Improving education experience with Augmented Reality (AR)

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In the modern world, information is everything. It is important that it can be accessed from anywhere and at any time. What is even more important is that information must be relevant to the user and presented in such a manner that it is easily understood.

Emerging technologies, such as augmented reality (AR) might within short period of time be widely accepted, as smart-phones are today. If this happens, it will probably change the way we perceive information and our reality. AR is not hype any more – it is a solid technology that is already used in some creative applications.

One area which might significantly benefit in the future from this technology is the education process. AR tools could guide students through learning process in enhanced way, as AR can upgrade traditional books with a digital layer. We think it will improve both, teaching and learning experience, and bring interactive dimension into the whole picture. We also predict that this new layer will encompass several senses which could speed up memorization process. Furthermore, AR learning method might raise common understanding of the learning material. Moreover, learning activities could be supervised by a mentor or automated process which might also lead to a lower school dropout rate.

Our still-in-progress ARAVET project is exploring mentioned predictions about AR learning method. We will present the results we have so far.

I. INTRODUCTION

Nowadays, information is a key to success. For decision makers it is important they have instant information access from anywhere.

On the other hand, with today's flood of information, decision making process can sometimes be overloaded. Computerized services offer centralized information management, user access control, information categorization and indexation, as well as full text search, but retrieved data are not always relevant to the query, which negatively influence decision making process. Without proper personalized presentation, content filtering and classification, decision makers are often left with excessive data that can impose a cognitive barrier for them.

As mentioned, it is important in which form the data are presented to the decision makers. Sophisticated technology, like augmented reality (AR), offers insight into data on a different level, as it combines real world with the digital one, giving users enhanced information presentation.

AR needs rich user collaborative interfaces, content filtering and real time personalization, and all these functions demand huge computing power. Rising use of cloud computing is addressing some of these issues. Therefore, in this paper, we offer a quick overview of current computing technology improvements and cloud systems that are significantly enhancing information processing. Moreover, we will glance over evolving adaptive systems, which can accommodate individual user experience and optimize learning process. As learning depends on information perception, we will also try to explain how information flow is processed inside the human mind and how do people perceive reality.

At the end, we will show our ARAVET results, which indicate that AR can be very useful in learning process as it can improve perception of received information.

II. POWER OF PROCESSING

Most computers still follow Von Neumann's computer architecture, where instructions are performed sequentially, but really fast. However, recent research in quantum and parallel computing have introduced next generation machines which process information differently and much faster than contemporary computers. Similarly to our brain, new computers are processing instructions concurrently. This kind of processing is not limited to a single processor, as instructions execution often includes multi-core systems or even more than one computer in form of computer clusters.

These days, we already have computer systems built from computers connected with each-other, forming global processing systems with thousands and thousands of cores that can process information extremely fast, which is needed for improved real-time user experience and development of Internet of things (IoT). Today, almost any electronic device can be connected to the web and it can send its sensory data to the cloud services. Moreover, these devices could also offer additional processing power, and therefore, enhance the overall performance of the system.

Moore's law [1] predicts that computer processing power will be doubled every 18 months. Reference [3]

predicts that by 2019 a 4000$ computing device could have computational capability of a human brain (20 quadrillion calculations per second). According to reference [3], by 2029 a 1000$ personal computer might be 1000 times more powerful than human brain. So, artificial intelligence might be recognized as conscious entity. The same reference also predicts that, it will be possible to use implants directly connected to the human nerve system or brain to enhance information processing. Experimental testing already proved that with use of a computer, information from human brain can be read and written directly into the brain [2]. There are also predictions saying that by the end of 2099 human brain could be completely reverse engineered and all aspects of brain functioning might be finally understood [3].

Namely, computing power could soon offer unimaginable possibilities resulting in self-adaptive global systems that could connect millions of people into collaborative environments, where user behavior could be analyzed in real-time. New technologies might offer creation of user tailored education process, where students could follow personalized curriculum adapted to their own learning skills. So, the whole education experience could be completely personalized and provided in an optimal way.

III. LEARNING

A. Nervous system and human brain

Learning is an elementary process. It starts in the womb and continues during our whole life. Senses provide us with information about our environment and nervous system transfers the electric impulses to our brain with speed up to 100 meters per second [4], where information is processed. Information processing is a base for human cognition, creating logical abstracts, reasoning, information classification and categorization.

Average human brain consists of 86 billion neurons and uses typically 100 W of power, which represents merely 20 % of the whole body energy consumption [5]. On the other hand, gorilla's brain has about 28 billion neurons, or around 33 % capacity of human brain [6]. Each neuron is capable of making around 1000 connections, representing roughly 1000 potential synapses, which mostly do the work of data storage. If we multiply each of these 100 billion neurons by approximately 1000 connections each neuron can make, we get 100 trillion data points, or about 100 terabytes of information [5].

Until recently, we believed that animals were incapable of processing information in the way we do it. However, tests on chimpanzees reveal, that they can be significantly better at certain tasks, especially those connected with motor skills and rapid movement processing [6]. Their brains are wired differently then human's, therefore, they are specialized for other purposes. Still, their overall intelligence is on the level of a three-year-old child. An experiment performed on a group of chimpanzees and human toddlers revealed, that humans, unlike other species, are capable of connecting with each other to obtain the information they need in order to solve a problem. This was something chimpanzees were not able to do. Researchers suggested that humans are born to share their thoughts [6].

Social collaboration is crucial for humans, so that they can better understand the world around them. Digital age raised this interaction to an unprecedented level. Today, almost everyone is connected to the Internet and everybody is exchanging all sorts of information. Information exchange has never been so easy and so momentous. On the other hand, modern communication often lacks emotional components.

B. Types of learning

To better understand the learning process, we are presenting various human personality types that significantly influence learning process [7].

In general, we can differentiate 7 types of learning, tightly coupled with types of human personality [7]:

- Visual (spatial) learners use pictures, images and spatial understanding, with as many colors and other visual media as possible. Good learning tools for visual learning are: spatial organization layouts with important words, mind maps, words replaced with images and extensive use of colors.
- Aural (auditory-musical) learners prefer the use of sound, rhythm and music to enhance their learning process. Very often, background recordings are used to help achieve special effects of visualization. Aural learners also use mnemonics (systems for improving and assisting the memory) and with the help of rhyme and melody they can better memorize the content. Music influences and enhances our emotions, and therefore learning.
- Verbal (linguistic) learners prefer the use of words, both in speech and writing. So, techniques involving speaking and writing such as word-based techniques of assertions and scripting help a lot this kind of learners. Reading content aloud with dramatic and varied intonation and/or role playing with others also enhances linguistic type of learning.
- Physical (kinesthetic) learners use body, hands and sense of touch. The use of physical objects helps this type of learning, too.
- Solitary (intrapersonal) type of learning is best when working alone and using self-study techniques of learning. Alignment of personal beliefs and values with goals and objectives is also helpful. Building associations and visualizations of feelings and modeling are very important, as all these techniques use the

influence of thoughts. Being creative with role playing enhances solitary type of learning.

- Social (interpersonal) learning promotes studying and learning in groups. This type of leaning is activated when a person works with others as much as possible. Role playing is very important in social learning, as it promotes interactions with others. During social learning it is recommended to extensively share thoughts with others through assertion, visualization, etc. Working in group to practice behaviors or procedures helps understand problem variations.
- Logical (mathematical) learning is based on understanding the reason behind something. This type of learning is best when extracting key points from material, making associations, especially when the content is illogical or irrational. The use of method which makes the object of learning fit into wider content, introducing skills, as well as thinking systems helps out logical learners a lot.

There might be even more types of learning that scientist haven't identified yet. Our senses and human personality significantly influence our learning process. As everyone has a different perception of the world around them, it is of a huge importance that each individual receives the information according to the nature of their own specific mind.

AR can play significant role here, as it can address different senses and personalize user experience. Therefore, it can boost performance of individuals and additionally stimulate their interests. With help of interactive technology, individual user interaction can be analyzed and then optimized to fit the needs of students.

C. Processing the information

Research done at Massachusetts institute of technology (MIT) [8] discovered that memories are stored in individual brain cells and when scientist stimulated specific brain cells, certain memory was recalled. Removing those cells resulted in loss of specific memory.

As previously mentioned, our brain's information processing is influenced by the type of person's nature. Almost all people have one dominant sense. For most of them it is vision. This means that people process visual information much better that information perceived by other senses [9]. The reason for this lies in our brain specialization.

Interestingly, smell is unusually effective at evoking memory. When smell is used to evoke a certain memory, person can remember 10-50 % more than without smell stimulation [9]. Marketers have recognized this as a very important marketing trigger, so they include it in their marketing activities to boost sales.

People who function in multi-sensory environments always perform better than those in uni-sensory environments. Their memory recall is better, and their memory lasts longer, even after 20 years from the moment of memory creation [9].

Having that in mind, students could use multi-sensory stimulation techniques to develop multi-sensory study skills and improve their memorization and thus the learning process. AR could help achieve that as it offers a multi-sensory interactive knowledge transfer environment.

According to new research, scientists discovered they can rewire our brain with special training. One type of such training can lead to partial synesthesia, where brain gets information in a multi-sensory way [9].

Synesthesia [9] is a neurological phenomenon in which stimulation of one sensory or cognitive pathway leads to automatic, involuntary experiences in a second sensory or cognitive pathway. People who report such experiences are known as synesthetes. So, simply put, synesthesia is a condition in which one type of stimulation evokes the sensation of another, as when the hearing of a sound produces the visualization of a color.

In the most common form of synesthesia, also known as grapheme, color synesthesia or color-graphemic synesthesia, letters or numbers are perceived as inherently colored. In spatial-sequence, or number synesthesia, numbers, months of the year, and/or days of the week elicit precise locations in space (e.g. 1980 may be "farther away" than 1990), or may appear as a three-dimensional map (clockwise or counterclockwise).

Only certain types of synesthesia have been evaluated by scientific research. It is very difficult to grasp this phenomenon and analyze it, as awareness and manifestation of synesthetic perception varies from person to person.

Synesthetes can remember significantly more information in comparison to average people. Special sets of exercises can also help our brain develop synesthetic functions. However, our brain would need constant practice to retain these functions, as synesthesia is not a natural condition for the majority of people. Psychological research has demonstrated that synesthetic experiences can have measurable behavioral consequences. Functional neuroimaging studies have identified differences in patterns of brain activation. Many studies [9] found out that synesthesia improves creative processes. Psychologists and neuroscientists, who studied synesthesia, have been infatuated by not only its inherent appeal, but also, by the insights it may give into cognitive and perceptual brain processes that differ between synesthetes and non-synesthetes.

AR can stimulate several senses at the same time, leading to improved learning skills (with practice – brain can be rewired to optimize performance) and memorization. With improved AR interfaces additional senses (five senses – sight, sound, taste, smell and touch) could improve cognition of information, and therefore learning process.

IV. AUGMENTED REALITY

A. Definition

Augmented reality (AR) is a live, direct or indirect view of a physical, real-world environment whose elements are augmented (or supplemented) by computer-generated sensory input such as sound, video, graphics or GPS data. It is a variation of virtual environment (VE), or virtual reality, as it is more commonly called. VE technologies completely immerse a user inside a synthetic environment [10]. While immersed, the user cannot see the real world around him. In contrast, AR allows the user to see the real world, with virtual objects super-imposed upon or composited with the real world. Therefore, AR supplements reality, rather than completely replacing it. AR is related to a more general concept called mediated reality, in which a view of reality is modified by a computer [10]. As a result, the technology enhances one's current perception of reality. Virtual reality replaces the real world with a simulated one. Augmentation of visual information is presented in semantic context, coherently with environmental elements and in real-time, similarly to synchronized sports scores on TV during a match.

With the help of advanced AR technology (e.g. adding computer vision and object recognition), the information about surrounding real world of a user becomes interactive and digitally manipulated, as artificial information about the environment and its objects can be overlaid on the real world.

Nowadays, AR is often related to mobile applications, but the concept is much wider and implications are almost limitless. Some new cars cockpits are already equipped with futuristic dashboards where information is projected directly onto the windscreen, giving drivers additional view on their surroundings [11]. Furthermore, Special Forces and astronauts use hi-tech helmets, where information is projected onto their visors [11].

In a few years, we might have special contact lenses that will display all kinds of information directly to our eyes [11]. These lenses could be connected to the Internet through our mobile devices. If such technology is to be developed, it would bring unimaginable new possibilities to our everyday life. People would be in constant interaction over several interfaces with everyone and everything. The reality as we know it could blend completely with the digital world.

B. Augmented reality in learning process

In the past, information (thus knowledge), was collected in form of books and, before printing was invented, the books were hand copied by erudite people. In today's world, the information is changing and emerging so fast that information on the print materials (paper books) is often outdated the moment it is printed out. Digital information can be easily edited, and therefore constantly validated. It can also be interactive and users can always retrieve up-to-date content, use bookmarks, 3D models or social networks, where they can collaborate with other users and exchange ideas and questions about educational material.

AR brings many advantages for teachers, as well, as it helps analyze the learning process of students and identify the elements that could be improved.

The final goal is to bring highly personalized learning content to the students which will help them learn faster, easier and better. As AR offers human and content interaction, students could stay more active during their learning process. They could be offered the opportunity to improve the learning content and even become content creators by giving their positive or negative remarks. Additionally, AR presentation layers could offer better understanding and access to social knowledge. Moreover, the multi-sensory presentation might significantly improve the memorization of the content.

Development of sophisticated user interfaces could be very beneficiary for learning process, as digital content can be endless and it can be downloaded on demand in real time from the servers and presented to the students any way they want. With personalization and interactivity, automatic algorithms could monitor the progress of individual students and then tailor curriculums according to their progress, skills and understanding.

As active contributors, students could leave notes and enrich printed content. Notes could be synchronized over cloud services and all active users could retrieve the change instantly. Teachers could improve the content, as well, according to remarks, links, images and data schemes, offering their students better understanding of the learning material.

Contemporary printed materials offer solid learning content which can be read by students at anytime. However, additional digital layer could offer performance of tests and experiments related to the content. In this way, students could better understand the processes described in the learning material, as they could see different visual and audible presentations and simulations of the explained process.

For an example, diesel engine in printed material is usually showed as a scheme of engine's internal structure, however a digital layer on a tablet can present interactive model of the engine, so students could (re)move the engine body parts and observe the simulation of the ignition cycle, etc. With interactive model, students could also change initial parameters, resulting in different model behavior.

The possibilities of such learning material presentations could be of immense help in medicine, engineering, rehabilitation, pharmacy, IT, etc.

In the long term, AR might improve users' sensor experience and provide them with the way to expand their senses to electromagnetic field, infrared and ultraviolet vision, ultrasonic and subsonic hearing, stereo phonic vision, etc.

Additionally, implementation of direct memory manipulation could significantly shorten learning process, so, students could focus on better processing and connecting the information and not just on memorizing it.

The application of this futuristic technology might provide solutions for controlling phantom limbs, robots or other remote objects [12].

V. ARAVET PROJECT

Our ARAVET project (Augmented Reality Application on the Field of Vocational Education and Training) started in 2013 as a Leonardo da Vinci project. Organizations from eight different countries are involved in this project. Each organization contributes with its own specific skills and knowledge from areas of technology, education and design. ARAVET project suggests that introduction of new technologies could drastically improve existing learning techniques and users' experience.

Implementation of AR in our pilot project introduced a digital information layer into existing books. So, books were enriched with digital content, connected to special markers. This enriched view was accessible through user smart-phones or tablets. Students could access 3D models and perform pre-animated actions to additionally visualize educational material.

In scope of our project three different fields were chosen for implementation of AR in order to better demonstrate the advantages of its use.

Firstly, we have chosen textile industry and we have implemented AR technology into the learning model of a sewing machine. Students could perform different actions on the sewing machine (from changing the bobbin to inserting a thread into a needle).

Secondly, we have implemented AR to help students learn about electronics. An operation cycle of the diode was presented with AR technology. Students were able to reverse the electric current and see why it stopped working. The interior of the diode was presented with a flow of electrons, so students could see this concept in a way they would never be able to experience if they were just reading about it from the ordinary textbook.

We have also implanted AR technology in the field of informatics. The AR implementation was used in learning materials about logic concepts and electronic gates (AND, OR, XOR and NOR).

All the results of our pilot testing (data were collected through surveys and then statistically analyzed) revealed that when using AR enhanced materials students understood the content much easier and faster than when using traditional learning techniques.

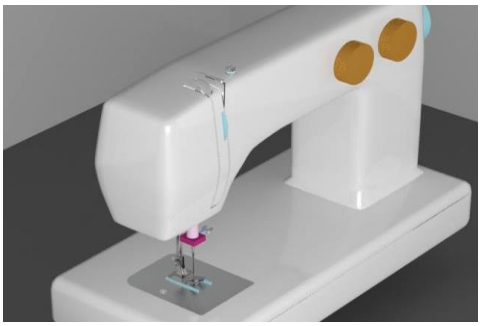

Figure 1: Sewing machine with animated actions

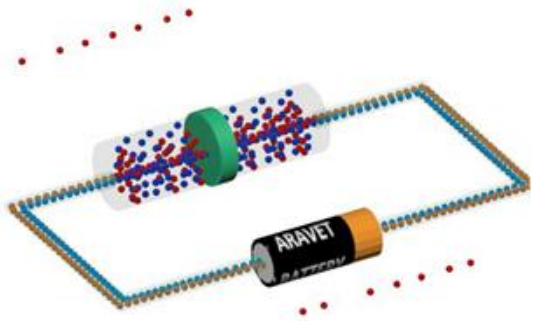

Figure 2: Animated diode behavior and electron flow

71% of the students understood the meaning of Augmented Reality in the way it was explained in the computer lab with examples from the Internet (with the use of mobile devices).

64% of the students found AR enhanced software easy to use and understood the way it functions.

Students were indecisive concerning usage of AR software. They neither agreed nor disagreed that AR software should replace the real device (e.g. sewing machine) during learning process.

62% of the students believed that AR software can help them better understand certain meanings.

59% of the students thought AR software is very interesting for using in the classroom during school lessons.

79% of the students understood very well the way that AR devices work.

55% of the students believed that AR software helped them understand specific meaning faster.

71% of the students were satisfied with the given instructions concerning AR software.

All the results confirm that AR is technology which could really improve understanding of educational material, especially in those fields, where it is important to understand the processes in detail.

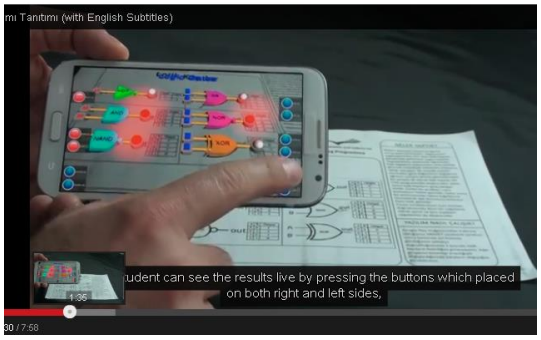

Figure 3: Virtual logical elements for testing the behavior of the printed elements

VI. Conclusion

In the future, the boundary between the real world and the digital one might fade away, as modern technologies offer personalized reality. In constant connection with global grid, technology offers instant access to any kind of information, no matter what kind of device user uses.

AR is a perfect example of how users can remove the boundary between the two worlds and equip the real world with digital data. Furthermore, bionic interfaces for human body might additionally improve capabilities of humans beyond anything we know today. Such systems might also provide an in depth insight into user interactions, behavior patterns and learning processes as data could be collected and stored in cloud based services for further analysis.

AR can provide interactive interfaces that enhance a process of learning and content editing in such a way, that current generation of students could learn faster, better and retain knowledge longer than before.

Evolving technology could lead to better understanding of the nature of the human mind and learning processes. This could also help improve machine learning and automated services that support learning processes.

Project ARAVET, with its limited scope, proved that digital data provided through AR interfaces can already supplement static content and improve student understanding of the processes described in the educational material. Moreover, it proved that students have positive attitude towards new technology and its use.

For now, AR is limited due to inadequate hardware. However, even this form can improve user experience. Next generation user interfaces might have the ability to present information in multi-sensory way or even connect directly to our nervous system and offer whole new range of sensors to improve human experience. With evolving next generation user interfaces AR might become commonly accepted as mobile technology is today.

References

[1] L. G. Roberts, “Beyond Moore’s law: Internet growth trends”, Computer, Vol. 33 (1), pp. 117-119, Jan 2000.

[2] A. M. Packer, L. E. Russell, H. W. P. Dalgleish and M. Häusser, “Simultaneous all-optical manipulation and recording of neural circuit activity with cellular resolution in vivo.”, Natural Methods, Vol. 12, pp. 140-146, 2015.

[3] R. Kurzweil., “The age of spiritual machines: When computers exceed human intelligence”, Penguin Group, New York, 2000.

[4] D. Kraus, “Concepts in Modern Biology”, Globe Book Company, New York, 1969.

[5] G. Brown, “The Energy of Life”, Free Press, New York, 1999.

[6] C. F. Martin, R. Bhui, P. Bossaerts, T. Matsuzawa and C. Camerer, “Chimpanzee choice rates in competitive games match equilibrium game theory predictions”, Scientific Reports, Vol. 4, Jun 2014.

[7] Blue Mango Learning, “The 7 styles of learning”, available at: http://www.learning-styles-online.com (10. 2. 2015)

[8] X. Liu et al., “Optogenetic stimulation of a hippocampal engram activates fear memory recall”, Nature, Vol. 484, pp. 381-385, Apr 2012.

[9] M. J. Mächler, “Synaesthesia and Learning”, Swiss Federal Institute of Technology, Zurich, 2009.

[10] R. T. Azuma, “Survey of Augmented Reality”, Hughes Research Laboratories, Presence, Vol. 6 (4), pp. 355-385, Aug 1997.

[11] N. Statt, “Augmented-reality contact lenses to be human-ready at CES”, CNET, available at: http://www.cnet.com/news/augmented-reality-contact-lenses-to-be-human-ready-at-ces (1. 2. 2015)

[12] N. Akpan, “How to master your third arm”, Popular Science, available at: www.popsci.com/how-master-your-third-arm (1. 2. 2015)

[13] R. Penrose, “Shadows of the Mind: A search for the missing science of consciusness”, Oxford University Press, New Yoerk, 1994.