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Using Marker based Augmented Reality and Natural User Interface for Interactive Remote Experiments

Ananda Maiti, Andrew D. Maxwell and Alexander A. Kist
School of Mechanical and Electrical Engineering, University of Southern Queensland
anandamaiti@live.com, andrew.maxwell@usq.edu.au, kist@ieee.org

***Abstract*—Remote Access Laboratories (RALs) use computer-based platforms to deliver educational goals for engineering and scientific laboratories. To pursue more effective user interfaces, RAL can now be integrated with Augmented and Virtual Reality features to enhance users' interactions and control features. A Natural User Interface (NUI) is one way to implement advanced input methods to capture data from users' natural movement. These methods aim to enable interactions with greater options and flexibility. This paper introduces a method to use augmented reality and a natural user interface to create interactive laboratory experiments. In this case, experiments have a virtual object which is download at the users' location. The users use a NUI device to interact with the virtual object. Interaction with this object is translated to operational commands which are performed on the real hardware in a remote location through the Internet. The paper presents both, an overall architecture to support such environments and an example RAL experiment using this method, in form of a Gearbox, to show the practical relevance of the approach within RAL. The new system permits hands-on-experience with virtual objects as a part of the RAL activity.**

Keywords— remote laboratories; e-learning; augmented reality; natural user interface; unity3d

I. INTRODUCTION (*HEADING 1*)

Remote Access Laboratories (RALs) permit accessing and utilization of physical hardware for educational experiments via the Internet. This technology has reached a level of maturity where there are many examples of fully working and educationally useful remote laboratories. By providing auxiliary information which human senses cannot directly detect, Augmented Reality (AR) can enhance a user's visual and auditory perception [18-19] or an environment or situation. There are early examples of AR in Education, e.g. [20]. Due to recent developments in technology, AR has received a lot of attention, both in popular culture for instance through Pokémon GO™, as well as in the educational technology domain.

It has become common practice to embed virtual objects in books, for example, or more correctly have software able to recall stored virtual objects for display within the book. Usually markers or computer identifiable codes are printed within the book and specific smartphone or tablet applications are then able to make the virtual objects visible. Other approaches are also being investigated [21], where there has been some significant work in the areas of AR, RAL and virtual systems. For example, Andujar et al. [22] have introduced the notion of Augmented Remote Laboratories (ARLs) and Restivo et al. [23] have developed a virtual system with haptic interaction (kinesthetic communication). The next step towards a more realistic experience is offering users the opportunity to interact with these virtual objects. Such technology can also help to address one of the key limitations of remote laboratories: the lack of opportunities to intact with physical hardware in a realistic and authentic way. This is particularly relevant where laboratories are being used to train students in using gear such as instruments or invasion pumps.

Natural User Interfaces (NUIs) [24] aim at reading and perceiving user inputs without utilizing a fixed position or restricted input devices such as a keyboard. Typically, NUI uses computer vision processing to identify and track whole body motion, hand or finger gestures. These devises are now widely used in gaming applications. Device such as the Microsoft Kinect™ and Leap Motion™ are able to capture complex body gestures with a high accuracy. Integrating NUI with AR or Virtual Reality (VR) [25] is a natural progression. Users therefore do not need to rely on conventional input means for interaction [26], instead they can directly engage with objects in AR or VR.

This paper presents a first step in combining RALs, AR and NUI by allowing users to interact with virtual objects in their physical workspace leading towards creating interactive engineering and scientific experiments. The key contributions of this work include an augmented reality architecture that captures the client-server nature of the RAL environment.

Notionally, experiments include a virtual object which is download to the user location. The user then selects a NUI device in order to interact with the virtual object. The interaction is translated into operational commands which are transmitted via the Internet to be executed on the real hardware at the remote location. The proposed system uses NUI devices and local camera feedback at the user site to permit the users' natural interaction with virtual objects representing the experimental setup. The interactions are processed in correspondence with the actual hardware located at the remote site. This work also presents an example implementation that demonstrates the feasibly of the concept.

The remainder of the paper is organized as follows: Section II discusses related work both in terms of AR as well as NUI devices and the combination of both topics. Section III introduces the proposed AR architecture and Section IV presents an example implementation using Leap Motion™, Unity3d™ and a LEGO™ based gearbox experiment and discusses the advantage and limitations of the proposed system.

II. Related Works

This section discusses the current state of AR and NUI applications.

A. *Augmented Reality Appications*

Augmented Reality (AR) is the process of adding information typically in the form of dynamic graphics (either 2D or 3D) onto a video feedback system. Such applications focus on providing visual feedback on the users' current view. AR typically involves mechanisms to observe, identify and track real-world objects. A primary method of tracking is through the use of markers. Markers are images or easily identifiable symbols that allows the AR systems to determine what virtual information must overlaid on the video, as well as its position and orientation.

AR methods are employed within the RAL framework to provide users with a rich immersive experience so that the disadvantage of non-proximal resource usage can be potentially compensated (i.e. simulated hands on experience can be achieved). Utilizing AR with a RAL environment creates a unique set of conditions to overcome depending upon the experimental setup [1-3]. Previously it has been primarily used to overlay information on to a video feedback from the remote experiment site. This has typically been done to enhance the users understanding and knowledge of concepts in the remote site that might be otherwise invisible or impossible to directly observe. In these instances, there are however no interactions with the AR feedback objects, where the AR only changes in accordance with the users' inputs into the experiment. This work presets a method to allow direct interaction between the AR visual components and the users which then affects the real hardware in the RAL.

B. *Natural User Interface devices*

Natural User Interfaces (NUI) rely on specialized devices to obtain information about the users' physical body position [4-6]. This is usually a stream of real-time data in the form of an array containing the X, Y, Z cartesian coordinates of the user's body parts, joints, and bone segments. NUIs are generally focused on "gesture" control. A gesture is a fixed set of known movements representing a particular transition the users' orientation and position. An NUI system defines a set of gestures that are recognized through the corresponding devices. The video output is determined based on those gestures. More recently, the physics engines have been included in the NUI applications [7]. This eliminates the need for gestures based solely on the users' body parts. These physics engines can allow direct interaction between a virtual object that represents the users body in a virtual 3D space and any interaction between these and the experiment objects results in the outcome. This paper focuses on this method of using NUI with a physics engine.

NUI has been used in RAL previously [8] using the Microsoft Kinect. This work however did not use virtual objects or a physics engine toolkit. There are multiple commercial devices available for NUI. Examples include the Microsoft Kinect™ which can track multiple humans' full bodies, and the Leap Motion™ which can track the palms and fingers of both hands of a user in a more confined space. Webcams have also been used to track hands for gesture input [9-10], however these are generally only able to provide 2D positional information and may not be able to capture complex interactions. Additionally, as is the case for RAL, hand or body movements can follow complicated set of paths in the users' workspace, thus webcam based devices at present are not considered to be effective or *useful* inputs devices for NUI in case of RAL.

C. *AR and NUI applications*

Application of NUIs is still generally confined to Virtual Reality e.g. with Oculus Rift™ [7, 12-13] including medical applications and visualization of data sets. These environments allow real-time interactions with virtual objects within a virtual space. For e.g. in [12], the Leap Motions and Oculus Rift was used. There are a few applications where the augmented reality with NUI has been used [11] which mainly compares the users' perception of virtual objects in a virtual reality with the augmented reality.

In this paper, a method to directly integrate the NUI devices with AR is discussed where the users' physical location and orientation can manipulate the virtual object as well as the real objects at a remote location.

III. The Augmented Reality Architecture

This section introduces the architecture that forms the basis for the work reported in this paper. In particular, it discusses the augmented reality architecture including the virtual objects, physics engine, methods of interaction, components of the AR and NUI system and the devices and ways to use them.

A. *Virtual Object*

A virtual object is a 3D representation of an object within a virtual space. Whilst a virtual object in VR can be of any conceivable type or form, a virtual object within RAL is generally designed to be as similar to the real physical object as possible. A virtual object can have multiple components that are joined together. These connections between the objects can be of various types such as hinges, gears, single point joints etc. This allows the components of the virtual objects move with respect to each other. The extent of flexibility (axis, moments, limits) can be confined as required by the experiential setup.

In the case of RAL, unlike VR, the constraints of the movement must be well defined. This is because the virtual object must behave in a manner consistent with the real hardware. Thus, the orientations and positions of the virtual objects must be clearly categorized as reflected by the real hardware.

Virtual objects can be stored in various CAD formats such as 3DS, STereoLithography (.stl), and wavefront (.obj). These files can be downloaded into client software and overlaid on camera feedback to create the AV environment. The RAL system proposed in this paper uses markers to determine when and where the objects appear in the video stream.

B. *Physics Engine*

A physics engine for AR/VR allows the developers to create virtual objects. These environments allow software developers to create complex virtual objects based on simple primitive geometric objects such as tessellations, spheres, cylinders, boxes. The physics engine allows the objects to behave in a realistic manner as if they were in a real-world environment with expected attributes such as weight, gravity and obey the laws of motions. Some virtual objects may also be added that may not be part of the experiments, and may not have the physics engine attached to them, but to hide unwanted objects in the video feedback. The physics engine and/or the AR/VR module is a software module that runs on the users' computers. This module may also be run partly as a cloud service. This module updates the users' scene, i.e. the part of the 3D environment the user see, either on a desktop screen or through a Head Mounted Display (HMD) when new information becomes available from the instrument server upon executing an operational command.

The physics engine creates the 3D environment corresponding to the video feedback. If using a HMD, the environment typically consists of the video feedback display. If predominantly virtual objects are used, the 3D environment becomes a virtual 3D game-like environment utilizing little real world data [14]. There can be two types of virtual objects: the *passive virtual object* which corresponds to an actual experiment objects (e.g. a box); and the *NUI virtual object* which are active, i.e. all changes in the 3D environment is initiated by the NUI virtual objects (e.g. a 3D representative hand). In case of the HMD based AR, the NUI virtual objects may to be shown to the users. For example, a 3D hand may appear in a desktop AR to simulate the users hand, but may not appear in a HMD based AR. Some examples of such game engines providing physics capabilities are Unity™ and the Unreal™ physics engines.

C. Natural Interactions

The natural interactions start by the users downloading the corresponding camera-readable marker and printing or fabricating it. It is also possible for the users to create their own marker designs and upload them to associate with the particular experiments. The camera is then placed over the markers. The remainder of the procedure is demonstrated in Figure 1. The client interface downloads the corresponding virtual objects. The experiments are then initiated and for each frame in the AR video feedback the following steps are executed:

- the experimental setup is updated according to the virtual objects;
- the virtual objects are update according to any special gestures such as zooming, panning etc;
- markers changes are also reflected in the virtual object; and
- once complete, the experiment is reset and the virtual objects are deleted.

If any virtual object is removed from the augmented workspace, then it is deleted as well. These objects can represent parts of the experiments that disappear from the remote camera feedback. For e.g. as an experimental setup, if a crane is used to pick up box and place it in bucket. The box remains a virtual object in the experiment session until it is dropped in the bucket. Once it is drop there can be no more interactions with it and the corresponding virtual object in the augmented space at the users site is also deleted. This is to prevent unwanted interactions from the user.

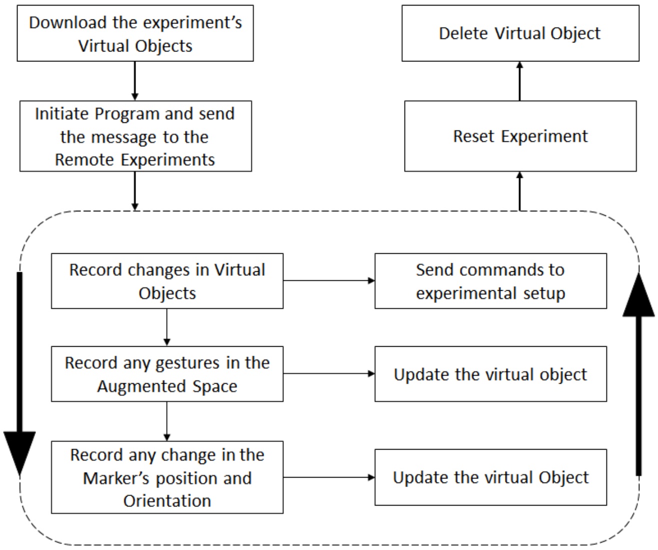


Figure 1. The natural interactions and processing the users' inputs

Figure 2 shows the whole system architecture. The RAL portion consists of experiment owners who create experiments with real hardware. They also create the virtual objects and the control programs for the experiment. There is also a camera provided for the remote site's video feedback.

The user side consists of the local camera feedback that is used to augment the users' workspace. The experiments' corresponding virtual objects and control program are downloaded to the users' site. The virtual objects are augmented to the local camera feedback to generate the AR output. The NUI devices at the users' site generates the positional data of the human body parts e.g. hands. This is used to create the NUI virtual objects e.g. virtual human hands. The physics engine uses the control programs, such as C# scripts in UNity3D™, to interact with the virtual objects generating the control commands. The commands are then sent to the real hardware. The AR output is created by combining the NUI objects, experimental virtual objects, and the local video feedback. There remote camera feedback from the RAL site to the user site shows what happens in the real experiment.

D. Camera Placements

It is important to place the camera, as well as the NUI devices and markers in correct positions. This can vary hugely between experiments. Most experiments will typically have the markers on a flat horizontal surface with the camera pointing downwards towards the markers. However, it now possible to create 3D marker objects as well, therefore allowing the camera to be placed in various orientations. This also true for 2D markers. The camera position and the NUI device position will determine the amount and shape workspace for the users.

3D printing (i.e. low cost additive manufacturing) is now a widespread and common manufacturing process and is routinely used to create customized holders and brackets for cameras. Although it is still difficult for individual students to procure such things, it is possible to positon cameras with everyday objects. Additionally, if a HMD such as the Microsoft HoloLens™ or mobile device display (Google cardboard [15]) is used then placement issues can be addressed more easily.

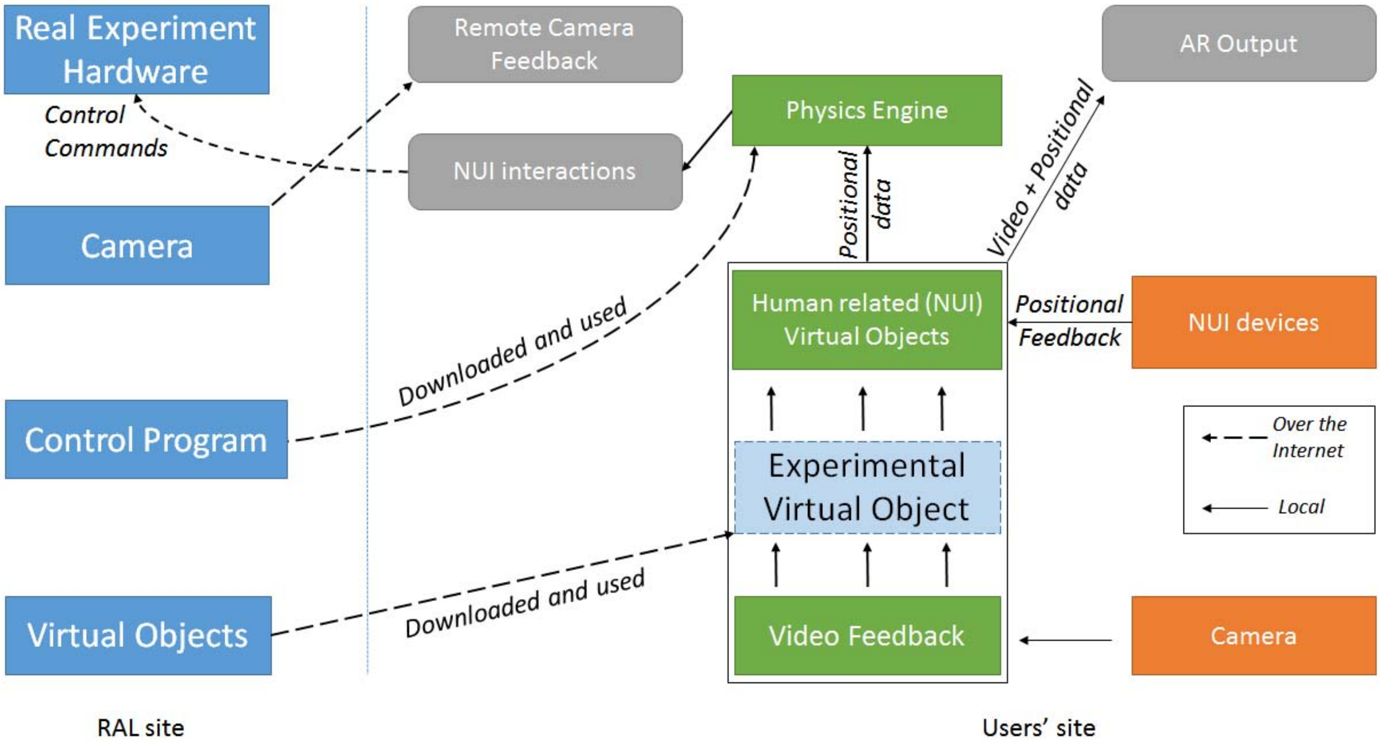


Figure 2. The RAL system Architecture

E. Supported devices

At the current time, it is difficult to integrate NUI devices with mobile devices such as HMD or smart phones for AR applications (noting that VR is simpler). Thus, the only supported devices for this technology at present are desktops. These could limit the amount of interactions possible. However, it may be possible to stream the video output from the desktops to the mobile devices e.g. HMD so that user can see the virtual objects directly.

IV. Example

This section presents an example of the NUI/AR/RAL implementations.

A. GearBox Experiment

This experiment in particular is designed for STEM education. The aim of the experiment is to teach the relationship between gears. There is a LEGO Mindstorms device that accepts WebSocket connections from clients to receive move and rotate commands. There is only one motor from the LEGO Mindstorms that connects to one gear which is then connected to other gears of differing gear ratio. The objective for the students is to determine the gear ratio between these sets of gears. The client side sends commands to the LEGO controller for rotating this motor by a specific degree.

In the AR RAL system, there is a virtual object representing the gear connections. This object is developed using the Unity3D™ environment, and is associated with a particular marker "logo" image which the user can download, print and then place on their table workspace. There are also Leap Motion™ components within the Unity3D program. These subroutines e.g. "LeapHandController" create and update the virtual palm and finger positions of the two hands within the 3D unity virtual environment. The hand components are updated in real time depend on their position and orientation with respect to the Leap Motion™ controller. The optimal position setting between the logo image and the Leap Motion controller is set within the Unity3D scene. The users place the Leap Motion according to this setting for the most effective visualization. The Unity3D physics engine then allows the virtual hands to freely interact with the virtual LEGO™ gear object.

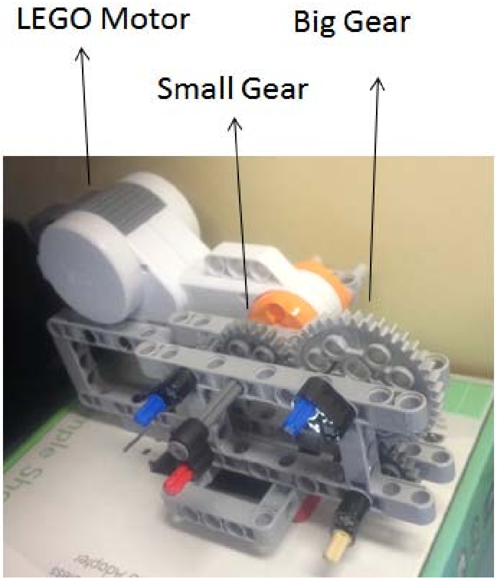
A webcam in this instance is used for the AR. The video feedback is overlaid into the Unity3D virtual 3D space and displayed on the computer screen. The video feedback may be streamed to a mobile device for a more realistic interaction for instance using similar constructs to the Google Cardboard [15].

Figure 3 depicts the gearbox experiment example. Figure 3(a) shows the NUI interface displaying virtual gears that the virtual hand can interact with. Figure 3(b) depicts real hardware for this experiment. Note that for any implementation, the virtual objects may not look exactly the same as the real hardware objects. Additionally, the experimental setups may be utilizing automation mechanisms that need not be part of the virtual object view.

B. User Interface

Once the program is started, the natural interaction can progress. The virtual gears are locked in their potions X, Y, and Z, and forces them to stay in a static position. The rotation is locked in the X and Z axis as well. This leaves the gears to only be rotatable around the Y axis. In this example, no gravity effects are in place, and the angular drag is set to 5 to prevent unnecessary rotations.

Figure 3. (a) The NUI with gears in them and the virtual hand



(b) The gearbox setup with LEGO Motors

A C# script is associated with the gear objects. Within this script, a subroutine is executed for every frame during runtime. The basic structure of the program is as follows.

1. Send an initial command to the LEGO Mindstorms controller indicating the initiation of the experiment sessions.
2. Rotation variables r_i are set to 0 for each gear g_i.
3. Once the interactions start, the current angle c_i change in the rotation c_i-r_i are recorded.
4. If the gear becomes stalled for time *t*, a command is sent with the current change in the rotation angle c_i-r_i and r_i is update to the current c_i. Until the Unity3D program receives the acknowledgment of the successful execution of the command, the scene is frozen and no more interaction is allowed or processed.

Depending upon the current status of the Internet, i.e. the network latency, the time *t* can be adjusted accordingly. If the latency is very high, then *t* can be increased such that there less freezing of the scene for updating the LEGO Mindstorms controller. Also, in this example there is only one motor to control one gear. However, if the students rotate the other gears, then the program translates the rotation required corresponding to the gear that is actually connected to the motor.

C. Advantages and Disadvantages

The main advantages of this interface over a regular interface is that the user can now tilt pan or even turn the virtual objects upside down. This allows them to directly observe the behavior of the virtual object. In this manner, the more realistic and authentic the virtual object and its behavior, the better the experience for the users. This type of interface however may not be particularly effective for some labs. For example in case of electronics circuit design labs such as VISIR [16], using AR with NUI will not contribute much to the experience for learning outcomes. However, for other experiments with relatively complicated interactions during setups and operation, such as a combustion engine with multiple wires and valves, this interface will give the users more realistic perception of how to use and interact with the objects compared to merely observing on a 2D desktop.

The users can also obtain hands-on experience about setting up the experiment. Users may be given the raw materials or half-built objects and asked to build or rectify the objects before running the experiment. Using virtual objects also provides a safer learning environment where users can interact with objects in ways they may not typically or cannot in the real world. Otherwise the NUI must restrict the users from performing interactions that would otherwise be impossible in the real world.

Integrating the NUI devices into the AR for RAL can enable the following aspects:

- It allows greater interactions between the virtual objects and the user. Other similar solutions using AR largely only depend on the visual feedback with much scope of altering the experimental setup [27-29]. With greater interactions, the experiments hardware (virtual) itself can be altered as well.
- Greater interactions may allow better scope of evaluation, identifying the ways the experiment is performed.

There are however certain limitations to this NUI and RAL integration:

- Although webcams are widely-used today, placing the camera for some experiments may pose a challenge.
- It uses special NUI devices that are presently not universally available.
- No haptic feedback is available. While there have been attempts to provide haptic feedback for RAL experiments, these have had a very limited degree of freedom, where the same device is not necessarily applicable for multiple experiments [17]. Without haptic feedback the users learning is mainly constrained to the visual components of the interactions.

D. Scalability

Scalability is an important aspect for any kind of RAL technology as experiments differ largely in terms of their constructions and overall goal. The NUI/AR technology described in this paper can be utilized for many experiments. However, the current level and clarity of inter-object interactions with NUI devices supported by most physics engines falls short of meeting the pedagogical requirement of all experiments. The main problem is that the axes of the interacting objects is limited. If the interactions between the hand object and any other object takes place in more than one dimension, then the interactions and visual aspects of the AR feedback deteriorates. In other words, the actions that takes place on the virtual objects must be very definite e.g. flipping a switch (involves a limited movement in a predetermined path), rotating a gear on one axis etc.

This can be improved largely by creating complex C# scripts (or equivalent) for the experiments to properly calibrate the actions and interactions for each individual experiment. Also, with improvements in the physics engines and AR technology, this problem can be resolved.

CONCLUSIONS

This paper presented a technology to integrate Natural User Interface (NUI) devices with Augmented Reality (AR) within the context of a Remote Access Laboratory (RAL). The system creates a virtual object for an experiment that is downloaded from the RAL website. The user possesses a NUI device such a Leap Motion™ that captures users hand movement in real time. The hand movement and the experimental setup's virtual object interact within the Unity3D engine. This movement generates events and commands are generated accordingly, which are sent to the RAL experiment and executed to reflect the changes made in the virtual environment.

REFERENCES

[1] M. T. Restivo, M. d. F. Chouzal, J. Rodrigues, P. Menezes, B. Patrão, and J. B. Lopes, "Augmented Reality in Electrical Fundamentals," International Journal of Online Engineering (iJOE), vol. 10, p. 68, 2014.

[2] S. Odeh, S. Abu Shanab, M. Anabtawi, and R. Hodrob, "A Remote Engineering Lab based on Augmented Reality for Teaching Electronics," International Journal of Online Engineering (iJOE), vol. 9, p. 61, 2013.

[3] J. Cubillo, S. Martin, M. Castro, and R. Meier, "Control of a remote laboratory by augmented reality," in Teaching, Assessment and Learning for Engineering (TALE), 2012 IEEE International Conference on, 2012, pp. W2B-11-W2B-15.

[4] L. Garber, "Gestural Technology: Moving Interfaces in a New Direction [Technology News]," Computer, vol. 46, pp. 22-25, 2013.

[5] D. Bassily, C. Georgoulas, J. Guettler, T. Linner, and T. Bock, "Intuitive and Adaptive Robotic Arm Manipulation using the Leap Motion Controller," in ISR/Robotik 2014; 41st International Symposium on Robotics, 2014, pp. 1-7.

[6] M. N. Kamel Boulos, B. J. Blanchard, C. Walker, J. Montero, A. Tripathy, and R. Gutierrez-Osuna, "Web GIS in practice X: a Microsoft Kinect natural user interface for Google Earth navigation," International Journal of Health Geographics, vol. 10, p. 45, 2011.

[7] C. Donalek, S. G. Djorgovski, A. Cioc, A. Wang, J. Zhang, E. Lawler, et al., "Immersive and collaborative data visualization using virtual reality platforms," in 2014 IEEE International Conference on Big Data (Big Data), 2014, pp. 609-614.

[8] A. Maiti, "Interactive remote laboratories with gesture based interface through microsoft kinect," in Remote Engineering and Virtual Instrumentation (REV), 2013 10th International Conference on, 2013, pp. 1-4.

[9] A. Saxena, D. K. Jain, and A. Singhal, "Sign Language Recognition Using Principal Component Analysis," in 2014 Fourth International Conference on Communication Systems and Network Technologies, 2014, pp. 810-813.

[10] Raheja, Jagdish L., A. Singhal, and Ankit Chaudhary. "Android based Portable Hand Sign Recognition System." arXiv preprint arXiv:1503.03614, 2015.

[11] A. S. Fernandes, R. F. Wang, and D. J. Simons, "Remembering the physical as virtual: source confusion and physical interaction in augmented reality," presented at the Proceedings of the ACM SIGGRAPH Symposium on Applied Perception, Tübingen, Germany, 2015.

[12] J. Blaha and M. Gupta, "Diplopia: A virtual reality game designed to help amblyopics," in 2014 IEEE Virtual Reality (VR), 2014, pp. 163-164.

[13] P. Apostolellis, B. Bortz, P. Mi, N. Polys, and A. Hoegh, "Poster: Exploring the integrality and separability of the Leap Motion Controller for direct manipulation 3D interaction," in 2014 IEEE Symposium on 3D User Interfaces (3DUI), 2014, pp. 153-154.

[14] Z. Zhang, M. Zhang, Y. Chang, S. K. Esche, and C. Chassapis, "Integration of Physical Devices into Game-based Virtual Reality," *iJOE,* vol. 9, pp. 25-38, 2013.

[15] S. W. Greenwald, L. Loreti, M. Funk, R. Zilberman, and P. Maes, "Eye gaze tracking with google cardboard using purkinje images," presented at the Proceedings of the 22nd ACM Conference on Virtual Reality Software and Technology, Munich, Germany, 2016.

[16] T. Fischer and J. Scheidinger, "VISIR - Microcontroller extensions," in Remote Engineering and Virtual Instrumentation (REV), 2015 12th International Conference on, 2015, pp. 177-179.

[17] M. R. Quintas, M. T. Restivo, J. Rodrigues, and P. Ubaldo, "Let's use haptics!," International Journal of Online Engineering, 2013.

[18] R. T. Azuma, "A survey of augmented reality," Presence: Teleoperators and virtual environments, vol. 6, no. 4, pp. 355-385, 1997.

[19] M. Billinghurst, A. Clark, and G. Lee, "A survey of augmented reality," Foundations and Trends® Human–Computer Interaction, vol. 8, no. 2-3, pp. 73-272, 2015.

[20] M. Billinghurst, "Augmented reality in education," New horizons for learning, vol. 12, 2002.

[21] N. Taketa, K. Hayashi, H. Kato, and S. Noshida, "Virtual pop-up book based on augmented reality," in Symposium on Human Interface and the Management of Information, 2007, pp. 475-484: Springer.

[22] J. M. Andujar, A. Mejías, and M. A. Marquez, "Augmented reality for the improvement of remote laboratories: an augmented remote laboratory," IEEE transactions on education, vol. 54, no. 3, pp. 492-500, 2011.

[23] M. T. Restivo, A. M. Lopes, L. dos Santos Machado, and R. M. De Moraes, "Adding tactile information to remote & virtual labs," in Global Engineering Education Conference (EDUCON), 2011 IEEE, 2011, pp. 1120-1124: IEEE.

[24] W. Liu, "Natural user interface-next mainstream product user interface," in Computer-Aided Industrial Design & Conceptual Design (CAIDCD), 2010 IEEE 11th International Conference on, 2010, vol. 1, pp. 203-205: IEEE.

[25] D. Müller, A. Chilliischi, and S. Langer, "Integrating immersive 3D worlds and real lab equipment for teaching mechatronics," in Remote Engineering and Virtual Instrumentation (REV), 2012 9th International Conference on, 2012, pp. 1-6: IEEE.

[26] Y. Ohta and H. Tamura, Mixed reality: merging real and virtual worlds. Springer Publishing Company, Incorporated, 2014.

[27] D. Müller, "Mixed Reality Systems", iJOE vol 5 (2), pp. 10-12.

[28] S. Odeh, S. Abu Shanab, M. Anabtawi, and R. Hodrob, "A Remote Engineering Lab based on Augmented Reality for Teaching Electronics," International Journal of Online Engineering (iJOE), vol. 9, p. 61, 2013.

[29] P. Maier and G. Klinker, "Augmented Chemical Reactions: 3D Interaction Methods for Chemistry," International Journal of Online Engineering (iJOE), vol. 9, p. 80, 2013.