Alternative methods of learning using Augmented Reality

Practical application
and comparisons with other techniques

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Abstract

The way that people acquire new knowledge and interact with the information has remained more or less the same in the modern history of humans, from paper based books to digital ebooks. The interaction with the information is practically non-existent, even more, the medium of showing the information is only two-dimensional, making the understanding of real world, three-dimensional concepts more difficult. Augmented reality, as a technology, has greatly improved in the past few years and now has the power to redesign the process of learning and teaching in ways that are still not contoured.

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Chapter 1

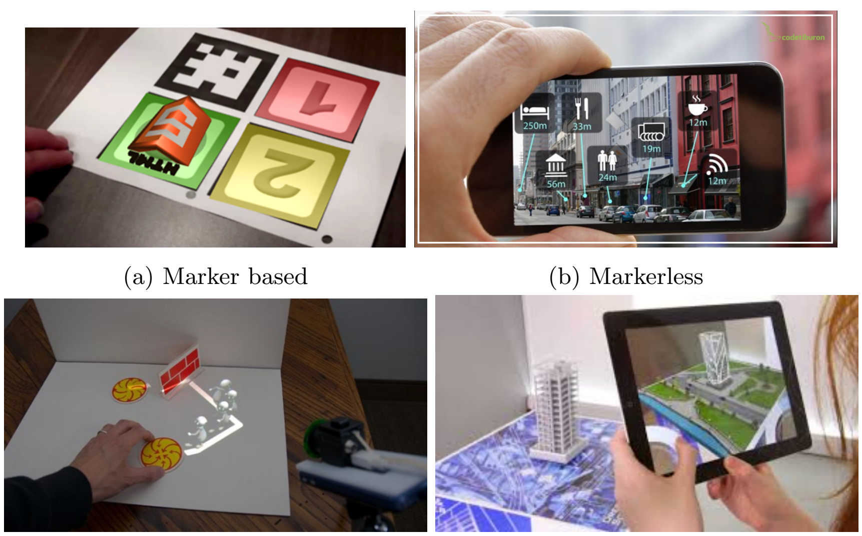
Augmented Reality

1.1 Introduction

The meaning of the word augment is to add or enhance something. In the cause of Augmented Reality, graphics, sounds and different feedback are added into our world to create an enhanced experience.

This approach is opposite to the one that Virtual Reality takes, which is to completely replace the reality with a computer generated one.

1.2 Categories of Augmented Reality



(a) Marker based

(b) Markerless

(c) Projection

(d) Superimposition

Figure 1.1: Categories of augmented reality

Having their own use cases, advantages and disadvantages, several types of augmented reality approaches exist.

Marker based

Uses a camera enabled device and some type of visual markers (like QR codes or certain feature points) to recognise this zones and execute certain actions like imposing a virtual object over the marker.

Markerless

Also known as location-based AR, it uses GPS, digital compass, velocity meter and accelerometer to track and recognise the position of the phone, making possible the instantiation of virtual objects that appear to remain in place even if the user moves through the world.

Projection based

The augmentation is realised by projecting light onto objects (the projection can also be done in mid-air with the help of laser plasma technology), though augmenting it. One use-case would be creating an interactive virtual keyboard.

Superimposition based

In this approach the original view is either fully or partially replaced with a newly generated augmented view. For this to happen, the object that needs to be replaced must first be detected, so image processing plays a vital role.

1.3 Types of devices

Head up displays

Mainly invented for mission critical applications like flight controllers and weapon system dashboards where crucial information needs to be presented directly in the visual field of the user. In this case the projected information is collimated (parallel light rays), focused on infinity so that the user's eyes do not need to refocus to view outside the world. A regular HUD is composed out of a projector unit, a viewing glass and a computer that generates the data that needs to be shown.

Helmet mounted displays

Represents the next logical step from the head up displays, moving the display from a fixed position to a mobile one, mounted directly on the helmet.

Holographic displays

They use light diffraction to generate three dimensional forms of object in real space

Smart glasses

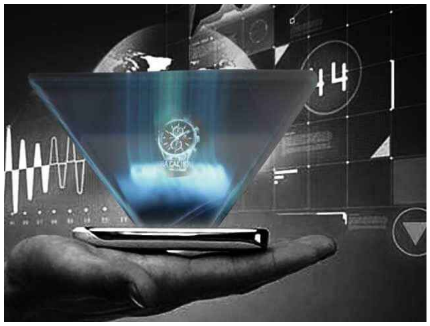
As the use case of Augmented Reality transitioned from critical application (mostly used by army) to applications available for the general mass of user, helmet mounted displays shifted toward a lighter form-factor, integrated directly in smart glasses.

Handheld AR

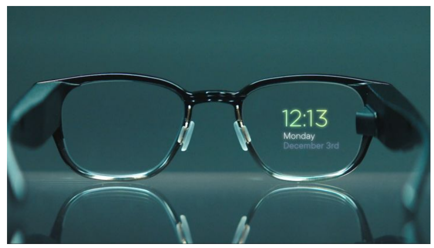
The majority of mobile devices enter in this category, as both major mobile software providers, Apple and Android offer augmented reality support (ARKit and ARCore). The advantage of this approach is that it makes augmented reality accessible to anyone with a decent smartphone, the drawback being the fact the user experience is not always satisfying as you need to to always hold and pin-point the device towards the zone you want to interact with.

(a) Head Up Display

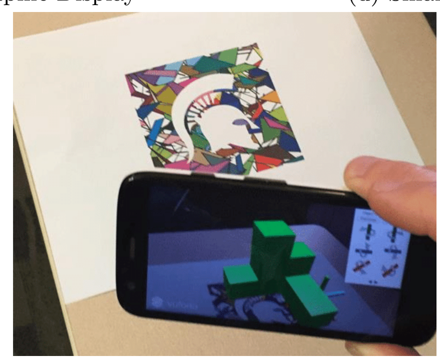
(b) Helmet Mounted Display



(c) Holographic Display



(d) Smart glasses



(e) Handheld

Figure 1.2: Types of AR enabled devices

1.4 ARKit

Primarily it does three essential things behind the scenes: tracking, scene understanding, and rendering, thus taking the heavy lift from the developer (as you only need to anchor virtual objects to the real world, and they stay glued to the physical position they were placed).

ArKit uses a technique called visual-inertial odometry (VIO). In more details, the position of the phone is tracked via the Visual system (camera), by matching a point in the real world (called feature point) to a pixel on the camera sensor for each frame. In parallel the pose is also tracked by the Inertial system (also called IMU) formed of an accelerometer and gyroscope. These two outputs are combined via a Kalman filter to determine which of the two system provides the best estimate of the real position.

The Visual system is refreshed every time a new frame is captured by the camera (30 times per second), while the inertial system outputs 1000 readings per second. Both the systems alone would accumulate errors in certain condition, but the fact that there are no interdependencies between them leads to an overall much better performance. For example,

Figure 1.3: ARKit feature points

the visual systems outputs weak results if the image is shaken, if the light is weak or the targeted object has a smooth surface (without particularities, like glass, or a perfectly white wall), during this time the Inertial part carries the load, and vice-versa in the case that the device is still (so there is no inertial data), the camera has the possibility to capture more accurate data, thus receiving priority as being closer to the truth from the Kalman filter.

Plane detection

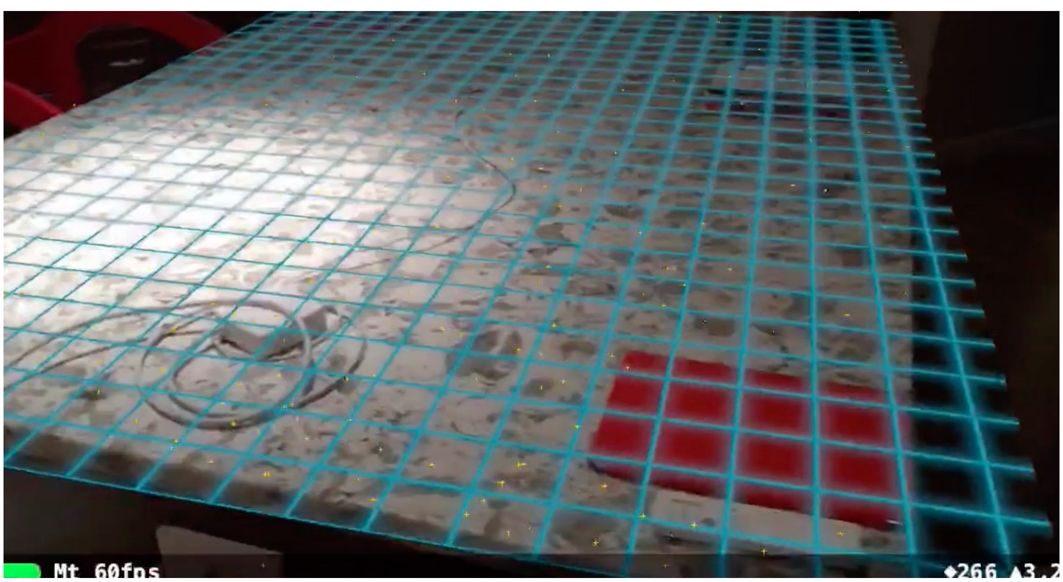


Figure 1.4: ARKit plane detection, spawning blue squares

In order to create an AR experience that can blend with reality, the ability to place an object on the ground represents one of the critical requirements.

This can be achieved using the feature points detected by the Visual system, each three points are considered to define a plane, and after doing multiple such calculations, the plane that represents the ground can be estimated.

Chapter 2

Improvements in learning by using Augmented Reality

2.1 Introduction

According to Shapley et al. (2011), lessons that are supported by technology will lead to more innovative forms of teaching and learning. This is because the use of technology involves real-world problems, current informational resources, simulations of concepts, and communication with professionals in the filed. In addition, learning using technology is believed to complement the traditional forms of teaching and learning (Yasak et al., 2010)

In recent years, as augmented reality emerged as a new technology, its potential for applications in education was discovered and the interest grew constantly. In research conducted by Teoh and Neo (2007), the respondents reported that it was boring to just hear the lecturer talking in front of them. The students believed that the integration of technology would help them in their learning process.

2.2 Impact of using Augmented Reality in learning

One of the aspects that discourage future students in following a science path is the thought that grasping abstract aspects it is going to impose them real problems. The majority of difficulties that appear are related with understanding multi-dimensional data.

Augmented reality is a great way of visualising three-dimensional objects, as it replaces classical wood or cartoon physical shapes that are used by teachers with virtual, augmented objects. Also, there are situations that not only require a three dimensional way of showing objects, but to also provide a way to observe dynamical interactions with the studied item.

The use of AR would also increase the time that students can spend studying different objects that otherwise would only be accessible inside the school hours, thus providing an unrestrained amount of study time.

Author/s	Field	Purpose of AR Use	AR Features Used
Chang et al. 2011)	Medical education (surgical training)	To provide training and to plan and guide surgical procedures	AR image-guided therapy
Yeom (2011)	Medical education (anatomy)	To teach and test anatomy knowledge (of the abdomen in particular)	nteractive 3D anatomy pictures and haptic feedback
Hedegaard et al.(2007)	Medical education using the electrocardiogram (ECG/EKG) AR system (called the EKGAR system)	To extend medical students' spatial awareness in relation to specific myocardial diseases by enabling users to navigate through and slice open 3D representations of a patient's heart	Vision-based 3D tracking technologies and interactive features
Singal et al. (2012)	Chemistry education	To provide an efficient way to represent and interact with molecules, leading to a better understanding of the spatial relation between molecules	AR technology for exhibiting the models
Cerqueira and Kirner (2012)	Mathematics	To teach geometry through the use of 3D geometrical concepts	Head-mounted display and personal interaction panel
Mathison and Gabriel (2012)	Biology (School in the Park project)	To teach participants that habitats are connected like links in a chain (food chain)	AR experience
Coffin et al. (2008)	Physics	To overlay graphics on top of the physical props to visualize these forces (speed, velocity, acceleration, pressure, friction, energy changes) invisible to the human eye	Augmented video, videoconferencing, tracked physical props (e.g. toy cars)
Fleck Simon (2013)	Astronomy	To show augmented views of the celestial bodies and support learning using spatial visual guides and views from a terrestrial observer	AR learning environment
Martin et al. (2011)	History	To gather information and enhance the experience of visitors to cultural organisations (museums and games archaeological sites)	Mobile AR educational

Table 2.1: Meta-analysis of research on the use of AR in different fields of education. Cited from [1]

2.3 Pitfalls and limitations

It is known that designing an application that actually improves the process of learning (no matter the form and the device it is running on) in a certain field is a task that requires serious research as usually these kinds of solutions are not that intuitive to use, for both teachers and students.

From other technologies, AR's advantage is the fact that it offers a hands on approach by integrating it's interactions capabilities directly with the reality (in forms of holograms), thus theoretically closing the gap between real life teacher driven learning and text-book based classical learning. This advantage comes with a price, as latter forms of e-learning have been present and researched for years now, they have come to a more mature stage, some of them ready to enter in student's life, but as AR approaches have the power to redefine everything, they have to catch up in making sure that these kinds of solutions are straightforward, thus simplifying the process of learning, not making it more complex.

From a technological point of view, only with the progress of software and hardware from the past few years AR has became feasible enough so that it can reach a large audience of people. At the moment, mobile devices (Hand-Held AR) are the only one that can bring AR to the masses, with only the majority of high-end phones and tablets launched in the past year and the half, having AR capabilities. The other types of AR (like smart glasses) would offer a more immersive approach, but the cost of these devices (HoloLens by Microsoft) makes them available only for companies and research purposes.

Chapter 3

Application in Musical domain

HoloPiano represents an application that we have developed for people that are eager to learn how to play piano. It uses Augmented Reality to show holograms over the keys that need to be pressed.

Figure 3.1: HoloPiano Concept Demo

In this case, augmented reality offers an unique approach for learning, allowing also people who do not have an extensive musical background to learn directly by doing, by approaching and mastering different plays in order of their difficulty, grasping dexterity, and theoretical background simultaneously.

3.1 Architecture

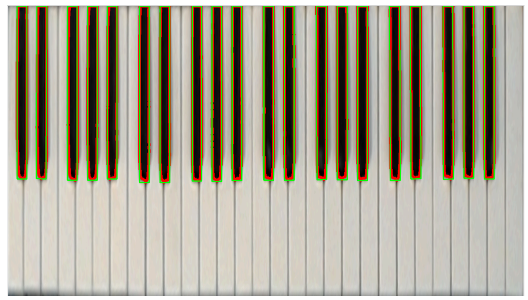
The flow of the app is the following, after startup, for more easy computing the device is going the ask the user to pinpoint the corners of the piano (look at each corner and make a pinch gesture), when the piano is incapsulated correctly, along with this data HoloLens is going to take a camera snapshot and send everything to a server where the position of each keys are going to be inferred, sent backed and mapped by the HoloLens. From this point the user can select a song base on its difficulty and start the process of playing (where holograms are going to be spawned up on the keys that are needed to be pressed).

An initial approach consisted in creating a Convolutional Neural Network that would infer the position of the piano and all its keys (without prompting to the user for specifying the pianos corners), but as the first generation of HoloLens doesn't have support for running inference locally.

As a backup solution we had chosen to prompt for those corners, so that after using image processing we just need to infer the position of all keys (as the application is designed to support multiple piano configurations).

Detecting the piano keys

(a) Original Image

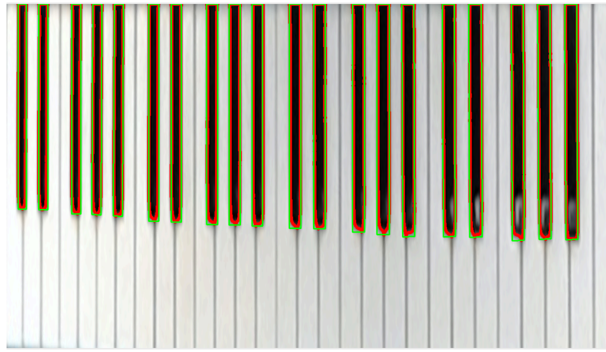


(b) Homographic Correction

(c) Final result

Figure 3.2: Steps for detecting the piano keys

(a) Original Image



(b) Homographic Correction

(c) Final result

Figure 3.3: Steps for detecting the piano keys

After receiving 4 coordinates and a picture, using Homographic Correction, the image is rotated such that all piano keys have a vertical angle. Then, using a watershed algorithm the contours of all the keys are generated and what is left is to filter the out-layers and to give each contour the musical note that it represents.

3.2 Conclusion

Unfortunately, after we have put together all the parts, we realised that the device we were using (HoloLens) is not powerful enough to maintain the holograms exactly on the position we are spawning them on, thus the holograms were drifting randomly over other piano keys, rendering the experience unusable.

The key component of our approach was the experience given by smart glasses, as other type of AR, like the one given by Handheld devices still represents an unfeasible approach, as we do not want to place a phone or a tablet between the user and the piano.

We believe that in the near future, as the hardware and software are continuously improving (at the moment of writing Microsoft announced a new version of HoloLens that is going to come with built in AI capabilities and improve precision), this approach is going to be realisable.

3.3 Alternative approach

A more analog, but working path that we took is to replace HoloLens glasses with a strip of very small, individually controllable leds that are going to be sticked above the piano keys, one or two leds (depending on their size) are going to directly map one piano key.

A few seconds before the user would need to press a piano key, the specific leds are going to be lit up, increasing in intensity until the moment they actually need to be pressed, then they will continue to blink prior to other keys needing to be pressed.

If by placing a camera above the piano, using image processing we could detect if the required piano keys were actually pushed correctly and offer specialised lightning feedback and dynamic context advance of the song progress.

For this approach, the strip of leds was connected to an Arduino board which exposes an API through that all the leds can individually be controlled. A Raspberry PI was used also used to orchestrate all the components.

Chapter 4

Application in Computer science

4.1 Introduction

4.2 Application

4.3 Conclusion

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