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An Innovative Self-learning Approach to 3D Printing Using Multimedia and Augmented Reality on Mobile Devices

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Abstract

Technology is evolving rapidly and it is becoming harder to keep up its pace. At a university environment, important investments are required so that students and professors can have access to novel technology. However, it is also fundamental to know how to use this novel technology to exploit its benefits. Tecnológico de Monterrey, Campus Monterrey, recently acquired several 3D printers so that the students could get familiar with this rapid prototyping technology and use them to deliver better quality projects. Nevertheless, the new challenge was to administrate the 3D printing process including 3D model verification, STL file generation, printing time and raw material. Since students were not familiar with 3D printing, the expert had to spend a lot of time with them explaining the whole process from the modelling to the printing stage, and verifying their work to make an efficient use of 3D printing time and materials. To overcome this situation, it was decided to make use of augmented reality and multimedia applications to generate tutorials for self-learning the whole process of 3D printing. Nowadays, the wide spread of mobile devices and wireless technologies brings a huge potential to e-learning changing dramatically the traditional instructor-oriented scheme. The learning process can take place in an informal setting having the tutorials available on mobile devices by just scanning a quick response code, usually known as QR code. The first QR code enables a link to download the free augmented reality Layar app. Then, several images can be scanned using Layar to open each of the video tutorials. These videos explain graphically step by step of all the processes involved and give different options of software to be used. The tutorials are easy to follow so that any engineering or design student can learn from them. This case-study offers an innovative learning approach that fosters self-learning and a more efficient use of technology resources.

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1. Introduction

There are many current challenges in education, especially in engineering and science. With the rapid change of science and technology, it is a huge challenge for universities to be able to teach up-to-date knowledge and tools so that the future engineers are familiar with the state-of-the-art technology. It has always been a challenge, but nowadays in just a few years, tools and technology become obsolete. For this reason, teaching and the whole learning process need to evolve too. Educational institutions need to think out of the box and come up with innovative ways of transferring new knowledge among their academics and students.

The accelerating technological change, increasing personalization, greater diversity of educational models and the proliferation of sophisticated data systems, are different trends that are leading to diverse roles for educators[1]. Education stakeholders need to be aware of these trends and consider them in their teaching models to be competitive and deliver what is needed in this new learning environment.

On top of that, educational institutions have budget constraints to invest in new technology and have to cope with bureaucratic processes in order to be able to obtain it. Along the process of getting new technology, come also different variables such as training experts to use the technology and to transfer that knowledge, maintenance, consumables, allocation of space, etc. Things need to be simpler and quicker to keep up the pace of development.

Having this setting in mind, and that Tecnológico de Monterrey had recently acquired new 3D printers that were not fully used, the need of transferring the knowledge in a quicker and simpler way was identified. Even though the technology was available, students were not entirely familiar with it and there were limited human resources to facilitate the 3D printing process including 3D model verification, STL file generation, printing time and raw material. It was in fact a bottle neck since an expert had to spent time with each team of students explaining the 3D printing process going from the modelling to the printing stage, and verifying their work to make an efficient use of 3D printing time and materials. As a solution, this case study suggests the use of augmented reality and multimedia applications to generate tutorials for self-learning the whole process of 3D printing.

2. 3D Printing and Augmented Reality

Rapid Prototyping (RP) is also known as layered manufacturing since it creates a physical or three-dimensional solid model in a layer-by-layer additive fashion by the fusion of material under computer control. Different materials such as fluids, waxes, powders and laminates are used to build the part or model depending on the computer-controlled processing technique. The advantages offered by Rapid Prototyping are time and money savings, quick product testing, easy verification and error elimination of product designs, and creation of models without limitations of their geometrical complexity[2]. 3D printing or Additive Manufacturing (AM) is the application of Rapid Prototyping processes to fabricate end-use products or functional long-term prototypes. One of its main advantages is the potential of creating complex geometries that are not possible with traditional manufacturing processes. There are many applications for 3D printing technologies, including architecture, construction, industrial design, automotive, aerospace, military, engineering, dental and medical industries, biotech, fashion, footwear, jewelry, eyewear, education, food, and many other fields. 3D printing opens up new possibilities for design, manufacturing and production being a great tool that is each time more accessible to people.

There are different 3D printing or AM processes depending on how the material is handled. In some cases liquid material is cured, it can also be melted, or laminates of material can be cut out and then glued together to form the desired shape. The most common 3D printing processes are Stereolithography, Selective laser Sintering, Selective Laser Melting, Fused Deposition Modelling, Laminated Object Manufacturing, among others.[3] The 3D printers acquired at Tecnológico de Monterrey work under the Fused Deposition Modelling Technique in which a plastic filament is melted by a nozzle and placed layer by layer on a table where the part is built from the bottom up. The 3D printers' model is the Rostock Max Delta, as shown in Fig. 1.

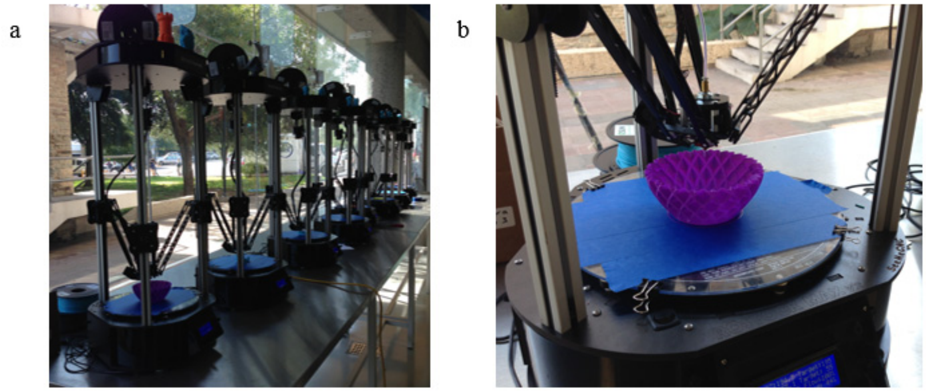

Fig. 1. (a) Rostock Max Delta 3D Printers (b) example of a 3D printed part

Augmented reality (AR) is defined as a combination of technologies that enable real-time mixing of computer-generated content with live video display. AR is based on techniques developed in Virtual Reality and interacts not only with a virtual world but also with the real world[4]. There are several definitions of AR depending on the technology used. However, in general purposes, AR could be considered any system with the following characteristics: combines real and virtual, is interactive in real time, and is registered in three dimensions. There are many applications of AR such as medical, manufacturing, entertainment and games, visualization, military, navigation, education, marketing, tourism, robotics, urban planning and civil engineering, etc. This case study focuses in the application of AR in education. The coexistence of virtual objects and real environments allows students to visualize complex concepts, interact with synthetic objects in the mixed reality, and develop important practices that cannot be staged with other technologies[5]. Besides, with the availability of mobile devices, the learning space is not constrained to a classroom or an equipped lab. Students can have the information anywhere they what and whenever they desire it.

3. Methodology

The methodology that was followed in this case-study was to first identify and understand the problem of having brand new 3D printers that were not being used since there were not enough instructors to teach and guide the students on the whole 3D printing process. This was a bottleneck and investing in additional headcount for this purpose was not a choice. Then, some background research on this technology together with AR was done to understand the state-of-the-art and capabilities of each of them. Having this in mind, a solution was proposed by combining these technologies for educational purposes making knowledge available for self-learning.

A group of students was in charge of the project and did some research to understand in detail the steps towards a successful 3D printing process. This group of students also did some research on the different AR tools and came up with a way of making information available to other students by using mobile devices. With all this information, several video tutorials were recorded including a complete explanation and guide step-by-step through the 3D printed process. The video tutorials included AR to enhance the user´s learning experience and also to make the information available to the students. Finally, a few students proved the method and did some 3D parts by themselves.

4. Generating the tutorials of the 3D Printing process

The 3D printing process, generally speaking, can be divided in the following steps:

1. Produce the 3D model or download the part
2. STL file creation

3. Verifying if the part is printable
4. Generating the G code
5. Verifying if the G code is correct
6. Setting up the 3D printer and printing the piece

4.1. 3D Model and STL file creation

The first thing to do is to produce the 3D model using any CAD software. There are special considerations and important rules that should be considered in order to have a successfully printed part: make your Mesh Water-Tight, remove Non-Manifold geometry, review the material design guidelines, the 3D designs must be in STL format, products cannot be bigger than the maximum build size of the specific 3D printer intended to use, the design file cannot contain more than one separate object, in case of making assemblies. 3D printing has become quite popular among designers and engineers, and nowadays is quite common to find databases where 3D models can be downloaded for different applications. So either way, designed or downloaded, it is required to have a complete 3D model of the part that will be printed.

Once the 3D model is created, it is required to convert it to an STL file, which is the file format needed in order to produce the piece in any RP or AM technique. STL initially stands for STereoLithography CAD software, being stereolithography one of the first rapid prototyping techniques. However, other names were given afterwards: Standard Triangle Language and Standard Tessellation Language. The STL file has the information of the surface geometry of the 3D object without any other data contained in a CAD file.

4.2. 3D Printing Testing

In order to check if your 3D file is printable, you need to use a 3D printing software to make the final adjustments, fix error in case it is necessary and verify that the file is ready. For this case-study, the software Netfabb was used. With Netfabb it is possible to move the piece to the origin, adjust it to the right direction and position, fix any errors and save the file again in STL format. Netfabb is a very reliable software that has a basic version that can be downloaded for free and professional versions that can be bought, depending on the application and the complexity of the models.[6]

4.3. G code generation

Once the STL file is verified and ready, the next step is to generate the G-code using a G-code generator for 3D printers. In this study-case, it was decided to use Slic3r. This software converts a digital 3D model into printing instructions for the 3D printer. It cuts the model into horizontal slices or layers, generates toolpaths to fill them and calculates the amount of material to be extruded[7]. In case the piece needs it, support material can be added to aid the 3D printing process. This support material is removed once the part is fully printed but is necessary in order to print, especially when there are unusual geometries.

At this stage, it also corresponds to select the printer settings. Some variables to define are quality and density of the desired part. The higher the density, the more resistant the piece will be but it will also use more material and will need more printing time. The thickness of the filament to be extruded is also indicated at this phase. Once all the details are defined, the G-code is exported and saved to an SD card.

As a final check-up, the G-code is verified using gCode Viewer, where step by step can be visualized and analysed to see how the piece is going to be printed[8]. The viewer works directly on the browser, without the need of downloading any software. The file is opened directly in the browser and the piece is visualized in 2D, layer by layer, getting also some estimates on the printing time and amount of material to be used.

4.4. 3D printer set up and printing process

The final step is to set up the 3D printer and start printing. It is very important to verify that the glass is perfectly clean, before starting. If the surface is not clean and there are some scrap left overs, the part will not attach to the surface and will lift up, ending up with a scrap part. Once the surface is clean, a thin layer of glue should be added to the glass to fix the layers to the surface. In contrast, if too much glue is added, then it would be hard to detach the part once it is finished since 3D models are somehow fragile depending on the material and the geometry. Also, make sure you have enough filament before starting.

Finally, once the printer is ready, the SD card is inserted into the 3D printer. The printer shows the G-codes available to print from which the desired one can be selected and start with the 3D printing. Fig. 2 shows an example of a 3D printed part following the here described process.

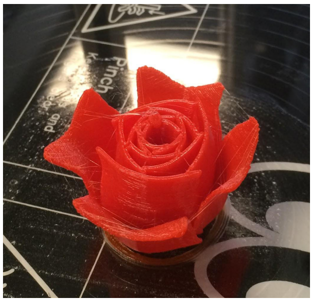

Fig. 2. Example of a 3D printed part

4.5. Tutorials and Augmented Reality

Since the beginning of the project, the team was looking for different options to include Augmented Reality in the video tutorials. A simple choice was to have the video tutorial among with a 3D printer and iPads or Android tablets with AR Apps, such as Layar and Aurasma.

Layar App is available for iOS systems, Blackberry devices and Android devices. This is a paid app but the price is fair for the service received. Layar allows to add digital video by scanning an image which could be the 3D printer. Aurasma is HP Autonomy's AR platform. It is available as an SDK or as a free app for iOS and Android mobile devices. Aurasma's image recognition technology uses a smartphone's or tablet's camera to recognize real world images and then overlay rich media on top of them in the form of animations, videos, 3D models and web pages. Both businesses and individuals use Aurasma to create and share their own augmented reality experiences as well as to discover hidden digital content around them. Teachers are among the most active group using the platform.[9,10]

There are three main categories for AR tools:

- AR 3D viewers, like Augment, allow to place life-size 3D models in the environment thanks to the use of trackers.
- AR browsers enrich the camera feed with contextual information. For example, user can point his smartphone at a building to display its history or estimated value.
- AR games create immersive gaming experiences, like shooting games with zombies walking in your own bedroom.

After recording the promotional video of the project, the team selected Layar as a tool for AR. Layar can be used on all screens and connected devices: on smartphones and tablets available on iPhone, iPad and Android. On PC and connected TV, AR works with a webcam, which can be quite complicated when you have to manipulate a tracker in front of your screen.

5. Results

Using Layar as an Augmented Reality tool enabled the 3D printing video tutorials to be available for people to access them. In order to do this, the user simply needs to scan the Quick Response (QR) code with the Apple or IOS system to download the app and access the tutorials. The QR code is shown in Fig. 3.

Fig. 3. QR code to access the video tutorials menu.

The 3D printing process was divided in 4 main steps: 1) STL creation using different software, 2) Verifying if the part is printable, 3) Generating the G code, and 4) Setting up the 3D printer and printing the piece. Once the user accesses the video tutorials menu, each video can be seen by scanning its corresponding image with Layar. The images are shown in Fig. 4.

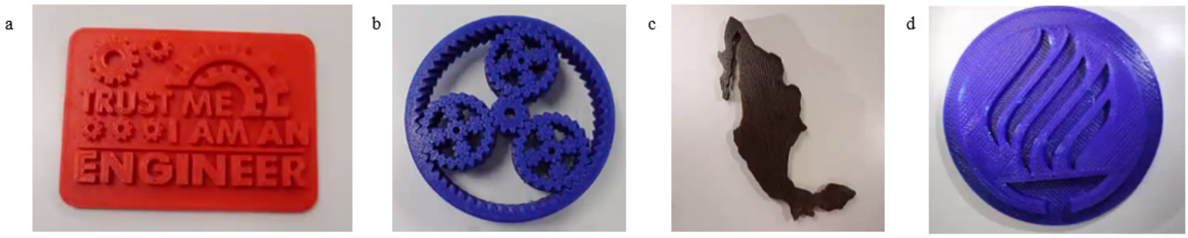

Fig. 4. a) STL creation, b) Part verification, c) G code generation, and d) Printing the part

This work resulted in a very innovative way of making information available for students so they can self-learn the process and make use of the technology available at their university. Even though the project was completed just a few months ago, it has shown promising results since students are more motivated to learn by themselves at their own pace and the instructor works more like a coach to solve specific doubts instead of spending lots of time with each of them teaching the whole process details. This has definitely opened a door to a world of new learning techniques for the students.

6. Conclusions

Working with 3D Printing processes and Augmented Reality shows how technology is evolving at an accelerated pace. Thinking in a world in which you can get exactly what you want, and not what is just available, was an interesting issue. You can actually design and print what you need and bring your product to market in days, instead of months or years. 3D printing and AR are relevant for everyone, regardless technological background.

3D printing trajectory seems to almost exactly mirror the story of the personal computer. Whereas the first computers were huge and expensive, now they can be found in the home of every individual. Likewise, 3D printers are each time more accessible looking forward to put a factory in everyone’s living room. This dramatic shift comes with a new set of applications with its corresponding challenges, but definitely ushering in a new lifestyle.

Similarly, the numerous applications emerging from AR are transforming the way people see and learn from their surroundings, and are revolutionizing companies’ business models. AR enhances user's perception of and interaction with the real world. The virtual objects display information that can help the user perform real-world tasks. Among the different applications, education is really important since AR comes as a game changer in the teaching models and learning environments.

The case-study presented in this paper combines the use of AR and multimedia applications to generate tutorials for self-learning the whole process of 3D printing. It offers an innovative learning approach that fosters self-learning and a more efficient use of technology resources. This successful case-study is just an example of the possibilities that these technologies can offer.

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