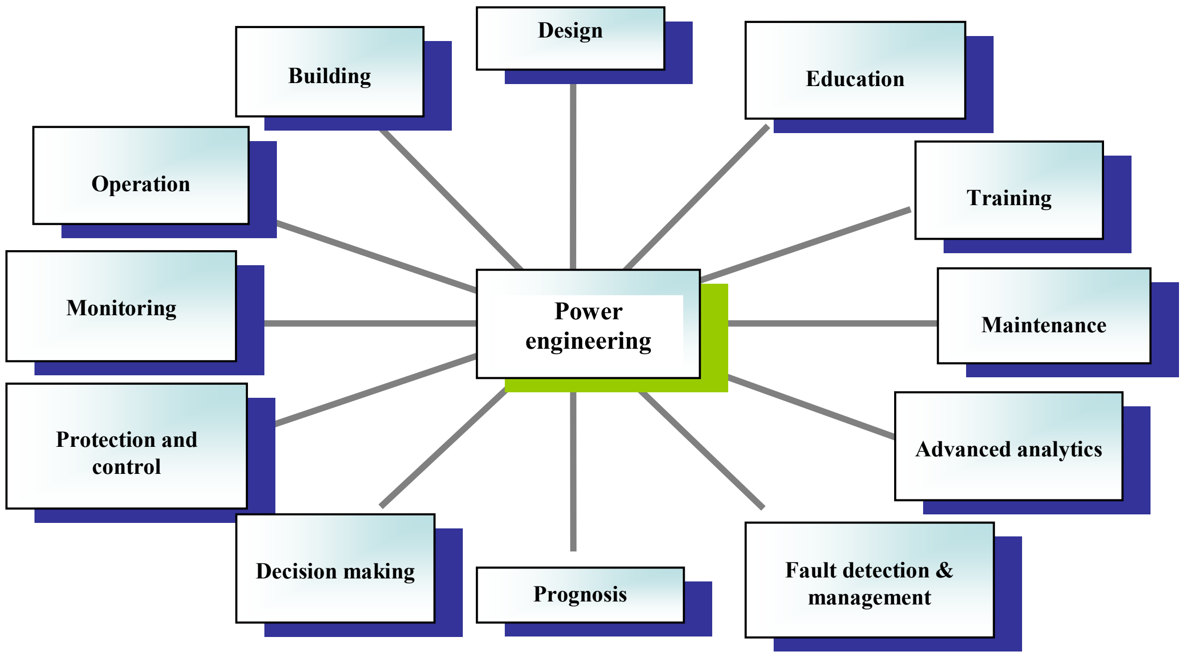

Fig. 2. Augmented Reality in Power Engineering.

Additional information brought into the reality from the virtual-reality consists primarily in:

- availability of real-time data measurements and specific information from other dependent systems,
- three-dimensional in-situ visualization of equipments and systems,
- step by step guidance for actions to be taken ,
- assistance for decision making,
- availability of results from Web SCADA applications and analytic functions,
- prognosis of future evolution of systems,
- assistance for fault detection and outage management,

possibility of effective communication.

In design, specialized virtual prototyping tools can be used to superimpose over the 2D design schemes the 3D images of the future equipment and/or additional information (geometrical or functional data). At the same time, AR helps the design engineer to determine the way in which a detail fits to a specific site in the real world.

During plant/ equipment operation, AR integrates and presents information that comes from different applications in a user-friendly way e.g., monitored data from the control room (Fig 3), in-situ visualization of equipments (Fig 4), protection and control, support for decision making, prognosis, fault detection and management, Web SCADA applications, advanced analytics functions etc. The information from different applications is brought to the individual in real-time whenever and wherever needed.

Fig. 3. In-situ monitored data from the control room available through Augmented Reality.

Fig. 4. Visualization of equipments available through Augmented Reality.

Maintenance represents a field in which AR may bring a significant working time and human errors reduction. AR is useful to locate a specific equipment or place, to determine its operational state and to access additional technical information [3]. Fig. 5 shows an example in which the scheme of an electrical substation is visualized nearby it. Another example of using AR for the Field Force Data Visualization (FFDV) and emergency restoration is given by EPRI [2].

The classical technical documentation and instructions based on paper documents can be replaced by information made available through AR, anytime, anywhere needed [12]. Fig. 6 shows how a thermal scheme is displayed in the control-room through AR.

Fig. 5. In-situ visualization of the design of an electrical substation in UPB, *Constantin Dinculescu* Laboratory.

Fig. 6. Information available through Augmented Reality.

Fig. 7 shows the way step-by-step instructions are displayed to aid a worker to take the correct actions. If the device is fixed on the head of the worker, he will be able to use both hands to perform manual tasks.

In training and education, AR is being at home, due to the high potential it offers to these fields [5]. For the new Digital Natives, that grow up with Internet facilities and have increased multitasking behaviors [17] and less patience, the use of augmented books and guides allows a faster and deeper understanding of the principles. Moreover, AR helps students to assess and analyze the performance of different design options within laboratories [18, 19].

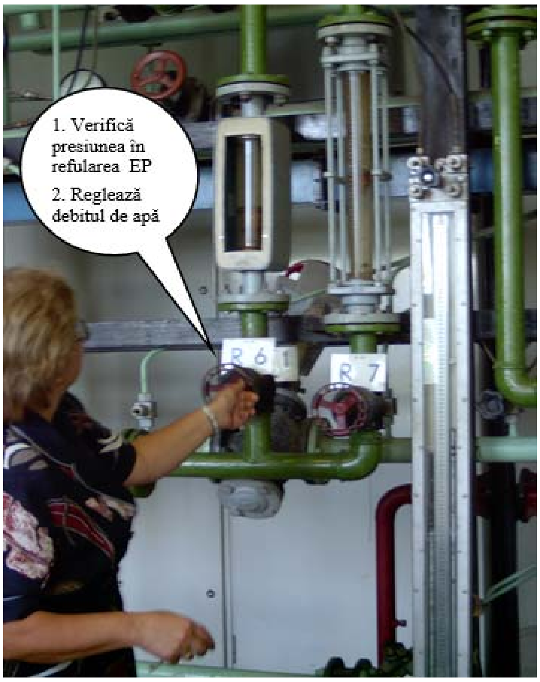

Fig. 7. Instructions available through Augmented Reality.

The text and image contained in a traditional 2D book or handbook is combined with interactive 3D virtual content in an augmented book [20]. Fig. 8 shows the way photos taken in real installations are used by AR to give a better understanding of the schemes.

Through different visualizations (Fig. 9), AR enables the display of additional information, explanations and guidance for learning and for training or improving abilities.

Fig. 8. Augmented Reality in books and handbooks.

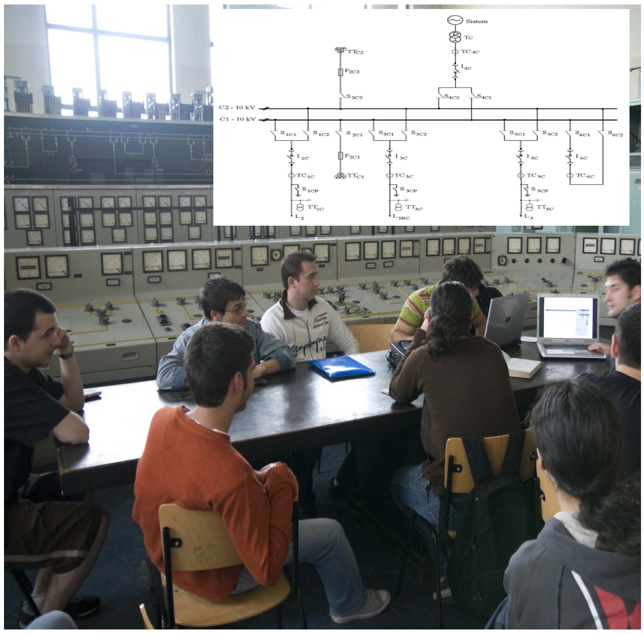

Fig. 9. Augmented Reality for supplementary visualizations of the actual substation network during explanations in UPB, *Constantin Dinculescu* Laboratory.

In laboratories, AR is used to show the students how the equipments are used within the real installations (Fig. 10) or how the equipments look inside (Fig. 11) [3, 18]. During lab work, AR can provide instructions, schemes and information on theoretical aspects. Thus, the AR based learning experience is also training the students to use the theoretical knowledge to solve practical problems [21].

Moreover, along with AR smart headlight can be used to better explain and understand the real installations. By using of a computer and a projector-based illumination, the target environment can be selectively illuminated to improve or manipulate the way reality reveals to individuals [22].

IV. STEP-BY-STEP IMPLEMENTATION OF AUGMENTED REALITY APPLICATIONS

There are large possibilities for applying AR in power engineering, in a large variety of ways. The authors consider that AR should be introduced in technical fields where it is possible to obtain important improvements by using simple augmentation through a smartphone or tablet.

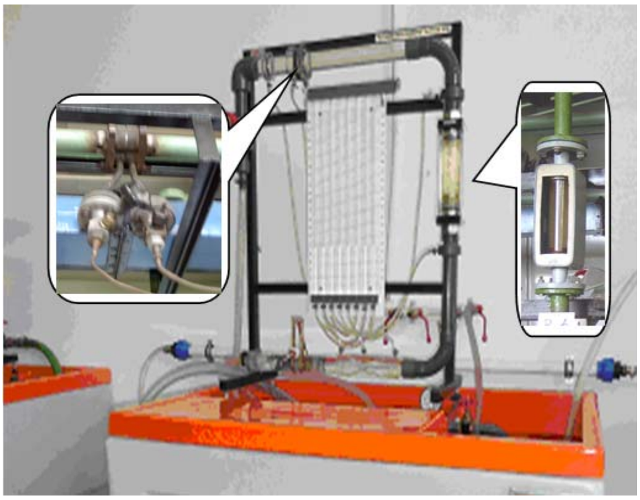

Fig. 10. The use of Augmented Reality to show the real installations.

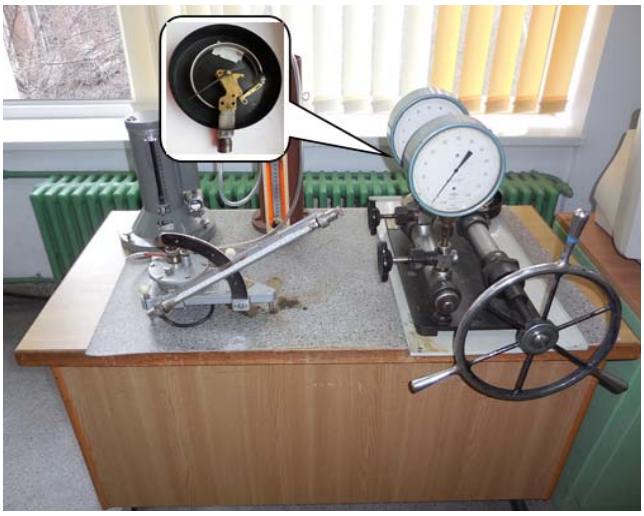

Fig. 11. The use of Augmented Reality for teaching in laboratories.

Table 1 contains seven main fields that we consider worthy for the development of AR projects. Types of augmented knowledge that can be delivered are: data, other available information, images.

TABLE I
WORTHY FIELDS OF POWER ENGINEERINF TO INTRODUCE AR

	Data	Information	Images
Operation	X	X	
Monitoring	X	X	
Decision making	X	X	X
Fault detection	X	X	X
Maintenance	X	X	X
Training & Education	X	X	X
Consultancy	X	X	X

The problem is to choose the right type of AR in the right field so as to maximize the benefits and minimize the risks of failure.

As AR brings new ways of interaction with the surrounding world, the transition towards augmentation should be made smoothly if the obtaining of most benefits is desired. The necessity of smoothness and even slowness is owed to the fact that people need time to understand what AR is about, to accept it, to learn how to use it and then really include it in their activity [10]. The interface with the user is delicate and needs time to adapt. The necessary adaptation time is strongly influenced by age and education, being shorter for young educated people.

To obtain most benefits with low risks, a step-by-step implementation of AR applications should be done. Starting with simple application implies a low investment, while letting also the user the necessary time to adapt to the change. The upgrading to a more complex application is worthy only after the simpler one is used at its most possibility and its implementation is evaluated.

Based on these arguments, the authors consider that the most suited start-field for the implementation of AR in power engineering is education, by allowing:

- AR visualisations within the manuals and handbooks, as in Fig. 8;
- AR visualisations of the actual components of the power plants, as in Fig. 9-11.

The fist step will be to implement these two features within three laboratories of the Power Engineering Faculty: the Laboratory of Non-electrical Parameters Measurement, the Laboratory Electrical part of Power plants and Substations and the River Hydro Laboratory.

For the software development, there are available free AR platforms, as Aurasma [23], Large [24], ARToolKIT [25], Layar [26] etc. Students can be involved in the development, thus increasing the AR-friendliness and shortening the time to an efficient use.

Once AR applications will be available, each student will use its own smartphone or tablet to overlay text, graphics or images over the view from the camera to receive more valuable knowledge.

Only after evaluating the results and impact of the first step of implementation, the future implementation steps will be considered, including technical solutions and the associated costs.

V. CONCLUSIONS

AR and Internet represent two powerful tools that open new ways for smart technologies. They foster the integration of huge amounts of real-time information from different fields, a better performance of the installations, higher speed in taking actions, faster restoration after outages, increased safety and reliability of the power system and lower costs. At the same time, AR can increase the effectiveness of the future real-time interconnection of smart systems.

We assume that there is a multitude of directions suitable for the use of AR within the energy chain. The main fields in which we recommend the use of AR are: operation, monitoring, decision making, fault detection, maintenance, training, education, consultancy.

To make most benefits from AR with a minimum of risks, a step-by-step implementation of the technology is proposed, which allows both the users to adapt to the change and the developers to evaluate the results and design the best future applications.

The firs step of AR implementation and evaluation should be in education, as the young, educated, generation is most opened for such type of novelties. Moreover, students could be engaged in using a free AR platform to develop the first simple applications. AR might be most useful in laboratories, for the visualizations of actual components from power plants. Future developments of AR should be considered carefully, after having the evaluation of the first-step AR impact.

Incontestable, an optimal information flow available in real-time represents one of the modern and powerful keys for reaching targets such as higher reliability~~,~~ and energy efficiency and lower greenhouse gas emissions. Therefore, we recommend the extension of the study, the development and use of AR applications in the field of power engineering.

ACKNOWLEDGMENT

This work has been funded by University Politehnica of Bucharest, through the “Excellence Research Grants” Program, UPB – GEX. Identifier: UPB–EXCELENȚĂ–2016. Research project title: “Analiza funcționării centralelor termoelectrice pe combustibil fosil, pentru integrarea optimă în piața de energie” / “The Analysis of the Operation of Fossil Fuel Thermal Power Plants, for the Optimal Integration into the Energy Market”. Contract number 88/26.09.2016 (acronym: CETEIOPE).

REFERENCES

[1] R.T. Azuma, “A Survey of Augmented Reality”, *Presence*, vol. 6, no. 4, pp.355-385, August 1997.

[2] J. Simmins, “Augmented Reality for Workforce Mobility. The Next Level”, Technical Executive Information, Communication, and Cyber Security (ICCS) European Engagement Summit, April pp. 28-29, 2015.

[3] G. Dini, M. Dalle Mura, “Application of Augmented Reality Technologies in Through-life Engineering Services”, The Fourth Conference on Through-life Engineering Services, Procedia CIRP 38(2015) 14-23, 2015, DOI: 10.1016/j.procir.2015.07.044.

[4] V.*S.* Pendyala, S.S.Y. Shim, C. Bussler, “The web that extends beyond the world”, *Computer*, vol. 48, no. 5, pp.18-25, May 2015.

[5] T. D. Chicioreanu, C.Gh. Amza, “Are teachers ready for the augmented reality?”, Conference Smart 2014, Social Media in Academia: Research and Teaching, Timisoara, Romania, September 2014, DOI: 10.13140/2.1.1538.0802.

[6] I. Opris, S. Costinas, V. Cenusa, “Numerical Methods applied for Power Plant Calculations”, *Modern Computer Applications in Science and Education*, 5th International Conference on Applied Mathematics and Informatics (AMATHI ’14), Cambridge, USA, pp. 83-90, 2014.

[7] S. Costinas, I. Triştiu, G.N. Sava, I. Opris, V. Tanasiev, “A New Mathematical Model For Assessing Optimization Decisions Of The Loading Factor Flowing Through Substation Transformers”, 2015 IEEE 15th International Conference on Environment and Electrical Engineering, Rome, Italy, June 2015, pp. 2109-2114, DOI: 10.1109/EEEIC.2015.7165503.

[8] M. Damian, I. Motoiu, L. Caracasian, “A Simulation Software for Cooling Towers Optimal Operation”, American Power Conference (APC), 60th Annual Meeting, Chicago, SUA, 1998.

[9] I. Motoiu, L. Caracasian, “Expert application for power plant operators’ training”, Optimization of Electrical and Electronic Equipments, OPTIM’98, Brasov, Romania, 1998.

[10] I. Opriş, L. Caracasian, “On the implementation of the functionalities of smart metering”,The 9th International Symposium on Advanced Topics in Electrical Engineering, Bucharest, Romania, May, 2013.

[11] I. Opriş, S. Costinas, C. Ionescu, D. Nistoran, “The household energy consumer in a smart metering environment”, The 9th International Symposium on Advanced Topics in Electrical Engineering, Bucharest, Romania, 7-9 May, pp. 43-48, 2015.

[12] S. Costinaş, S.C. Georgescu, I. Opriş, “Smart solutions for the auxiliary power supplies schemes in hydropower plants”, *University “Politehnica” of Bucharest Scientific Bulletin*, Series C: Electrical Engineering, vol. 76, Iss. 3, pp. 245-253, 2014.

[13]. E. Gobbetti, R. Scateni, “Virtual Reality: Past, Present, and Future”, CRS4 Center for Advanced Studies, Research and Development in Sardinia Cagliari, Italy, 1998, PMID: 10350926.

[14] R. Wright, “Augmented Reality as Experimental Art Practice: from Information Overlay to Software Assemblage”, Proceedings of the 22nd International Symposium on Electronic Art ISEA, Hong Kong, 2016.

[15] M. Levinson, “Is the Smart Grid Really a Smart Idea?”, *Issues in Science and Technology*, vol.27, no. 1, pp.39-48, Fall 2010.

[16] H. Ishii, K. Matsui, M Kawauchi, H. Shimoda, H. Yoshikawa, “Development of an Augmented Reality System for Plant Maintenance Support”, Conference of Cognitive Engineering in Process Control, CSEPC2004, Japan, November 2004.

[17] K-K. Loh, R. Kanai, “How has the Internet Reshaped Human Cognition?”, *The Neuroscient*, 07/2015.

[18] A. Srivastava, P. Yammiyavar, “ARIEL: Augmented Reality Based Instructions for Electronics Laboratory in Engineering Education”, working paper, October 2016.

[19] S.K. Ayer, J.I. Messner, C.J. Anumba, “Augmented Reality Gaming in Sustainable Design Education”, *Journal of Architectural Engineering*, January 2016, DOI: 10.1061/(ASCE)AE.1943-5568.0000195.

[20] J. Dorribo-Camba, M. Contero, “Incorporating augmented reality content in Engineering Design Graphics materials”, Frontiers in Education Conference, FIE, 2013.

[21] A. Srivastava, “Enriching student learning experience using augmented reality and smart learning objects”, Proceedings of the 18th ACM International Conference on Multimodal Interaction ICMI 2016, pp. 572-576, Tokyo, Japan, Nov. 2016, doi: 10.1145/2993148.2997623.

[22] T. Kanade, “Smart Headlight: A new active augmented reality that improves how the reality appears to a human”, IEEE International Symposium on Mixed and Augmented Reality (ISMAR), Sept. 2014.

[23] Aurasma Platform. Available: https://www.aurasma.com/

[24] Large Platform, Available: http://www.largeproject.eu/en/

[25] ARToolKIT Platform. Available : http://artoolkit.org/

[26] Layar Platform. Available: https://www.layar.com/