Title:
Application of VR and AR Tools for Technical Drawing Education

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Keywords:
Virtual Reality, Augmented Reality, Technical Drawings, Teaching and Learning.

DOI: 10.14733/cadconfP.2019.xxx-yyy

Introduction:
There are concerns from Higher Education (HE) institutions and industry about the decline in standards of Technical Drawings (TD) due to the lack of understanding of basic principles and conventions that underpin the best practices. There is growing evidence that simulations/animations along with augmented and virtual reality (AR/VR) technologies can improve learners' engagement, competence, and skills; especially when compared to traditional didactic methods. The purpose of this work is to develop and examine the overall effect as well as the impact of virtual and augmented reality -based methods and tools on the teaching and learning experience of technical drawing principles in the context of higher education settings. The development of tools and methods is based on the findings of a previous international study in three different categories covering the perception of TD education, assessing of TD knowledge and ability, and expectations of TD education.

TD has a been always an essential component in the formation of new product designers and engineers. They play an important role in communicating the technical product specifications (TPS) (i.e. material, size, shape, tolerances, etc.) for manufacturing during the new product development process. The decline in standards due to the lack of understanding of basic principles and the conventions of drafting skills that underpin these practices represent a challenge for HE institutions and the traditional teaching strategies. Despite engineering and product design students are known to prefer visual, sensing, inductive, and active learning styles; most engineering education and in particular the teaching of technical drawing skills has relied on auditory, abstract, deductive, passive, and sequential teaching styles [1].

The introduction and broadening of 3D tools as a key teaching component in the design process has significantly change the teaching of TD related subjects as a result. However, HE institutions are still left with the challenge of developing new T&L tools and methods to make sure students acquire the knowledge and skills on TD required to meet the demands of both academia and industry [3-4].

AR/VR technologies have already found potential applications in areas of education where students are facing some learning challenges. These applications have incorporated for example desktop-based virtual reality technologies to stimulate learning, to teach abstract concepts, to teach scientific inquiry and engineering subjects [2]. AR/VR offers to HE institutions an efficient way to present complex and difficult theories/concepts to design and engineering students. Students can comprehend complex theories and concepts with the contextually enriched interaction offered by AR technology. For example animations have shown to provide more enthusiasm for the learning activity, better performance in understanding the appearances and features of objects and improve the spatial visualisation capabilities [5].

In this paper, the authors present development of 3D interactive AR/VR teaching system from a design-based method to help engineering and product design students improve on critical and complex topics related to TD skills according to an international survey and as part of a broader European funded research project. This work shows that human-centred approaches can improve the understanding of students needs and facilitate the development of AR/VR technology applications for T&L within an international and multidisciplinary team.

Development of AR/VR Tools and Animations:

This paper addresses the use of low-cost mobile based AR/VR tools developed with the support of animation and simulation tools alongside text-based teaching methods. Having several approaches to teaching would give students a variety of options when learning technical contents. Individual students may require different support as the concentration and abilities of the students may change due to personal circumstances, environment, age, among other factors. In the initial stage of this study, a comprehensive research to identify the area of TDs that require support from AR/VR technologies in order to overcome T&L issues is carried out. 320 people from UK, Bulgaria and Turkey, with different educational background (engineering/design, student, instructor/lecturer, manufacturing sector employee, vocational college/ high school / university student, and teacher/trainer), participated in a survey. This is used to identify their TD perception, knowledge and skill levels and expectation of TD education. The research show that current teaching methods can be further supported by AR/VR and animation technologies to improve engagement and T&L of relatively complex subject. The program identified six aspects of technical drawings which were separated into modules to improve the learning experience. From the analysis, the following module areas were selected for developing AR/VR content and animations:

- Dimensioning and Tolerances
- Sectioning, Projections and Perspective Drawings
- Dimensional Tolerances, Edge Tolerances, Shaft and Hole Tolerances
- Geometric Tolerance/Form-Position Tolerances
- Surface Treatment Markings/Surface Roughness
- Production and Assembly Drawings

The team decided to use a Formula Student Race Car as the centerpiece of the project (Figure 1). This car is developed by the engineering students at the Technical University of Sofia which has been designed (i.e. CAD) and physically manufactured. This car model gave a wide range of different components to be used within AR/VR and animation. Context/environment for each part was assigned in AR/VR and animations to help the student understand the component and to give a more real-world experience.

Several software packages were used to achieve the required output including the Adobe suite (Photoshop, Illustrator, and InDesign) to create the storyboards, and graphics. For 3D content generation, SolidWorks was used to model the car, which was then imported into 3D Studio Max to start the animation process. The model was converted to polygonal data (low for AR/VR and high for animation). Appropriate textures were then applied to the model, and various animation methods were utilised to create the content, including camera and object movement.

Unity was used to create interactive AR/VR applications with ARCore for building the AR experience. In this phase, multi-disciplinary knowledge and skills help to effectively create the content that would be visually rich to be used by students and industry to engage in the modules. Interactivity is key when creating an engaging experience. Not only should the user be able to look around the environment, but they should also be able to interact with components and complete objectives. A multi-disciplinary approach allows the effective and appropriate use of individual skills within software, programming and design.

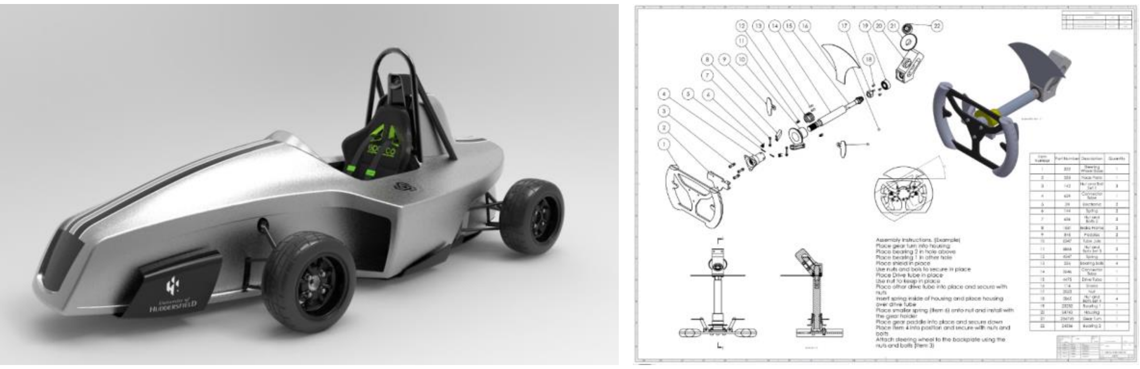

Fig. 1: 3D Modelling of Formula Student Race Car and TD for stearin wheel assembly.

The development of AR/VR and animation requires hardware considerations before the development phase. The requirements for the student/teacher for this project would be:

- VR headset
- Competency of modelling SolidWorks or equivalent
- Design for manufacture experience, experience in TD details
- Some experience using AR and VR
- Mobile Phone (Android 7.0+)
- Powerful computer

<u>AR/VR Technical Drawing Case Study:</u>
Several AR applications have been developed for improving student understanding of tolerances. Tolerancing is defined as an extension of dimensioning of TDs. It specifies a range of accuracy for the shape, size, and position of components so that when they are manufactured all parts can fit and function properly when assembled. Currently, tolerances covering form (straightness, flatness, circularity and cylindricity), orientation (angularity, perpendicularity and parallelism), location (position and concentricity) and runout (symmetry, circular runout and total runout) have been completed. Figure 2 shows cylindricity tolerances in AR with surface parameters. Also shown is an AR game where the car can be driven using the onscreen controls on a floor defined in AR environment on Android.

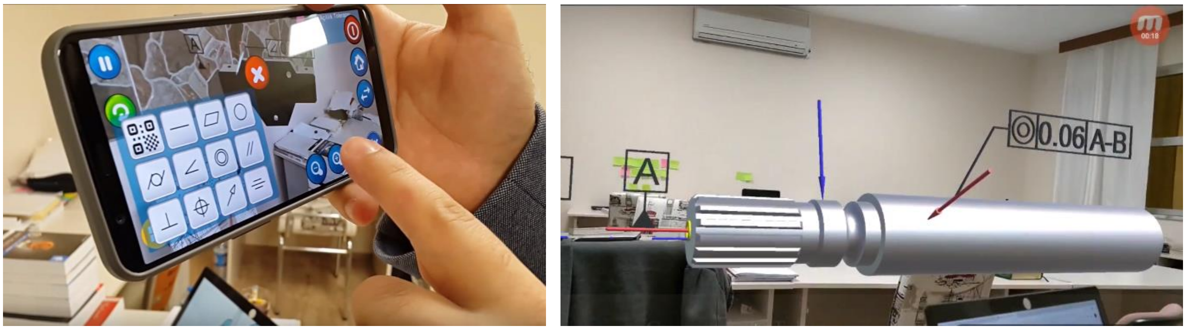

Fig. 2: Mobile AR Applications and sample AR training simulation.

VR development includes the creation of 3d content and the programming of interaction. Depending on the desired level of both realism and interactivity, either high-level programming languages may be used; but these required extensive knowledge of programming or game engines such as Unity, Unreal or similar.

The vehicle has been rendered with panoramic and stereoscopic cameras to be viewed in a Samsung Gear VR. This VR device enables a decent field of view and good head tracking due to the sensors. The controller can be used to navigate and interact with the scene. The disadvantage of this device is that it only works with the latest Samsung phones and has a relatively low level of immersion which would be good enough for this type of T&L activity.

Discussion and Conclusions:

The use of AR/VR in education is promising and useful in T&L. A multi-disciplinary approach is crucial. This approach brings a different perspective to T&L methods and content development which results in a better experience for students. Individuals from different backgrounds (engineering and design) can offer their expertise in the content development and application of software. Running international projects require the use of methods and tools to facilitate the communication of content.

The process of creating the AR/VR content is time-consuming if not developed using effective design and visualisation methods. Students are more accustomed to using 3D games with a high level of visual detail where a substantial amount of investment may have been available for commercial projects. Therefore, a careful consideration of end-user requirements and expectations is needed to engage students. Interactivity is essential when creating AR/VR content. While animations may not have any interactivity, it would provide a visually pleasing platform to communicate the information. However, large file sizes may limit its use as it would require high internet speeds to download the animation content which could be hosted on a website, however, many educational institutions have fast and free internet available.

Development of AR/VR traditionally requires low-polygon modelling techniques but on multidisciplinary projects, teams normally use their daily-use software to generate 3D content which may limit the level of interactivity as optimisation between software would reduce performance and increase file size of any developed media. Several headsets and mobile phones (Android 7.0+) would also be required to give each student the experience. For this reason, several platforms have been developed to ensure that all students would have an experience with each T&L method. Projecting the view of the VR user onto a screen may also be a solution to this problem.

Positive feedback was received from the initial pilot study where selected students used the developed AR/VR and animation content. Further work includes the development of an AR/VR application to other operating systems to reach a wider market. Students would be able to choose a method tailored to their needs. These didactic resources should be easy to use and must be developed with a good level of educational usefulness

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