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PROJECT

Urban infra revolution - Circular economy materials and novel method development to produce recyclable and functional urban construction products

Lappeenranta, Finland

TOPIC

Circular economy

EDIT 28 APRIL 2021
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# Virtual and Augmented Reality as Innovative Tools for Supporting Project Implementation - ZOOM-IN 3

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3D modelling makes it easier for citizens to understand and comment on planned developments in the Urban Infra Revolution project. The use of modern Augmented Reality tools allow persons to understand the project and provide feedback on topical areas related to the city centre development.

Currently, VR/AR is a rapidly developing sector. Nowadays, it is used not only in the entertainment industry, but also in more and more new operational applications, including in the analysis, maintenance and reparation of complex equipment, in the control of production process, including tools adapted to machines, in military applications and in education. The versatile application of VR/AR shows that it can be used for urban public planning processes as in the context of the Urban Infra Revolution project. A key element of this project is the communication with the target beneficiaries, as this makes it possible to successfully introduce the project progresses, this way delivering on a specific of local law according to which all citizens must agree on the implementation of solutions in the public space. In the relation to this local legal framework, the project consortium particularly paid attention to communication activities, also creating the model that presents an idea of Lappeenranta in 2050. 3D modelling makes it easier for citizens to understand and comment on planned developments. The 3D model is accompanied by a survey to allow citizens to provide feedback on topical areas in the city centre. The survey focuses on concrete and current topics for the Lappeenranta and is accessible through the website in Finnish language.

## What is a virtual and augmented reality (VR/AR)?

The origin of virtual reality (VR) can be dated to 1957, when Morton Helig worked on a project called SENSORAMA. This construction was based on images, but it engaged all the senses of the viewer during the projection. This project was however never widely used due to the high costs[1]. Another invention related to an alternative reality was the virtual helmet prototype called Head Mounted Display developed in 1966 by Ivan Sutherland, a professor at Harvard University. In this case, the main barrier for its wide application was the excessive weight of the device.

The actual heyday of 'virtual reality' (VR) took place only in the 1990s[2]. At the same time the term augmented reality (AR) began to be applied. While VR means that a fully artificial environment is displayed in front of the user's eyes in which the person can freely look around (and even move), AR is based on the environment that has been produced on the basis of the actual image generated by elements and it is widespread incorporating new elements (it shows extra information beyond the real world)[3]. As term AR was introduced by Tom Caudell and David Mizell in the Boeing company as both created the first system used to train pilots[4]. The next step of its application was in the field of medicine. Subsequently, the development of virtual and augmented reality was stimulated by the entertainment industry in particular computer games. Today, the most popular applications of the augmented reality are games like Pokémon Go or some of the new Google Maps utilities.

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# Application the virtual and augmented reality in the different areas of human activities

Currently, VR/AR is a rapidly developing sector. Nowadays, it is used not only in the entertainment industry, but also in more and more new operational applications, including in the analysis, maintenance and reparation of complex equipment, in the scope of control in the production process, including tools adapted to machines, in military applications and in education. This short text presents just two areas of applications for VR/AR technologies: architectural design and education.

One example of VR/AR application areas is construction and architecture. Construction, architecture and other related areas have relevant opportunities to support the design and education using virtual and augmented reality. For example, they allow for the development of elements of spatial imagination, which is particularly important for students of architecture[1]. During higher education, competences related to spatial information are developed in many ways, ranging from traditional methods, such as printed plans and physical models (2D and 3D), to modern visualization methods. Modern methods based on created virtual space help students better understand architectural designs. Additionally, they reduce the costs in the project presentation phase - they make it possible to avoid creating expensive models and printed presentations. 3D visualization is also used in a professional area. Virtual reality is also becoming a standard in construction today. It is very often an element in BIM (Building Information Modelling) technologies[2].

An interesting example is the use of virtual technologies in the field of virtualization of cultural heritage[3]. The exemplary system has been developed by the Pontificia Universidad Católica del Perú. The first step in creating augmented reality was to use the drones to record a spatial image of the real objects. Next step was digital processing and computer processing (Figure 1). A properly processed image could be seen through special googles. The system enables spatial observation. Changes in the position of the head make it possible to observe various parts of the object. The system is currently used both for research work and for educating students, in particular for master's programmes and doctoral studies.

PICTURE 1.  3D visualization of historical object.

One of the most important areas of application of virtual and augmented reality are training and education. It could be used in science, technology, engineering, arts, and mathematics (STEAM) education in many areas, including the imaging of chemical processes, reactions, structure of materials, structure of chemical particles, as well as the visualization of the magnetic and electromagnetic field, flows and other mechanics, in particular the behaviour of materials[4]. Interesting possibilities in this regard are offered by the virtual laboratory called "Ironmaking", which was developed at the RWTH Aachen University in Germany. With this system, it is possible to introduce issues related to complex technological processes. The system is dedicated to the issues of the blast furnace process. It takes into account numerous, complex phenomena occurring in this process, in particular mechanical, hydraulic and physico-chemical phenomena. Another example is a system called TEALsim, developed at MIT (Massachusetts Institute of Technology). The system is dedicated to issues related to electromagnetic phenomena and can be used in education in such fields as electronics or mechanics. It visualizes the magnetic field lines, helping to understand the issues of electromagnetism[5].

Virtual systems are also widely used in education in the field of production engineering. An example is the tool called VCIMLAB (Virtual CIM Laboratory), which was developed at Eastern Mediterranean University in Cyprus. It is an educational application dealing with computer-integrated production and automated production systems that uses industrial robots, CNC machines and automatic assembly devices[6]. Of course, there are more examples of solutions in the use of virtual technology. The process of chemical vapour deposition (CVD) is simulated, and issues related to the production of biofuels or renewable energy are visualized. The augmented reality is also used in the product life cycle assessment (LCA analysis). All these tools are a valuable complement for education and science.

Table 1. Examples of areas of use the virtual and augmented reality

| Kind of application | Source of information |
| --- | --- |

Virtual reality

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|---|---|
| MEDICINE : COVID-19 | Singh R.P., Javaid M., Kataria R., Tyagi M., Haleem A., Sumand R.: Significant applications of virtual reality for COVID-19 pandemic, Diabetes & Metabolic Syndrome: Clinical Research & Reviews, 2020, 14 (4), 661-664. |
| ECOLOGY: visualisation of underwater environment | Dantes G.R., Suputra P.H., Sudarma I.K., Suwastini N.K.A., Dantes K.R. : Evaluating and redesigning virtual reality 'underwater tourism' application based on heuristic method, International Journal of Business Information Systems, 2020, 35 (2). |
| SPORT / MILITARY : military and sports training | Ahir K., Govani K., Gajera R., Shah M. : Application on Virtual Reality for Enhanced Education Learning, Military Training and Sports. Augment. Hum. Res., 2020, 5 (7). |
| ARCHITECTURE : architectural design | Peng L., Du Y., Zhang Z. (2021) The Application of Virtual Reality Technology in Architectural Design. In: MacIntyre J., Zhao J., Ma X. (eds) The 2020 International Conference on Machine Learning and Big Data Analytics for IoT Security and Privacy. SPIOT 2020. Advances in Intelligent Systems and Computing, vol 1283. Springer, Cham. |
| ART: art exhibition design | Chen J.: Application of Virtual Reality Technology in Art Exhibition Design. Design Engineering, 2020, 581 - 589. |
| ENTERTAIMENT : TV productions | Song Q., Wook Y.S. : Exploration of the Application of Virtual Reality and Internet of Things in Film and Television Production Mode. Appl. Sci., 2020, 10, 3450. |
| TOURISM : Virtual Underwater Tours | Nomikou P., Pehlivanides G., El Saer A., Karantzalos K., Stentoumis C., Bejelou K., Antoniou V., Douza M., Vlasopoulos O., Monastiridis K., Dura A.: Novel Virtual Reality Solutions for Captivating Virtual Underwater Tours Targeting the Cultural and Tourism Industries, Proceedings of the 6th International Conference on Geographical Information Systems Theory, Applications and Management (GISTAM 2020), 2020, 7-13. |
| INDUSTRYL safety trining | Morélot S., Garrigou A., Dedieu J., N'Kaouab B.:Virtual Reality for Fire Safety Training: Influence of immersion and sense of presence on conceptual and procedural acquisition, Computers & Education, 2021, 104145. |
| MEDICINE : different applications (mainly training) | Javaid M., Haleem A.: Virtual reality applications toward medical field, Clinical Epidemiology and Global Health, 2020, 8 (2), 600-605. |

Augmented reality

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|---|---|
| MEDICINE : assisting the oral and maxillofacial surgery | Chen G., Zeng W., Yin H., Yu Y., Ju R., Tang W.: The Preliminary Application of Augmented Reality in Unilateral Orbitozygomatic Maxillary Complex Fractures Treatment, Journal of Craniofacial Surgery, 2020, 31 (2), 542-548. |

| | |
|---|---|
| EDUCATION : exploring the natural environment of Hong Kong | Ng S.C., Lee H.C., Cheng K.N., Ngan H.H.: A mobile application with augmented reality in exploring the natural environment of Hong Kong, International Journal of Mobile Learning and Organisation, 2019, 14 (1). |
| EDUCATION / ARCHEOLOGY : 3D models regarding pre-Inca cultures | Cabanillas-Carbonell M., Canchaya-Ramos A., Gómez-Osorio R. : Mobile application with augmented reality as a tool to reinforce learning in pre-Inca cultures, 2020 IEEE Engineering International Research Conference (EIRCON), Lima, Peru, 2020, 1-4. |
| AVIATION / TRAINING : emergency procedures training | Gangabissoon T., Bekaroo G., Moedeen W.: Application of augmented reality in aviation: improving engagement of cabin crew during emergency procedures training, ICONIC '20: Proceedings of the 2nd International Conference on Intelligent and Innovative Computing Applications, September 2020, 32, 1–8. |
| ARCHEOLOGY : visualisation of cultural heritage sites | Fernández-Palacios B.J., Morabito D., Remondino F.: Access to complex reality-based 3D models using virtual reality solutions, Journal of Cultural Heritage, 2017, 23, 40–48.<br><br>Čejka J., Zsíros A., Liarokapis F. : A hybrid augmented reality guide for underwater cultural heritage sites, Pers. Ubiquit. Comput., 2020, 24, 815–828. |
| EDUCATION / RELIGION : learning tajweed | Andriyandi A.P., Darmalaksana W., Maylawati D.S., Irwansyah F.S., Mantoro T., Ramdhani M.A.: Augmented reality using features accelerated segment test for learning tajweed, TELKOMNIKA Telecommunication, Computing, Electronics and Control, 2020, 18 (1), 208-216. |
| INDUSTRIAL TRAINING : supporting the manufacturing processes | Eder M, Hulla M., Mast F., Ramsauer C.: On the application of Augmented Reality in a learning factory working environment, Procedia Manufacturing, 2020, 45, 7–12. |
| INDUSTRY : different applications | de Souza Cardoso L.F., Martins Queiroz Mariano F.C., Zorzal E.B.: A survey of industrial augmented reality, Computers & Industrial Engineering, 2020, 139, 106159. |

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[5] Potkonjak V., Gardner M., Callaghan V., Mattila P., Guetl Ch., Petrovi V.M., Jovanovi K.: Virtual laboratories for education in science, technology, and engineering: A review, Computers & Education, 2016, 95, 309-327.

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# What kinds of benefits and threads are connected with using this kind of tools?

Today, the virtual and augmented reality technologies are becoming more and more popular, as they have a lot of advantages the most important of which is the price. The simulation is usually much cheaper than the activities undertaken in the real world. An example may be aviation training, where the price and risk are significantly lower with using VR/AR equipment. They do not replace completely the training on real machine, but there could be significantly cheaper in the first stage of the preparation for the future pilot. The VR/AR could also play an important role in training for emergency situations, including wayfinding and emergency behaviour studies in construction industry. The simulation gives more realistic experiences than 'false alarms' and 'playing role' studies.

The other important element is the user's involvement. The technology allows to immerse completely in 'another dimension' and to focus on the training tasks. It makes VR/AR increasingly attractive to students through the elimination of disruptive factors. The trainee pays full attention to a specific topic thanks to the involvement of a user in a virtual environment[1]. It allows to increase the learning achievements.

The VR/AR technology could also increase the interest in learning. It offers new ways to not only visualize the problems but also to interact with the environment to solve the problems effectively and efficiently. It could help for example in technical sciences improving laboratory skills and formation a positive attitude of students to laboratory work through the previous preparation and possibility to repeat the experiment a lot of times[2]. Thanks to the novelty aspect this method of learning improves students' enthusiasm, while enhancing the teaching effect. This technology can also be used for the effective improvement of visual thinking skills[3].

The important factor is also improving quality and decreasing the development time for new products in different area, including architecture design. If the VR technologies are effectively implemented, this can result in improved product design, including the quality of the design[4]. The prototype solution could be clearly defined and realistically simulated using VR/AR systems. It also helps with testing some product functionality and dynamic behaviour. Another innovative aspect of this technology is the efficient collaboration enabled during the product design, especially in the context of visual planning, including the potential user involvement[5].

Virtual technologies, however, do not only offer advantages, as they also have significant limitations. The most basic limitation is the needed possession of an appropriate hardware and software. However, the VR/AR technologies have been popularized during the last years mainly thanks to the videogame industry and cheaper devices, but they still have a quite high cost that could be a significant barrier for educational applications. Moreover, proper VR/AR systems for particular purposes are not always available. Sometimes the training requires the use of dedicated solutions that are not cheap (although usually many times cheaper than specialist industry devices) and a significant amount of time is needed to prepare them. Another limitation is the adequate knowledge and training. Common people do not always have full knowledge about possible solutions and opportunities offered by VR/AR technologies[6].

The acquisition of equivalent skills in virtual training and in laboratories conducted on real equipment may also be debatable. Although, the research shows that the trainees had the same competences related to a given topic, it is worth considering whether they actually acquire similar skills. The first issue is the differently developed motor skills[7]. A more important issue is the development of certain character features. In the case of a virtual training, the person has the impression that he is playing a video game and nothing serious can actually happen, such training will not develop a real sense of responsibility[8].

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# Urban Infra Revolution project

The Urban Infra Revolution project offers an answer to important global challenges connected with circular economy. The project tests new solutions to reduce CO2 emissions in urban construction development. Side streams from industry (ashes, green liquor dregs, tailings, construction waste) are utilized in urban construction by combining them into a high-value material to replace concrete. Next, the automated, fast and versatile additive manufacturing construction system creates the small architecture products in a comprehensive urban scale. The material and the piloted technology are multifunctional and enable for aesthetic design with revolutionary shapes different kind of products. In the same time, the material composition has very low CO2 emissions as a result of the low energy usage. Selected pilot structures are manufactured and tested in Lappeenranta city.

One of the key elements of the project is  the communication with the target beneficiaries in relation to the successful introduction of the project progresses so as to comply with a specific of local law, according to which all citizens must agree on the implementation of solutions in the public space.
In the relation to this local legal framework, the project consortium particularly paid attention to the communication activities e.g. creating the model that presents an idea of Lappeenranta in 2050. The way, the project can offer an enhanced communication capacity towards the citizens. 3D modelling makes it easier for persons to understand and comment on planned developments. The 3D model is accompanied by a survey to allow citizens to give feedback on topical areas in the city centre. The survey focuses on concrete and current topics for the Lappeenranta citizens and is accessible through the website in Finnish language.

The use VR/AR technology in the project is connected with designing the future vision of the Lappeenranta city through the modelling of the city as well as the implementation of industrial scale piloting products. This is an innovative user-centred adaptive approach to design. It allows to create further visions of the city in 2030 and in 2050 in augmented reality. The contemporary plan of the Lappeenranta city is enriched in the planned piloting products. The special platform shows the effect to citizens (Figure 2).


FIGURE 2. The screen from software – the main screen.

The initiative is particularly interesting for the citizens. The presentation of a 3D model of the city centre of Lappeenranta to the public during the Greenreality Carnival was a success in terms of public engagement. The model is published online and can be viewed in the https://www.greenreality.fi/en/lprnyt/3d-city-model-created-lappeenranta-city-centre-take-look-year-2050-and-comment-current-issues.
The 3D city model is a part of the Urban Infra Revolution (UIR) project and it takes into consideration the results of the project (Figure 3 and 4).


FIGURE 3. The screen from software - the model presents an idea of Lappeenranta in 2050 with using AR technology (overview for a part of city)

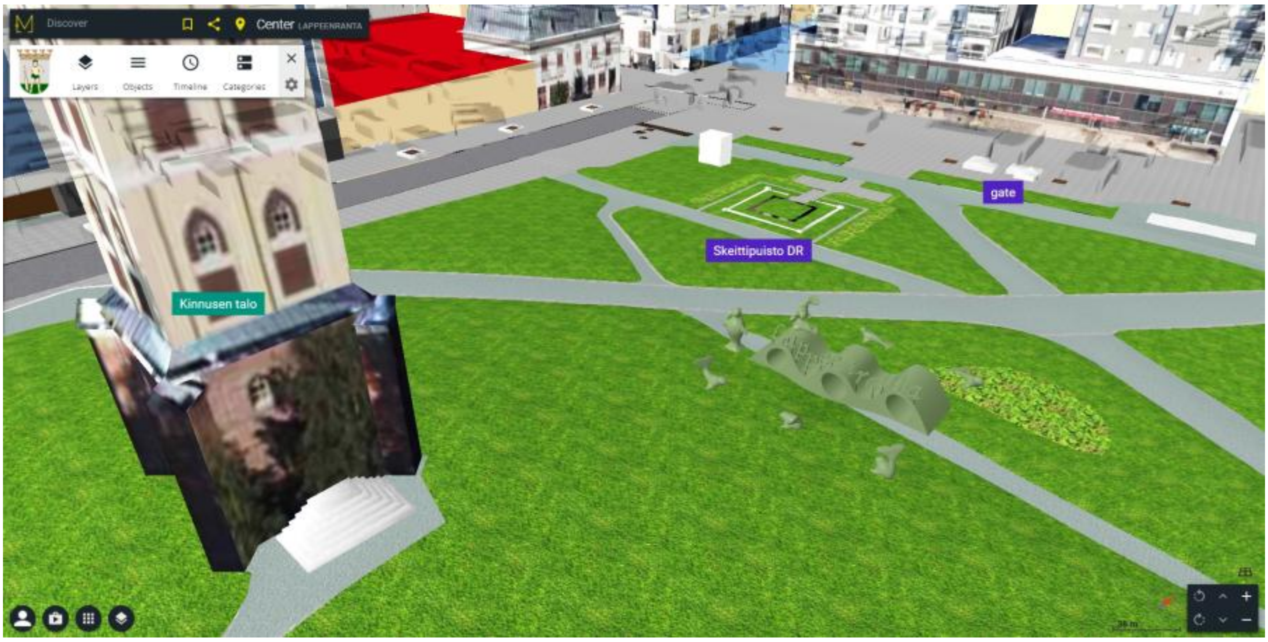


FIGURE 4. The screen from software - the model presents an idea of Lappeenranta in 2050 with using AR technology (chosen detail)

Moreover, based on the augmented reality, the project consortium will also create the physical place called "virtual cave", where each person using special googles will have the opportunity to do virtual walk in Lappeenranta city. Unfortunately, this part of the project was delayed because of COVID-19 pandemic. Nevertheless, the project shows that the VR/AR tools could be effective not only for the project promotion, but also for the project communication – notably important to achieve the acceptance of stakeholders in the project.

# What are the future perspectives for this technologies?

The Zhang et al. reflected on  the further area of VR/AR technologies development[1] and according to them the most important directions are:

- user-centred adaptive design,
- attention-driven virtual reality information system,
- construction training system incorporating human factors,
- occupant-centred facility management,
- industry adoption.

The Urban Infra Revolution project is in line with the above mentioned areas. It clearly contributes to the area user-centred adaptive design through active citizen participation in the social consultation. Moreover, the used AR system was designed valuing the participative approach of all project potential users – youth and elderly people. The project is also in line with the trends with respect to AR/VR for the design products through critical in-depth discussion with active involving different participants.

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# Conclusions

The possibilities for the development of virtual technologies are only just being recognized and are being applied to more and more new areas. The advantages of virtual technologies, in particular cost-effectiveness, the possibility of multiple repetitions of the training or experiment, simultaneous access for many people, the possibility of modifying and changing parameters for design, the learning avoiding the risk of damaging the equipment, constitute the basis for their further development. The aforementioned benefits make the VR/AR technologies an efficient tool for supporting projects implementation.
In the future the AR/VR will be probably more used in the design and improvement of existing solutions. Thanks to this technology it will be possible also to introduce new scenarios in the context of project implementations and modify these according to changing society's needs building on a wide stakeholder engagement. The VR/AR

tool also facilitates the increasing of individualization of communication since using the platform such as in the UIR project each person could take an ‘individual’ walk in the virtual city.

Circular economy

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