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USING THE ELLA PLATFORM TO CREATE VIRTUAL TRAINING

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Abstract
The article describes the Ella platform used as a tool for creating virtual training. The introductory part of the article presents the starting points for effective training as a tool for increasing the competitiveness of enterprises. Furthermore, the article provides examples of virtual training that has already been carried out, and Ella platform has been used in their preparation. The main part of the article is devoted to presenting the Ella platform as a modern and innovative tool for creating virtual training. This article also presents the result of applied research and development.

Keywords
Industrial engineering, virtual training, augmented reality, Ella platform.

1. Introduction

The training and its development were not initially considered to be activities that could help companies create added value and successfully meet the challenges of competition. However, today this approach is gradually changing. Companies that use innovative training and development practices are more likely to achieve better financial result than their competitors which do not. Training and development also help society develop the human resources necessary to meet competitive challenges. Nowadays many companies promote the view that learning through training, developing, and managing knowledge helps employees strengthen or increase their skills. As a result, it is possible to improve or manufacture new products, create new and innovative processes, and provide high-quality customer service. It is also necessary to ensure development activities and career management so that employees prepare for possible managerial and leadership positions and that the motivation is to keep talented employees at all levels of the corporate structure. The emphasis on education through training, development and knowledge management is no longer in the category of so-called bonuses. It is considered to be necessary if companies want to gain a competitive advantage and meet employees' expectations [5].

2. Education as a tool for increasing competitiveness

Businesses are currently struggling to remain competitive in the global market while demand for a capable workforce continues to increase. Technologies such as social media, tablets and computers reduce the costs associated with staff management, training, and their placement in the workplace. However, the challenge is to simultaneously ensure [5]:

- That these training methods include the necessary elements such as practice, feedback, variable pace, etc.
- That training can be carried out through a combined learning approach where companies are trying to find a balance between private training based on self-learning technologies and methods that enable interpersonal interaction.
- That the training covers all aspects of future staff assignments.

Employees from younger generations are better oriented in today's technologies, which can increase the demands of the company's educational methods. They expect the training to provide a fun, multidimensional, technologically demanding variant and provide immediate feedback. The role of training has expanded beyond the design of the training program. Effective training design remains essential but HR managers and trainers are increasingly required to develop systems that motivate employees to learn in training programs and outside them, as well as to create knowledge and share this knowledge with other employees of the company [4].

The nature of the training gradually changes from a one-off event to the creation of a sustainable training environment. This environment involves a combination of different training methods, such as employee collaboration, online teaching, traditional classroom training or modern enabling technologies (mixed reality). Non-formal education outside the boundaries of the official course is increasingly coming to the fore. Still, it is a voluntary activity whose frequency reflects the quality of the design of the employees training system [5].

Fig. 1. Role of training and development of employees in the company ([5], self-processing).

The current rapid development affects the employee-employer relationship. Fast changes in the business environment and the effect of competition may quickly cause a fall in profits and the need to change the company's commercial policy. Companies are reluctant to provide employees with job stability because these changes also affect employee qualification requirements. On the other hand, many people often change their jobs to find a more prospective and interesting job or to maximize the experience they can gain for their career development without creating a long-term commitment to any company. For this reason, skills development and career advancement are in the best interest of the enterprise and its employees. Companies require a motivated and productive workforce which possesses the necessary skills and can quickly learn to do new tasks to meet the changing needs of customers and the market. In response to the high turnover of employees, companies create a working environment providing a wide range of additional training and development opportunities that motivates talented employees to stay in their company [5].

Creating the right conditions and the possibility of direct career progression within the current position reduces the need for a job change. As a result, the employee acquires the required skills for higher positions through training and retraining. On the other hand, all investments in an employee who has remained in the enterprise and constantly generates added value will be returned to the enterprise. Moreover, workers want to constantly develop skills that are useful for their current employment and their interests and values. Due to the increasing time-consuming nature of work, employees are also interested in maintaining a balance between work and out-of-work interests. All these factors are built on a well-designed system of training and retraining of workers, which provides a practical and fast way of learning, easily adaptable to the current situation.

3. The use of virtual reality in education

Teaching methods designed to teach complex knowledge and skills are often based on so-called managed social constructivist education theories. These theories promote the learning and mastery of authentic tasks in personalized and realistic situations. Immersive technologies make it possible to improve this type of education by fully immersing the user in the virtual environment. By creating richer stimuli, e.g., using headsets, it is possible to create sensory immersion and thus deepen the effect of psychological immersion, thus evoking a feeling of virtual presence (illusion of a place).

Virtual reality provides sensory immersion by focusing on audio-visual stimuli combined with haptic elements. The user can turn his head, in the real world while the virtual world responds to all movements and interactions to preserve the illusion of presence. Virtual reality learning has its advantages and disadvantages. It is necessary to know the basic principles, properly evaluate the suitability of the application of this technology and adapt it to the educational process requirements. With the proper implementation, virtual reality will effectively transfer training into practice.

4. Five pillars of virtual reality education

During the years of virtual reality's development, many potential applications have emerged in the education process. Five pillars represent five reasons why virtual reality is beneficial as an educational tool [3].

Pillar 1 – A shift from the abstract to the specific

Virtual reality can transform abstractions into specific experiences, allowing a better understanding of the submitted substance. Rossou [6] used the so-called virtual playground in his studio, as shown in Fig. 2. In it, the virtual robot explained mathematical concepts,

Fig. 2. Virtual playground [6].

which led to a more fun form of learning, with children better understanding the substance explained.

Pillar 2 – Act, not just observe

Virtual reality allows experiencing the subject of education without affecting the real environment. This is particularly beneficial if the real situation is dangerous or difficult to imitate in practice. A good example is the training of future neurologists when training on living patients is often not an option.

Pillar 3 – To perform the impractical or impossible in practice

Virtual reality allows you to perform activities currently unfeasible. This fact is often used in geology or archaeology, where students can virtually visit places, they would not be able to visit.

Pillar 4 – Manipulate reality

The real world is built on specific physical laws that virtual reality simulates. However, virtual reality is not bound by these laws and can change them. Students can try out movement on other planets or the impact of changes in physical laws, which can significantly help them understand their principle.

Pillar 5 – Beyond reality

As already mentioned, virtual reality is often used to simulate or manipulate reality. But it is possible to take its boundaries even further. In the study, Bailenson [7] presented a new way of learning, where each student was immersed in a virtual environment and perceived to be the center of attention of the teacher. In a virtual environment, students were not limited by the number of seats, but they could all watch the lecture from the same place, i.e., the teacher maintained eye contact with all the students simultaneously.

5. Current applications of virtual training in the industry

The current rapid development and gradual decrease in virtual reality's investment costs help implementation in various industries. Businesses use the ability of virtual reality to faithfully simulate the real process and situations that are dangerous and difficult to imitate. For this reason, it creates a suitable environment for safe and effective training. Many companies from different industries have adopted virtual training as part of their corporate education system.

In the current market, some companies offer virtual training solutions as a product for other businesses. One example is Edgecom's training solutions. The training solutions offered include [1]:

- virtual maintenance-oriented training,
- virtual training focused on assembly training and sequencing,
- virtual training oriented to quality control,
- logistics-oriented virtual training.

Virtual maintenance-oriented training allows the training of employees to master maintenance operations of industrial robots, CNC and other machines. Training guides the user through all necessary actions, monitors his progress and warns of errors. Figure 3 shows a sample of the robotic cell maintenance process. The training uses an entirely virtual environment with a high degree of interaction and a high level of immersion and VR headset with the necessary sensors and controllers for smooth movement. It uses a teleport as a type of different movement.

Fig. 3. Edgecom virtual maintenance training solution [1].

One of the other solutions offered is virtual training of the assembly process. Complex assembly tasks are suitable for virtual reality training. Repeated virtual reality training streamlines employee performance and prevents costly errors that could affect production [1].

The employee is introduced to the assembly process step by step. This virtual process corresponds to its real copy using the same tools and movements. Training provides the necessary instructions for each operation. Figure 4 shows a sample of the virtual assembly training.

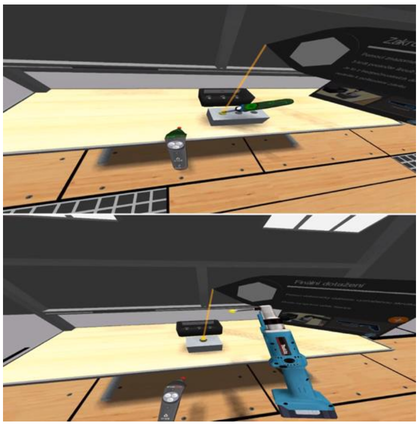

Fig. 4. Virtual assembly training solution [1].

There is also a great interest in virtual training in the field of internal logistics. This type of training makes it possible to use the virtual environment and the faithful functional virtual model of the selected means of transport with identical control elements and driving characteristics of a real means of transport.

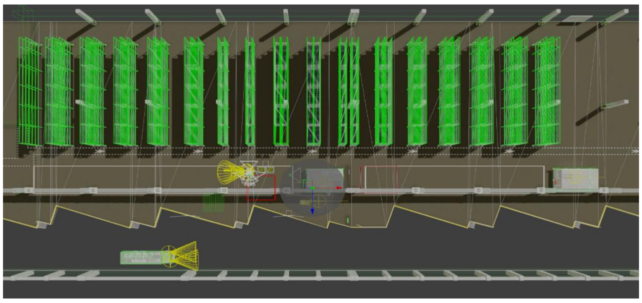

Fig. 5. Environment solution for virtual logistics training [1].

Logistics training allows you to set different levels. Specific events in the level can be activated or deactivated for specific training. For example, if a worker will pass a component interfering with the path of a forklift, this component can be activated, deactivated, or moved to another level. As a result, the trained employee will not know if and where this attention testing event will occur. These random events are specified during the process of collecting data on the real situation in the workplace. These can be falling crates, obstructions in the road, another intersection for forklift trucks, etc.

6. Use of the Ella platform for creating virtual training

Ella Platform was created as part of its own research as an integrated software ecosystem on which multiple software applications are built on. These applications focus on the design and analysis of internal logistics, monitoring, and simulation of automotive logistics assets also for virtual training. The platform allows individual solutions to share data about virtual worlds, objects and to process common real-time information about the state of industrial operation. This helps provide users (customers) with uniquely integrated solutions with higher added value. The following technologies were used to create the platform: C++, Python, OpenGL PhysX and others. A large part of the system logic is scripted in Python through the visual programming module (Figs. 6 and 7).

```
namespace ella
{
    namespace userInterface
    {
        class CameraViewPolicy;
        class CameraViewPolicy_Ortho;
        class CameraViewPolicy_Perspective;

        class EllaToolsExport Camera : public PtrBase
        {
            //==============Default methods start=================================================
        public:

            static Sptr<Camera> New();
            static Sptr<Camera> Alloc(const String & typeName = "");
            static Sptr<Camera> ConstructObject();
            ~Camera() override;

        protected:

            Camera();
            void Construct();

        public:

            static void FillClassDefinition(const Sptr<ClassDefinition> & def);
            void Serialize(const Sptr<serialization::OutputArchive> & ar) override;
            void Serialize(const Sptr<serialization::InputArchive> & ar) override;
            //===============Default methods end==================================================
        private:

            Double44 _pose;
            Sptr<CameraViewPolicy> _viewPolicy;

            Sptr<utilities::DelegateSignal> _onSendEvent;

        public:

            const Double44 & GetPose() const;
            void SetPose(const Double44 & pose);
            void SetPosition(const Double4 & position);

            const Sptr<CameraViewPolicy> & GetViewPolicy() const;

            Bool IsPerspective() const;
            Sptr<CameraViewPolicy_Perspective> GetViewPolicyPerspective();
            void EnablePerspective();

            Bool IsOrtho() const;
            Sptr<CameraViewPolicy_Ortho> GetViewPolicyOrtho();
            void EnableOrtho();
```

Fig. 6. Example of Ella platform scripting [2].

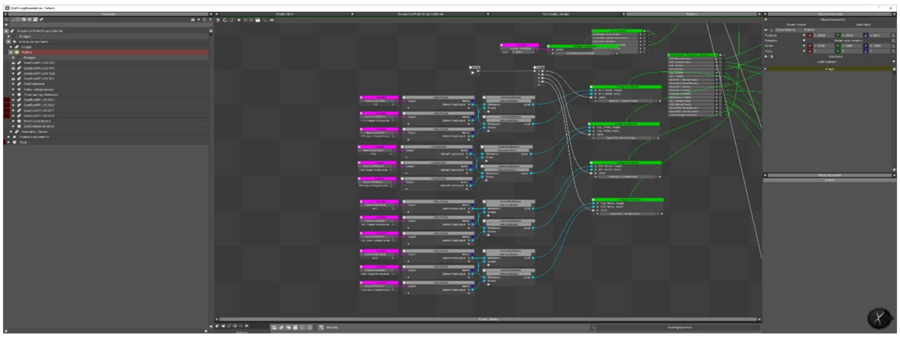

Fig. 7. Example of work in the Ella platform [2].

Ella thus contains a complete set of tools for the creation of industrial applications and software aimed at:
- simulation and emulation of logistics processes,
- design of enterprises Industry 4.0,
- data collection, analysis, and real-time evaluation,
- control and navigation of logistical assets,
- creation of specialized levels for training in virtual and augmented reality,
- server solutions without graphics support,
- 3D web interfaces.

A graphical representation of the developed Ella core, tools and products is shown in Fig. 8.

Therefore, the Ella platform forms the basis for creating training programs in virtual training sessions. It has been developed and designed to allow efficient and easy programming using visual programming. This means all applications and software solutions can be programmed within Ella platform with an integrated visual programming tool. Visual programming allows you to create variable systems, from small real-time vehicle control to complex virtual world simulations. As a result, it allows for high productivity when starting to work with the platform.

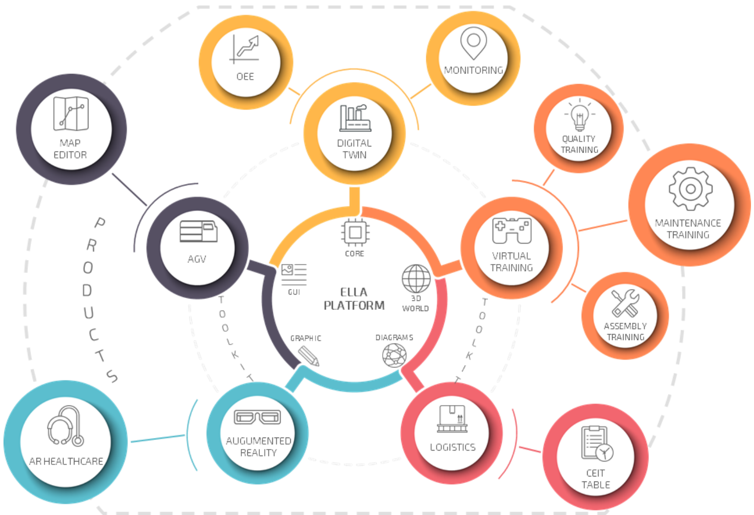

Fig. 8. Ella platform – core, tools and products [2].

Fig. 9. Example of visual programming in the Ella platform environment [2].

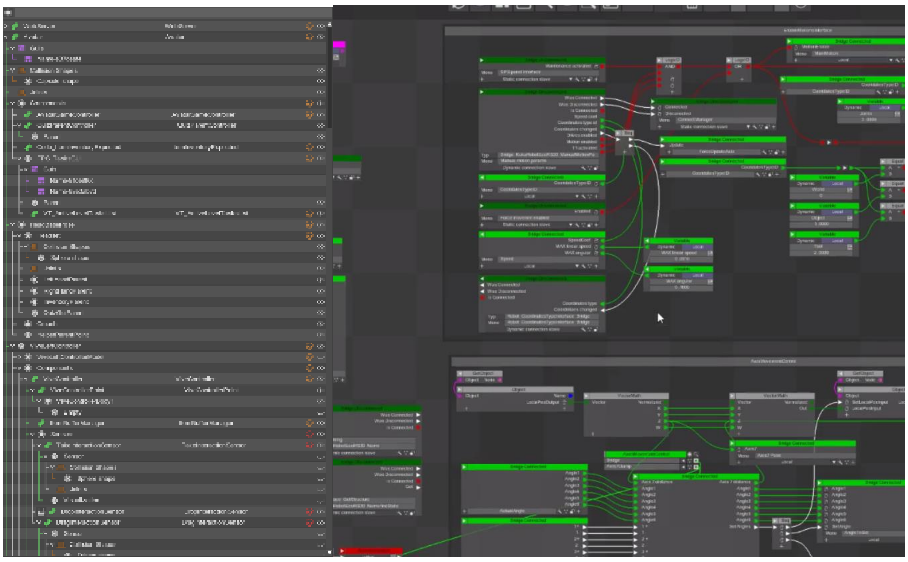

Fig. 10. Example of visual programming in the Ella platform environment [2].

This software platform allows connecting a wide range of modules coexisting in a virtual reality environment. This is supported mainly by:

- compatibility with Windows operating systems,
- compatibility with modules created in C++ languages,
- graphical core supporting OpenGL 3.3 and above,
- integrated support for serialization of modules,
- 3D user interface,
- support of multi-monitor systems and touch control.

Band modules designed to visualize the virtual environment and objects in it include:

- 3D environment editor,
- 3D model import (fbx, dgn, dwg, stp, glb, gltf, jt),
- post-process module (Motion blur, DoF, SSAO),
- environment showing the most realistic appearance of 3D objects (Physical Based Rendering),
- mesh optimization with high resolution.

The Ella platform allows you to create training in a simpler 2D variant and the variant for full immersion in virtual reality. These variants are then accompanied by different minimum software configurations for the smooth creation and course of virtual training, which are listed in the Table 1.

The versatility of use and user specific requirements are also supported by the wide variability of the operating system and programming languages shown in Fig. 11.

Tabela 1
Minimum configurations for virtual training variants.

	2D variant of virtual training	VR variant of virtual training
Processor	i5 7300	i7 7700
Memory	8GB	8GB
Graphic Card	NVIDIA GTX	NVIDIA GTX 1080
Virtual Glasses	–	HTC Vive Pro

Fig. 11. Operating system and programming languages [2].

7. Virtual Training System Toolkit

A key tool of the Ella platform for creating virtual training systems is the Virtual Training System Toolkit. This tool contains a set of interfaces and components that allow to create and interact with the virtual world in an efficient way.

Therefore, the Virtual Training System Toolkit allows to view training in a virtual reality environment. It contains below listed main parts, which will enable standardized rendering of the scene in virtual reality, movement around the virtual environment and interaction with the environment.

7.1. Dynamic quality management

It is a module that allows visualizing even relatively complex design data and corrects jumps and decreases of frames per second (FPS). It also serves as a module that automatically adjusts the level of detail when the standard 90 FPS is dropped (which is necessary for a smooth running of virtual reality).

Module for moving around the virtual environment allows the user to move around a virtual environment that is larger in length than the standard space for virtual glasses. It is about moving with the teleport system. The module also ensures that the user can move only through predefined zones (management of permitted transport destinations).

Controllers' interaction module ensure that it is possible to interact with virtual objects such as:
- moving of objects,
- the tool selection,
- door opening etc.

Module for performance optimization in virtual reality provides higher performance of virtual reality for new series of graphics chips.

The Virtual Training System Toolkit also contains various:
- Components (Avatar 2D/3D, inventory, interactive zones for capturing objects and interacting in the world, teleport zones, assembly toolkit containing screws, tighteners, etc., cable toolkit, means of transport or robots toolkit).
- Diagrams (Virtual Training Diagrams – VT GUI).
- Materials (basic library of materials (iron, glass, aluminum, plastics, ...).
- Various language mutations, language manager.
- A library of models and components created as part of a specific virtual training project.

8. Implementation to a virtual training

The creation of virtual training takes place in five steps. An example of implementation for training with a robotic system is shown in Fig. 12.

Step 1 – Input data collection
- 3D laser scanning,
- factory layout and equipment data,
- production process information,
- information on rules related to safety,
- 3D models of factory/equipment if available.

Step 2 – 3D dodelling
- import from 3D formats (.stp, .jt, .fbx. ...),
- 3D modelling from photo documentation and drawings,
- 3D modelling of robots, accessories, control panels, environment ...,
- CAD data preparation & optimization (PIXYZ),
- creation and application of custom materials.

Step 3 – Inverse kinematics
- connection of serial chain of rigid links,
- closed form solution of robot inverse kinematics,
- inverse kinematics for 3–7 axis robotic systems.

Step 4 – Level programming
- virtual factory model creation,
- custom editor module development,
- customer specific training modules.

Step 5 – Virtual training system implementation
- user management,
- statistics management,
- virtual charts,
- learning management system.

The Ella platform is used in steps 3–5.

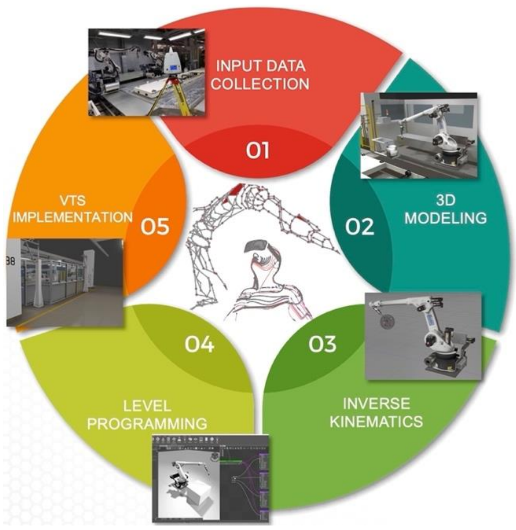

Fig. 12. Five steps for virtual training creation (example for robotics system) [2].

9. Conclusion

Ella platform is a comprehensive platform for connecting software and hardware components of virtual training. However, the use of virtual training in education has two main levels. The first is the already mentioned hardware and software security, and the second is the education scenario itself. These two areas cannot be separated. While the hardware and software sector are evolving very dynamically and is difficult to predict for the near future, the field of education scenarios depends on the development of industry-dominated work activities that we can better predict (Industry 4.0 and Industry 5.0, current requirements of enterprises for knowledge, skills and competences of employees). They are connected by postulates of didactics, psychology, or sociology. Part of the ongoing research is precisely the creation of procedures that allow such a combination of the two main levels so that economical or time-efficient and effective virtual training can be compiled.

The virtual trainings that were implemented with Ella platform focused on industrial companies has been dedicated to automotive production, logistics, or EHS area. Their creation was based on specific customer requirements. Still, it was also necessary to reflect conditions that do not arise from these requirements but should be considered, for example, employee fluctuation, the application of safety and ergonomics (in training but also in real conditions of work), thus industrial engineering principles. It would make it easier to develop these solutions if there were procedures that are common to various forms of training and, at the same time, procedures on how to create training in different areas. These procedures would form a methodology combining the two education levels mentioned above. The creation and such methodology is the aim of further research by authors.

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