Bringing Live Animal Closer

The visual grammar of information design in Augmented Reality

Thesis presented by Chenrui Ye
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Abstract

Augmented Reality (AR)—displaying virtual elements in the real world—is a hot topic in the last few decades. As the technology is limited, many of the AR conceptual designs served for mobile applications because of easy access to the camera and the portable feature of cell phones. However, the AR goal to expand the upper limit of the reality is restricted by the screen size. This thesis explores the possibilities of the visual languages in Augmented Reality using the zoo as a case study. AR real-time explanation works well within the zoo context for enhancing the visiting experience. This thesis proposed a system of visual languages and interaction workflow in AR design on mobile devices.
Introduction

Human dreams of implementing technology seamlessly to construct a convenient world dated thousands of years ago, from the first rock an anthropoid used to sharpen a wood stick for hunting. Countless Si-fi movies indicate the trend of technological life blueprint in the future, like Iron Man Series from Marvel Studio, where Tony Stark works on the projected objects in the air together with the virtual assistant Jarvis (Figure 1) (Favreau 2008).

This can be seen as a signal of media painting out a better life through the fictions to meet audiences’ appetite on how to ample the real world. Augmented Reality (AR) “refers to all cases in which the display of an otherwise real environment is augmented by means of virtual (computer graphic) objects”(Milgram and Kishino 1994). Nowadays, many applications use 3D models to expand the fun engagement adding on the real world in many fields, such as education, tourism, industry, medical service, etc. These applications build with image recognition technology, even based on the geolocation, like Pokemon Go Game (Pokémon GO (version 1.117.1) 2019). It is a game encourage users to walk outdoors to catch the Pokemons by throwing balls to them in a real world through camera (Figure 2).

As information design aims to inform people in communication design practice (Meirelles 2013), it works potentially well with Augmented Reality technology as a tool in the real-time explanation, when adding the digital messages on the real object or space. The goal of information design is revealing the behind meaning and providing instruction by highly organizing the raw data. Information Design took a step forward when it is no longer limited by printing tech on space and dimension. Design started to move to the digital devices which provides the overview and zoom in function for the information as a whole and full of details. Human seek the larger space when the vertical and horizontal dimensions of computers are not enough for holding the information. Besides fully take advantages of adding virtual objects on the real world just like described in the fictions since long time ago, the infinite space of presenting more information conveniently perceivable is another attraction of Augmented Reality technology.
Figure 1. Tony Stark works on the projected objects in the air together with the virtual assistant Jarvis.

Figure 2. A game screenshot from pokemongolive.com.
A huge opportunity is to build a consistent visual language system to serve the development of the AR application in portable devices because of the limitation of the hardware and the affordance of the users. The applications in market start in exploration stage. The popularity of the game Pokemon Go (Pokémon GO (version 1.117.1) 2019) reveals the eagerness of high-tech applying in daily life for normal people but also shows the limitation of the AR/VR existing in games primarily. As mentioned before, the advantage of AR is the unlimited space for potential information presentation. Moving everything on the portable devices like goggles and a mobile is not fully take that advantage. How to design a functional visual system for AR without letting it become an extra limitation is the mission of this thesis. In other word, building this visual system to discuss the possibilities of the AR design, and encouraging more designers to work on the context supplement with the progress of hardware improvement.

The responsibility of an information designer is not only enhancing the experience by organizing data well, but also explore the possible directions for design serving much serious problems like saving the planet. To apply the information in protecting animals and environment is a good direction to apply design thinking in the practical issues. It is not the measures out of reach. Instead, it is how we contribute to the nature and society as the role of a designer. The zoo has developed several tools or facilities in a good intention with bad implementation. Combined with the information design, these establishments can fulfill its mission properly.

Zoo is an appropriate context to implement the experiments since there are multiple objects and status to explore. The animals are positively moving, hiding, and playing, which provides the possibility of applying design in terms of distance, the relationship between individuals, and the object moving speed (including static states). In addition, zoo has huge amount of audiences to interview and gather feedback from, in a friendly and relaxed conversational situation.

My design about the AR visual languages and interaction workflows is based on the existing technology (like facial recognition) and expand in some conceptual technology (like eye tracking in the virtual world) in the future. The facial recognition works well with human now, but it can also benefit the animal visiting experience if it is advanced enough to distinguish the individual animals.
in the same species. The recognition of animals allows more
opportunities in presenting individual information, thus, enhance the
understanding and build the bridge between the human individuals
and animal individuals, which are the essential steps for empathy
construction.

The primary mission of this thesis is to explore the design
languages on AR based on the research and evaluation. It requires
observation, interview, usability test. In the following statement, the
design limitation and constraints will be discussed according to the
technology it applied.
State of the Art

2.1 Augmented Reality Display

Paul Milgram, Fumio Kishino defined Augmented Reality in 1994 as:

"The display of an otherwise real environment is augmented by means of virtual (computer graphic) objects."

The virtual object is a reflection of the reality, like the 3D models and the images. They proposed a reality-virtuality continuum (Figure 3). In that model, Augmented Reality (AR) is observing the real world through a filter- the camera on the mobile phones. As the name indicated, the real environment gets more information through such filter. Meanwhile, as this term stays right next to the "real environment", the AR focuses more on the reality instead of the virtuality.

Figure 3. Reality-virtuality continuum from Paul Milgram and Fumio Kishino
However, new technologies have arisen spreadly in recent decades. For instance, the appearance of holography makes the virtual element indistinguishable from the real objects (Figure 4).

https://mashable.com/2016/12/10/magic-leap-rony-abovitz-responds/
Based on Milgram and Kishino’s work, instead of categorizing Augmented Reality (AR) and Augmented Virtuality (AV) into Mixed Reality (MR), Carlos Flavián proposed a clear boundary between these two Pure Mixed Realities (PMR). As he explained, the AR and PMR both work primarily in the real world and the user interact with both virtual and real object. However, the virtual elements in PMR is indistinguishable as they are not superimposed on real world (Figure 5) (Flavián, Ibáñez-Sánchez, and Orús 2019).

The virtual elements are normally 2D or 3D objects, like tags or cartoon characters. Sometimes, AR also works with other media like sound or video. In order to make the virtual items merged well into the real environment, many sensors and technologies need to be involved, such as “Multimedia, 3D-Modelling, Real-time Tracking and Registration, Intelligent Interaction, sensing and more” (Chen et al. 2019). AR also requires technology like simultaneous location and mapping (SLAM) system, visual inertial odometry (VIO), inertial measurement unit (IMU), and so forth (Pangilinan, Lukas, and Mohan 2019).

The technologies and hardware make today’s AR experience come true. However, in this thesis, the experiment and discussion are not focusing on the technologies which support AR. It is primarily about design possibilities which adopting future or near-future tech methods.
2.2 Augmented Reality in Exhibitions

The experience from Flowers Bloom in an Infinite Universe inside a Teacup from teamLab is projecting flowers inside a teacup and the flowers blooming (Figure 6) and withering (Figure 7) while the visitors finishing their tea. This exhibition builds on the image recognition technology and light projecting. It is good to think about the whole design strategy: it starts from the idea, but it adopts previous study and experience to design the speed and the natural style of withering flowers and relate that with the human emotions. In this case, the design is taking the visitors experience into account after exploring the feasibility of technology and science. The flowers petals spread naturally while the audience drinking their tea, and then, as the title indicated, bloom again (“Flowers Bloom in an Infinite Universe inside a Teacup | TeamLab / チームラボ” 2016).

Similarly, in the zoo case study, the experience flows should be set up from user experience perspective in addition to the grammar of the visual languages in AR. For instance, the buttons and interaction could work for multiple distances when the user moves the camera to track the animals around. Moreover, in order to create positive communication leading by the animal, setting the distance limitation of the button function may work for empathy perspective by revealing the character of the animals. It shows that how and how much this animal wants to communicate. Unlike the current experience, this limitation of the buttons puts the animal into a positive position in the interaction.
Figure 6. Flowers blooming.
https://www.teamlab.art/w/flowersbloom

Figure 7. Flowers withering.
https://www.teamlab.art/w/flowersbloom
NBA 2K is a series of basketball simulation video games where the user could control the players to win (NBA2K 2019). Figure 8 shows the selecting effect of the current controlled player 11 in the blue circle on the ground (In these images, the white team is controlled). The potential switchable player is marked by the white circle (player 31) calculated by the position and the direction of the player 11. In Figure 9, holding the tutorial button shows the access to the specific player, who are marked by button icons above their head.

Similarly, the zoo is also a place where animals live together. The visitors want to interact with the specific individual animal so that the target selecting and switching need to be clear. In NBA 2K19, the potential players are all labeled by the same element- a basketball- with icons. These players can be directly accessed by pressing the corresponding buttons. Therefore, for the design of object selecting and switching function, same elements should be used. Besides, how to call out the buttons is another interesting aspect to explore.
Figure 8. Player dribbling.
https://www.youtube.com/watch?v=WkBCnd0tULo

Figure 9. Switch player.
https://www.youtube.com/watch?v=WkBCnd0tULo
2.4 Augmented Reality on Mobile Devices

The most accessible method to experience AR is using the mobile phones. Every smart phone has camera and Gyro-sensor which detect the graphic and position in the space. Besides, 80% America families have smart phones according to Consumer Technology Association. All these premises enable AR technology to enter daily life.

Even AR as a technology that could be adopted in many scenarios, this thesis is focusing on visual languages on mobile phones because it is the most accessible device that general people could get. Furthermore, it worth talking and comparing because so many people are working on mobile application development to catch up the AR era. Therefore, some limitation on small screen design need to be discussed.

As Augmented Reality Technology expand from game industry to normal life, companies release the applications in many other categories including education, virtual effects, exercise, tools or utilities, business, and food and drinks (The examples show in the Table 1).

In all these different categories, the applications share some pattern in visual design and the interaction workflow. All of them ask for camera access, and many of them have the steps of plane detection, objects choosing, placement, animation and interaction.

In terms of the visual element, these Apps use the translucent and floating buttons to fit the virtuality into the real world. Most of them are solid white and locate on the edge of the screens in order to distinguish from the colorful world. In the example of Trace, the measurement function allows the users to change the lightness from white to dark to fit in the sophisticated context. The grid is clear and visible by changing the scale according to the real context, but it increases the steps of the user interaction on clicking the button and drag the slider. None of the app have the function of zoom in/out- one reason behind is the range of the camera only allows magnifying. All of them work on the plane, which tightly bonded with the reality, the physical 3D world. By placing the object in the fixed spot in the space, it merged realistically. In addition to
the visibility problem, the combination with the reality is the magic of this technology. It is not actually an Augmented Reality immersive experience if the information layer is completely floating on top of the object. Besides, as the lens of the extra information layer, the mobile devices have the mission of holding enough information. However, with the confliction of the small screen, moving around the camera to capture information in the large scene is the key scenario.

<table>
<thead>
<tr>
<th>Category</th>
<th>AR Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Game</td>
<td>Leo AR Camera</td>
</tr>
<tr>
<td></td>
<td>AR Sports Basketball</td>
</tr>
<tr>
<td></td>
<td>Stack AR</td>
</tr>
<tr>
<td></td>
<td>Alice in Wonderland AR quest</td>
</tr>
<tr>
<td></td>
<td>AR Dragon</td>
</tr>
<tr>
<td>Education</td>
<td>Bookful</td>
</tr>
<tr>
<td></td>
<td>Dinosaurs Everywhere</td>
</tr>
<tr>
<td></td>
<td>Star Walk 2</td>
</tr>
<tr>
<td></td>
<td>Wonderscope</td>
</tr>
<tr>
<td></td>
<td>MauAR</td>
</tr>
<tr>
<td></td>
<td>Complete Anatomy</td>
</tr>
<tr>
<td></td>
<td>WWF Free Rivers</td>
</tr>
<tr>
<td></td>
<td>Froggipedia</td>
</tr>
<tr>
<td>Virtual Effects</td>
<td>INK HUNTER</td>
</tr>
<tr>
<td></td>
<td>Ikea Place</td>
</tr>
<tr>
<td></td>
<td>Lego AR Studio</td>
</tr>
<tr>
<td></td>
<td>CSR Racing 2</td>
</tr>
<tr>
<td>Exercise</td>
<td>AR Runner</td>
</tr>
<tr>
<td>Tools/Utilities</td>
<td>Measure</td>
</tr>
<tr>
<td>Business</td>
<td>Augment - 3D Augmented Reality</td>
</tr>
<tr>
<td>Food &amp; Drinks</td>
<td>Living Wine Labels</td>
</tr>
</tbody>
</table>

Table 1. The AR applications in categories.
2.4.1 IKEA Place

IKEA Place (version 4.0.0) 2019 use carved icons with white filled which stands out the environment well even on the white wall paintings which are influenced by the environment shadow (Figure 10). Firstly, IKEA Place provides the friendly conversational instruction to onboard the first time users to get used to playing with AR.

Secondly, as suggested, the user will click the plus button to browse the catalogue and pick the furniture to place. The catalogue window slides in from the bottom and it is independent when the user is swapping to look through and choose in the scrollable and level-supported function as pulling data from the back-end database.
Next, before placing the furniture, this App asks for moving around the mobile to detect a plane, which happens in almost all of the AR Apps. The detected object or plane marked by the working dots in yellow followed with the gesture icon (Figure 11). After successfully detected, the plane marked by the gray dots net (Figure 12).

![Figure 11-12. IKEA Place screenshots on detecting surface.](image)

Finally, the furniture could be moved around and placed in the room. Before placement, the furniture is floating in the space and the location is marking by the shadow on the floor. Using two fingers press on the screen could rotate the object. The confirm button is highlighted in another theme color for IKEA-blue which is encouraging the users to tap (Figure 13).
In addition to the visual element Ikea Place is using, the interaction workflow (Figure 14) followed some rules. AR application takes advantages in room placement, which is delivered well from IKEA, the world-wide successful home furnishing company. It serves for the need of after effects and measurement of the furnitures and the space by placing the 3D model in the users' room through a few steps, which are similar to the explanation of “Wayfinding” in Universal Principles of Design (Lidwell, Holden, and Butler 2010).

The Wayfinding Principle explains the four stages: Orientation, Route Decision, Route Monitoring, and Destination Recognition which are correspond to the IKEA Place: Scan, Browser (Orientation), Pick (Route Decision), Move (Route Monitoring), Place(Destination Recognition). Finding the furniture, the user wants through looking through the catalogue is like the determination of the destination after comparing with the other locations or furniture. Next, picking among the possible choices of different colors and details is like decide between routes. Then, move the furniture around to see how it looks in the environment while evaluating that
with the space, the color and the style of the room. It is similar to route monitoring, which is using the reference substance to make sure the user is still on the right way. Finally, placing the furniture to see the whole picture is like reaching the destination.

These principles need to be implemented in the zoos’ AR information layer design, from choosing between the individuals to picking which one to interact with.
2.4.2 AR Dragon

AR Dragon (AR Dragon (version 1.9) 2019) is a virtual pet simulation game in which the user has a dragon as a pet. The plane detection is unique among the AR Apps - they show the progress bar of scanning and tell the user where the best location is to place your pet dragon (Figure 15). This causes the delay and disabled button when the user is sitting comfortably with no good flat planes.
After the dragon being summoned (placed) on that plane, users can start playing with it. Unlike many of the other AR Apps, the buttons are colorful and have circular progress bar around (Figure 16). The dragon is always facing the users however they turn the screens around but is rotatable if replace on the spot.

![Figure 16. AR Dragon Normal Screenshot](image-url)
AR Dragon grows even when the user not open the App. As there is no preview, the placement sometimes makes the dragon break because the user has no idea how big the dragon at this moment is and can only see piece of the dragon (Figure 17).

Figure 17. AR Dragon Overflows
AR dragon has a lot to do since it is a game. The animated movement and the interaction attract the users to play for a relative long time. The majority of the operation happen in the last a few section in the interaction workflow in Figure 18.

Instead of "Object Choosing", the users get a dragon egg randomly. But they will hatch the dragon immediately and get the unique dragon of their own. Users play a lot in the sixth stage, they feed the dragon by throwing food and play the ball-catch games to make sure the dragon is in good mood.

From the review in App Store, the users get excited about bringing dragon into the real world. But they got frustrated when there is no plane around them. One of the users asked for a virtual home for the dragon where the dragon could be located on a virtual plane.

When talking about the reality part in AR concept, how to enhance the real world without distracting too much is the conflict challenge here. This AR dragon just needs a plane in the real world, there is no other interaction with the objects in the environment. That’s the reason the user wants a virtual room since there is no harm to migrate all things virtually. Two things the AR design need to explore: one is the distraction caused by the virtual elements, the other is relating virtual elements closely with the real context.

![Figure 18. AR Dragon Interaction Workflow](image_url)
2.4.3 The interaction workflow of the AR mobile Apps

Through the research of the mobile apps in multiple categories from Table 1, an interaction workflow pattern is found. All of them ask camera access to activate AR filter. Many of them have the stages of place detection, object choice, and object placement but appear in different order, see the Table 2.

<table>
<thead>
<tr>
<th>Stages</th>
<th>Camera Activation</th>
<th>Plane Detection</th>
<th>Objects Choice</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>User Actions: Tap, Scroll</td>
</tr>
<tr>
<td>User Actions</td>
<td>Tap</td>
<td>Move around</td>
<td></td>
</tr>
<tr>
<td>AR Runner</td>
<td>Allow camera access.</td>
<td>2. Move mobile around to detect the plane while the user could see the grid and dots during detecting.</td>
<td>1. Select the field size; Select the game mode; Select the field shape</td>
</tr>
<tr>
<td>AR Dragon</td>
<td>1. After camera activation, there are some instructions and pre-games like hatching the dragon, getting introduction, naming.</td>
<td>3. The Place detection is the first step of summoning the dragon.</td>
<td>2. Firstly, the user gets an egg and randomly hatch a dragon.</td>
</tr>
<tr>
<td>CSR Racing 2</td>
<td>Allow camera access.</td>
<td>2. Move mobile around to detect the plane while the user could see the grid and dots during detecting.</td>
<td>1. Pick the mode and the size about the car.</td>
</tr>
<tr>
<td>Lego AR Studio</td>
<td>Allow camera access.</td>
<td>Move mobile around to detect the plane while the user could see the grid and dots during detecting.</td>
<td>Scroll to browser the side menu to pick an LEGO figure to locate on the detected plane.</td>
</tr>
<tr>
<td>Objects Placement</td>
<td>Objects Animation</td>
<td>Objects Interaction</td>
<td></td>
</tr>
<tr>
<td>-------------------</td>
<td>-------------------</td>
<td>---------------------</td>
<td></td>
</tr>
<tr>
<td>Drag, tap, Spread, Move</td>
<td>Move</td>
<td>Tap, Press, Drag, Move</td>
<td></td>
</tr>
<tr>
<td><strong>3</strong></td>
<td>Tap to place the field, which is a circle shape with arrows showing the starting direction</td>
<td><strong>5</strong></td>
<td>Step into the start point and the time count. The user need to reach the next point to active the following destination.</td>
</tr>
<tr>
<td><strong>4</strong></td>
<td>Place the dragon on the plane.</td>
<td><strong>5</strong></td>
<td>The dragon starts moving.</td>
</tr>
<tr>
<td><strong>3</strong></td>
<td>Place the car</td>
<td><strong>4</strong></td>
<td>The car will open the doors to invite exploration.</td>
</tr>
<tr>
<td></td>
<td>Provide the floating translucent instruction on how to rotate and place.</td>
<td></td>
<td>The dragon or the figures move around.</td>
</tr>
<tr>
<td>Stages</td>
<td>Camera Activation</td>
<td>Plane Detection</td>
<td>Objects Choice</td>
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<td>-----------------------------------------------------</td>
</tr>
<tr>
<td>User Actions</td>
<td>Tap</td>
<td>Move around</td>
<td>User Actions: Tap, Scroll</td>
</tr>
<tr>
<td>Ikea Placement</td>
<td>Allow camera access.</td>
<td>Move mobile around to detect the plane while the user could see the grid and dots during detecting.</td>
<td>Browser the furniture and pick the desired one</td>
</tr>
<tr>
<td>AR Basketball</td>
<td>Allow camera access.</td>
<td>② Move mobile around to detect the plane while the user could see the grid and dots during detecting.</td>
<td>① Choose game mode and the size of the basket.</td>
</tr>
<tr>
<td>Star Walk 2</td>
<td>Default by the virtual sky with stars. After active the camera, AR mode could be access.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measurement</td>
<td>Allow camera access.</td>
<td>Move mobile around to detect the plane while the user could see the grid and dots during detecting.</td>
<td>Locate the dots on the objects and stretch the virtual ruler to see the real-time length.</td>
</tr>
<tr>
<td>Trace</td>
<td>Allow camera access.</td>
<td>Move mobile around to detect the plane while the user could see the grid and dots during detecting.</td>
<td></td>
</tr>
<tr>
<td>Objects Placement</td>
<td>Objects Animation</td>
<td>Objects Interaction</td>
<td></td>
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<td>-------------------</td>
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<td></td>
</tr>
<tr>
<td><strong>Drag, tap, Spread, Move</strong></td>
<td><strong>Move</strong></td>
<td><strong>Tap, Press, Drag, Move</strong></td>
<td></td>
</tr>
<tr>
<td>Place the furniture after moving and scaling. User could see the shadow on the ground indicating the supposed position while moving around. The highlight arc shows the front of the furniture.</td>
<td></td>
<td>Relocate and change direction.</td>
<td></td>
</tr>
<tr>
<td>③ The basket stands automatically locate after the plane found. User could drag to rotate.</td>
<td>④ The net is waving while rotating.</td>
<td>⑤ Drag the ball to throw or use the knob to control. User get points or missed alert popping up while playing. The stand also changes it height to increase playability.</td>
<td></td>
</tr>
<tr>
<td>See the real time length while moving the camera to locate the end point of the length measurement.</td>
<td>Stars twinkle and locate in the 3D objects which helps the user to recognize the constellations.</td>
<td>Using the slider to control the lightness and the AR Effects.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>The exist measure points could be detected when move close to them. The square could also be automatically detected and suggested by the measure.</td>
<td>Active the grid to measure the distance. A switch to control the lightness from white to black which could work well on both light and dark place.</td>
<td></td>
</tr>
</tbody>
</table>
2.4.4 The visual languages of the AR mobile Apps

The AR Mobile Apps use the translucent and floating buttons to fit the virtuality into the real world. Most of them are solid white and locate on the edge of the screens in order to distinguish from the colorful world (Figure 19).

The AR Mobile Apps also use similar visual effect on the tutorial and instructions like floating windows or pop up cards (Figure 20). As unintuitive actions exist all over this type of Apps, the tutorial is necessary but needs to be subtle.
2.5 The Presentations in Zoos

Zoos are popular places to visit for weekends and holidays, as well as one of the most effective educational organization among many animal conservation institutions, which attracts tons of visitors each year. The basic definition of a zoo from Worldwide Zoo Database (WZD) is based on a list of criteria and rules. It describes zoos as “expert scientific or educational facilities of long-term character, which breed species of wild animals or domesticated animals by exposure way for reasons of education or for preservation and conservation of animal species” (“WZD - Worldwide ZOO Database” n.d.). Zoos are social, natural, and historical intersection (Nekolný and Fialová 2018). Many facilities and methods are adopted to attract more people, which combines social and natural features in theme parks (Nekolný and Fialová 2018). For example, there is a Skyfari Sky Ride and a Soaring Eagle Zipline Ride in Southwicks’ zoo which are typical theme park attractions that attract a high volume of visitors. These rides combine the fun of the birds’ eye view flying with the animal viewing, which demonstrate one of the primary strategies zoos take when planning with technology or freshness in recent decades.

In order to provide comprehensive information for better understanding animals, zoo planners take strategies to engage visitors, for example, common signage and interpretation. Perdue, Stoinski, and Maple wrote a research paper on consequences of educating effects with only signage, with interpretation video, and with staff presentation. It shows the result that people remember more information and show more interest when there are videos or in-person presentations appearing. In other words, the assistance of technology stimulates visitors’ experience when there is no guarantee of zookeepers’ presence at any time. Visitors spent more time in the exhibit and gave more accurate answers to conservation interview questions when there were videos and presentations. The in-person presentation was better with encouraging participants than the video, while video acted better than the signboard (Perdue, Stoinski, and Maple 2012). Similarly, the AR technology could achieve such effects by providing engagement potentials. However, Perdue, Stoinski, and Maple also mentioned the inconformity of people’s responses and observation outcomes, which questions the effects of technology on visitors’ subconscious perspective.
Swanagan researched in interactive methods in zoos and the conservation effects. The study states that “the return rate was higher for visitors who had higher levels of interaction with the elephant exhibit.” He suggested zoos adopt more digital methods like interactive computers and electronic graphics to keep information up to date, which “provide a means for the visitor to obtain experience with learning how to take citizenship action to resolve issues” (Swanagan 2000).

Nicholas Kelling and Angela S Kelling implemented AR signage into the zoo. Their research demonstrated the potential of AR technology to balance the animals’ natural instincts and human engagement with minimum cost. They used 3D printing figures to link the animal exhibit with the introduction video. However, their work didn’t provide the detailed function architecture or interface design, which left some space to explore for the following chapters in this thesis. However, the concern they mentioned is meaningful: how to ensure this system does not substitute visitor-animal direct interaction (Kelling and Kelling 2014). They left out the possible measures.

Such concern appears in other scholars’ research as well. A study about interactive technology from four themes have been conducted in Melbourne Zoo. They analyzed the impact of the usage of iPad, screens, and Apps, in which they claimed that the technology amplifies human-animal encounter by extending time and space, as well as parties that involved. However, such technologies did not “contribute to the sense of being physically immersed in the same environment as the animal”. It was caused by looking “back-and-forth between screen and animals” (Webber et al. 2017). Referring to immersion, Augmented Reality is preferable in this case when visitors can look at the animals and the interpretations at the same time and in the same space through the AR camera. Moreover, the detached unnatural feeling of technology implementation in zoos can be eased when the visitors use AR applications, which blurs the boundary of artificial and natural.

Additionally, other technologies are helping with improvement of visiting experience as well. For instance, the Giant Panda Cam (Figure 21) in Smithsonian’s National Zoo live streams around-the-clock (“Giant Panda Cam” 2015). The live stream camera eliminates the block of time and space for panda lovers checking panda activities whenever, wherever. It not only continues the memory and
affection which visitors gain from the zoo, but also attracts live-stream users to visit the zoo in-person to see the pandas. It is how zoos like Smithsonian achieve their goal, by merging conservation ideas into people’s daily lives. The test of solicitation cards from Swanagan’s study (Swanagan 2000) works similarly. It is a sign of preservation willingness from visitors if they filled out solicitation cards filled and sent them back.

Figure 21. The Giant Panda Cam Headquarter in Smithsonian’s National Zoo.

[Link to image: https://ceolynabors.com/2014/01/19/pandas-and-cats-at-the-zoo/]
2.6 The Animal-Human Emotional Bond

Humans and animals all have feelings, of which they share some, including empathy. According to an article from Global Environmental Change, “Empathy means taking the perspective of the other and feeling an emotional bond with that other” (Brown et al. 2019). Cecilia Heyes distinguishes empathy into two entries, “Empathy1, an automatic process that catches the feelings of others”, and “Empathy2, controlled processes that interpret those feelings” (Heyes 2018). When people feel empathetic for animals, they are capable of perceiving the feelings and translating those based on their perception. Heyes’s study claims empathy is a learnable ability through vocal channels, facial expression, or other stimuli. That indicates the universality of inter-species empathy, which is more capable to be spread among humans and animals.

Empathy is the emotional basis of conservation in empathy-sustainability hypothesis: “empathy – through processes of perspective taking and emotional connection – is a pre-requisite for sustainable interactions with the biosphere” (Brown et al. 2019). Animal conservation can benefit from such emotional bond between humans and animals through a series of interactive engagement strategies adopted by zoos.

From a study in Korean Zoos on visitors’ satisfaction measurement, the visitors most caring attribute is “display” dimension, which contains “children-friendly display”, “visitor safety”, and “ease of viewing”. While the least satisfactory attributes marked in animal welfare dimension, which includes “natural behaviors of animals”, “well-being of animals”, and “naturalized enclosure” (Lee 2015). Zoos have a mission of educating the public about preservation but may fail if they do not show enough thoughts about natural display.

Visitors come to zoos to get closer to nature, where they may learn about animals’ welfare. When people realize animals’ welfare is important in preservation, they might change their opinions from solely thinking zoos as entertainment places. Correspondingly, human presence influences animals’ behaviors. They may have negative, neutral, and positive impacts on animals, depending on the species’ traits, humans’ roles, and human-animal interactions (Sherwen and Hemsworth 2019). Furthermore, the influence is
mutual. When animals participate in the interaction, humans get encouraged and motivated to try more, which may lead to excessive animal tolerance and result in a bad experience. To avoid future bad experience, the design of AR experience in zoos should take all the aspects into consideration, from the previous chapters reviewing from AR definitions to human-animal emotional bond.

In summary, from the previous analysis, many AR Design failed to address the efficient solution of combining the virtual objects together with the real world like AR Dragon, which adopt a plane in the environment. For enhancement purpose, Information Design in AR needs to be merged well with the dimension and clear convey necessary information in depth.

AR haven’t been systematic explored in decades. Even though there are a lot concept design around the Internet, they address problem half way through incompletely. The static screenshot design has the limitation of solving the problems occur during the movement in the real environment from different angles.
Case Study of the Franklin Park Zoo

3.1 Why use zoo as case Study

3.1.1 The role of zoo in human society

All creatures are sharing the resources on earth since the Big Bang happened 137 billion years ago. Undoubtedly, human is playing the dominant role on this planet where animals squeeze themselves living toughly. The shrinking habitat and the pollutions are threatening the species significantly. People can only think about taking care of other animals once their own life needs have been fulfilled. This is the time when people find out it is urgent to save the earth and animals are important to keep balance of the nature. People come up with the measures to protect animals. They build the nature reserve, adopt biotechnology, and educate public. Zoo is one of the ways to educate people and preserve species. Meanwhile, it is the most common way for the public understand and observe animals comprehensively and scientifically.

In addition to those physical measures protecting nature, the designers, animal-protectors, and the zoologists work closely to create a series of media education pieces like the websites, the documentaries, the associations, etc. The appearance of technology contributes to high quality design. It is information designers’ mission to create visualizations revealing hidden stories behind data which call up curiosities and understanding – the basis of empathy. For instance, the documentary Blue Planet II from BBC (Honeyborne 2018) is popular and reputed with elegant scenes from audiences. The data visualization about extinct animals named A Disappearing Planet (Flagg n.d.) shows the extinct rate.

Zoo is changing positively all the time. It was personal possession of royal in the very beginning when animals locked in the small cage with no rights. However, it is for the public now and cares more about animal’s natural habits. It evolves from cages to wild
simulated habitat which visitors need to take the special bus to see the animals. Furthermore, zoo is adopting more strategies to attract audience. They are playing 3D movies and audio navigation, installing playground and interactive game devices. Many zoos have petting fields where visitors could feed and touch docile animals. All these strategies improve the level of visitor engagement, help building the bridge between human and animals by leaving great memories and experience with animals.
3.1.2 Why zoo is good for AR design exploration

Augmented Reality contains real environment and virtual elements. To build the whole system for Augmented Reality, the choice of environment needs to be carefully considered from the space to the practical scenario. The space should have wide range in dimensions to place the virtual elements, no matter plane or solid. The practical scenarios need to be abundant enough to cover aspects of audiences, the weather, etc.

Zoo is an appropriate context to implement the experiments. The animals are positively moving, hiding, and playing, which provides the possibility of applying design in terms of distance, the relationship between individuals, and the object moving speed (including static states). There is enough information to be consider when discussing AR design, like the animal qualities, characteristic, and life routine.

Last but not least, millions of people are visiting zoos around the world, which provides chances of testing the prototype based on the visual and flow language system in AR. The feedback from the visitors of all age ranges, the zoo keepers, and the specialists could be collected and used to better construct the AR system from designer perspective. Another principle of choosing topic is interest. Obviously, zoo is an enjoyable place which is worth putting design thinking in blueprint.
3.1.3 How AR Helps Zoos

Augmented Reality in the mobile devices provides a macro perspective, in which people move in a relatively small zoo area, holding their phones. Unlike the 3D involved AR games, the objects (animals) in this thesis are uncontrollable. They can be treated as part of the environment. With the limitation of movement scale in front of the animal exhibit and animal appearing location, visitors benefit from AR technology to explore under such constraints. Audiences see animals and interact with information in a closer view with the freedom provided by phone-camera angle and zoom functions.

Another advantage of Augmented Reality is the instantaneity. From the observation in the zoo, parents sometimes fail to answer children’s questions about an animal’s current behaviors. There is not always a zookeeper around to answer their questions, or the zookeeper may be taking care of other groups. In this case, the AR system allows visitors to explore freely as individuals or groups. AR technology analyzes the animal’s behaviors based on the algorithms and data collected from environment detective and camera reflection. The technology supports explanations of animal’s status, even animal’s feelings, which offers a more emotional visiting experience. The visitors reflect animals’ emotions to create the empathy connection between them.

Zoos are making efforts in raising personal connection for visitors in order to achieve goal of educating about public conservation (Kelling and Kelling 2014). AR helps in a way not only by advocating actions, but also by minimizing the artificial influence on the natural environment. A well-designed AR service can balance the distraction problem as well, by assisting direct animal-human interaction.
3.2 Augmented Reality Design possibilities

Zoos provide visiting experiences as a service to their audiences. Audiences experience visiting, dining, observing, talking, and interacting, which are all intangible. The visitors leave with the memories and feelings, probably with the byproducts like the photos, the journal, blog, and the shared stories as well. Based on Service Quality Theory from Kristian Gronroos, there are two dimensions of service quality, “a technical or outcome dimension” and “a functional or process-related dimension”(Gronroos 2000). In this case, the observed animals are the technical quality while how these animals are being displayed and observed is the process quality. In this study, the main focus is how they are being displayed and meant to be interacted with.

First of all, it is animal’s choice to interact with the human or not. It is obvious inappropriate to break animals’ habits and desires when the zoo advocates their mission as preservation and protection. Therefore, there is no control over the animal part. However, the development of modern animal exhibitions and the improvement of the technology provide methods to strengthen the communication and the interaction between animals and visitors. For instance, the Shedd Aquarium designs giant large glass to reveal the under-water scene of how beluga whales swim and dance in the water. Not to mention the signs and the videos telling animal stories or fun facts in the aquarium. Augmented reality as a technology also provides a new exploration perspective by enhancing the animal displaying process, i.e., the memory construction process mentioned above. More examples will be discussed in the following section.

A good experience in a zoo contains enough interaction between people and animals. The experience needs to be as fun as when animals are present as when they are absent or even under tough situations like bad weather or dark environment. Animals hide or stay still, and their nature of acting in the night and sleeping in the day is contradictory to humans’. This leads to the absence of the animals during the visiting time, even leading to the boring feeling of the visitors. However, Augmented Reality could show virtual information to compensate these disadvantages. When the animals are hiding, some symbol adding in the real environment can point their location out to indicate to visitors where to explore. When the
animals are sleeping, AR could add virtual video or animation to perform how animals move in the area when they are awake, even showing them multiple figures in different times in a day. Thus, visitors get much more information in their limited visiting time via those technologies. Their needs and expectations are met, and they even will be surprised by the experience. In this way, people get a new angle every time they visit the zoo.

**Indicators**

When animals are hiding, which happens often, it is kind of fun to point out the animals from the plants and rocks. Visitors always point out animals to each other during their visiting for their own interactions. But sometimes, the animals hide too well to find, like how they are doing in the wild, adopting advantages in their evolution with the camouflage colors, patterns, and technique. In this scenario, AR could provide an animal target filter to reveal the hidden ones in the phone view. When visitors are using this method, in order not to ruin the fun of spotting animals – because normally, people come to an exhibition, they look around to find the animals, and they look up again according to the photos on the information board if they failed the first time - these indicators do not show up in the beginning. First, the indicators are hidden for visitors to enjoy the fun, and then give hints step by step. First, the device outlines a similar shape and pattern area to the animal (Figure 22) together with the label. This outline is gently flash to draw attention (Figure 23). Second, after a while, if the visitor fails to point out the lions from the wood, then the system will point out the animal directly with the name tag (Figure 24).

Moreover, the animals have a high chance to not be in the phone perspective when visitors are using their phones to find the animals. Then the edge indicator could have users notice which direction to move to get better area for such experience of finding, guessing, and spotting (Figure 25).
Figure 22. Similar shape and pattern area to the animal.

Figure 23. Outline flashing keyframe.

Figure 24. Pointing out the animals.
**Virtual animal movements**

Sometimes the animal is easily seeable but may stay still or nap. At this time, Augmented Reality could add a virtual figure of that animal to strengthen the observing dimension by adding movement to it. It is indicated that visitors come with expectations of seeing animals active, in change. In order not to distract much attention which is supposed be put on the animals themselves, this added movement can be combined with the animals’ own. The virtual animal emerges from the real animal and gradually appears (Figure 26), then stands out to change position and expressions, like yawning. Moreover, this kind of virtual experience can be provided sporadically instead of displaying in a loop, and only appear when real animals are inside the phone view. These principles prevent visitors from focusing on the virtual part too much and ignoring the live animals.

However, in many of the scenarios, there may not be any animals in the exhibition. At this moment, a fake animal projection could meet the visitors' expectation of seeing something active to some extent. Therefore, they get an enhanced visiting experience from the zoo. There are no distraction issues at this time – the virtual animals are a completely positive solution.

**Animal Trace**

When the animals are not displayed in the exhibition, which happens often, zoos can also consider displaying the animals’ tracks in certain time span in addition to the fake projection mentioned above. This track could be dynamic and condensed in time so that the visitors can get a glance of what animals’ routines are in a short time. Animals may wander around, or do something repeatedly, like pacing. Refer to Figure 27. The route shows the lion wandered around the trees and got closer to the root in the middle. The trace is controlled by the button in the corner according to the time (Figure 28). User can also drag the progress bar to watch in their own pace.
Figure 25. The edge indicators.

Figure 26. Virtual animal projection emerges from the real lion.

Figure 27. Animal trace.
**Dark View**

In Augmented Reality design, environment light is a commonly ignored attribute. It is essential to make reflections on the objects and create shadows for real and immersive experiences that match the object’s environment. Obviously, the shadow and reflection need to change according to the light source in the environment. Besides, the virtual objects can take advantages of the contrast with the environment to create special events, like the mild nightlight and the distinct escape route symbols. For the lion exhibitions, the nightlight view can create a stage-like feeling of the animal stars, which recalls the happy childhood memory at circus (Figure 29).

In the zoo, the light is often natural like the reality of the wild, and even when it is artificial it mimics the sunlight. Thus, sometimes, visitors may encounter cloudy days or the dim light in pre–evening. In this situation, the animal trace mentioned above could be made to stand out by night-glowing effects, for distinguishing from the environment. Not only can it be more visible, but also create a mystery and exploring atmosphere (Figure 30).

Besides, some animal exhibition areas adopt special light for dark environments, like the bluish light in the Shedd Aquarium to create the ocean feeling. Another example, the aquarium also uses an extra yellow sliding glass pane outside the tank to show the dive man’s perspective. The sliding nature of the pane tries to limit the influence of the unnatural light on fishes inside the tank. Even so, it is inevitable that it influences the inside creatures. However, there is no such bad effects with the same experience on the phone – it only requires a yellow filter.

In addition, in dark environments, animals are hiding better. However, the thermal camera captures the animal trace well in the dark, just like how documentary Big Cats (Big Cats 2018) did to reveal the pumas in wild of how they are hunting. Conveniently, AR can provide the thermal filter in an easy way, as long as designers keep in mind the distraction problem mentioned before.
Figure 28. Dynamic animal trace according to time.

Figure 29. Nightlight pointing at lion.

Figure 30. Glowing trace in the dark.
Virtual human figure interaction

Another interesting experience would be visitors watching virtual figures of themselves interacting with the animals in the same space from third person view. There are many applications providing simulated 3D models of users which may work well together with zoo space, a human-animal interaction space. In this space, visitors can locate their own virtual figure wherever they like and virtually interact with animals, like chasing, feeding, rolling, and patting (Figure 31).

The human 3D model is not only limited to the cartoonish style. With the development of technology and Holographic Laser Projection, visitors will manipulate the virtual figure like moving in front of a mirror. Even though the projections may be invisible to the animals, posing and shooting close photos and videos with animals is still an attempt to bring the two creatures closer.

Figure 31. Virtual child projection with lion.
3.3 The design challenges in Augmented Reality

Considering the possibilities of design space through Augmented Reality, I tried some interface designs and prototypes which cover two main directions. One is labelling of animal identity and position, the other is display of the information. For the first part, I tried to use the method adopted often in games like character targets, and the combination of name tags and buttons. The information display mainly explores the content and position of the somewhat transparent information card. After finishing the static interfaces design, I moved to edit the video I recorded from Franklin Park Zoo with some virtual objects using After Effects from Adobe Suite¹.

A semilucent wheel with icon buttons distributed around it is used over the lions’ head. It creates an exciting mood when looking at how the live animal is combined with the gamified elements. However, from the mock up video, some problems float up, which are not apparent when working with the static interfaces. For instance, the button exceeds the screen when animals get too close; the selecting and switching functions can be confusing when there is more than one animal in the field. These challenges can be summed up in the following categories: the distance between humans and animals, the distance between individual animals, dimensions, the moving status and the engagement levels.

¹ The video link: https://youtu.be/xOwzKWGSbZ0
3.3.1 The distance between human and animals

Distance here means the interval between visitors and animals. The virtual elements are tied with animals to create a quite real experience where these elements scale proportionately to fit the distance change. However, with no control of how animals move, the elements in the perspective of phones will exceed the screen when animals are too close or be hard to read when they are far.

Zoo set up the glass or barriers to separate exhibition and visiting area to guarantee security for both animals and humans. Nevertheless, zoos adopt strategies to provide closer view of animal observation, for instance, the giant glass shows the underwater world in the Shedd Aquarium, and the decorative jeep which can be entered at the edge the lion exhibition in Franklin Park Zoo. These methods have nothing to do with animal behavior control, but possibly intrigue animals getting closer curiously. Even though, there is no guarantee that animal would do so. Thus, the expectations of animals staying close during the visiting time could not always be met. Regardless, zoos are still charming at the random of animal behavior and uncontrollable. Visitors moving to follow the animals or trying to find themselves a better view prove this charm. Although those animals stay in the exhibition place, they do whatever they want according to their habit.

Therefore, the Augmented Reality design could adopt animal behavior as a interact principle; visitors cannot operate when the animals are far, which may indicate that they do not want to communicate by keeping distance. It is reasonable to disable the information buttons when animals are too far away. Doing so solves the problem of buttons becoming too small to tap when scale with far animals. However, it is not suggested in order to solve the problem. There are multiple ways to solve this problem like providing the view zoom-in function or enlarging the button. It is proposed to create level up experience for visitors. Similarly, when the animals are too close, disabling button function provides great chance of letting visitors to enjoy observation in such close view.
3.3.2 The Dimension

The Augmented Reality works with not only the reality of the environments but also the space of it. It is acceptable if virtual objects do not fit in the real environment. They do not need to be like real objects because it all depends on what kind of experience designers want to create. For example, the giant dinosaur in the museum and the furniture placement may need to be more real, while the AR game may stray further from the reality. However, the spacial relations also need to be considered. It is named Augmented Reality for a reason – the application needs to adopt the real space. The adding on flat stickers in Face U (FaceU - Inspire Your Beauty (version 5.1.0) 2019), a camera application that add cute cats’ ears and paws on the selfie camera, which is not adapt to the three-dimensional world, have no augment to the reality. Thus, it is really a sticker filter – the so-called AR is just advertisement concept. However, in my design, the visualizations of information boards are integrated into the space through depth.

The exhibit areas in zoos normally have one side against the wall, which means it is the inaccessible side for the visitors. Basically, the area has multiple angles from the side and the front. It is technically two-dimensional view from phones, but it feels like three dimensions to the audiences. In this situation, bringing depth concept into design could increase the feeling of reality, like the perspective in the elegant oil paintings. In the interfaces design, the depth can be created by shortening one side and moving the vertex of the rectangle information board to meet the perspective principles (Figure 32). This design merges information board well with the lion, because the lion exists in phone for three-dimensional likely scene.
The depth helps with the match of the virtuality and reality, however, it may cause the readability loss for the images because the content is distorted according to the rectangle. On the lion’s appearance information board, the length and the height scale are not perfectly proportional, which may cause confusions. However, the system itself is dynamic. It detects the ground or the walls as the reference to understand the world which they are going to work in. The relatively depth-adopted information board will change to the rectangle when users move in the zoo or rotate their phones to eliminate the distortion confusion.
3.3.3 The Objects

Object refers to the component captured by AR technology, in most cases, the camera. In this thesis, it refers to the animals in same exhibit space. Zoos often keep individuals of same species in one area, and sometimes even some individuals in different species but have similar habitat and diet in the same space. The animals have distinct social relationship, which result in the different positional relations. They play together, lean on each other, or act respectively. These activities cause the different sizes and positions in phone perspective.

Thus, the target needs distinguished visual symbols when there is more than one object in the scene. AR can mark all interactable animals in the view, just like the one-control-more team game, for example, NBA 2K series. The current controlled player is marked by white circle, while making the passing move, the players who have potential to catch the ball is marked in similar symbol in other color (NBA2K 2018). Building on this, the view focuses on the closest animal to the visitors and show all clickable buttons of explorable information. Those buttons will not only be automatically disabled when animals move to far or close position, but also be switched when visitors move the camera on the phone to capture another animal. This automatic switch is the system prediction of the potential behavior of the user. It may take wrong of the users’ intention. Thus, taking the recovery from the mistake in to consideration, providing the manual switch by tapping is necessary. Like mentioned before, the experience with viewing the information when animals are far is not ideal. Therefore, the alert showed in the Figure(33) will pop up to instruct user.
Animals may hide too well to be spotted by cameras, or they just cover the special attribute for camera to distinguish the individuals. However, linking the geolocation with the chip on animal may solve the problem, even provide more precise information.

However, it is disturbing to interrupt the integrated experience when visitors concentrate on getting information from one animal. In other word, the indicator of existence of other animals should not be strong or sudden, which increase more risk of robbing their attention. Paying attention on the indicator appearance interval or auto switch may solve the problem. Similarly, remind visitors when they are initiatively moving camera or make the alert subtle may also count as solutions. To sum up, do not let anything ruin the fun of spotting animal by visitors themselves.
3.3.4 The moving status

When use the gamified button wheel to circle the target, the wheel follows the animals in a relatively fixed position with them. In contrary, when the animals stay at one position, in order to remind the visitors that there are some explorable individuals, the wheels expand and shrink periodically centered with objects. This dynamic changing reminder keeps changing till it attracts visitors' attentions.

Sometimes, animals' movement causes the change of the relations in the environment, like individuals blocking each other or strange angles hard for visitors to observe. For instance, what changes could the system adopt when animals hide their head behind the trees or inside the water while there are virtual wheels around them? In this case, the glowing effect could also benefit the indication of the animal presence. The basic idea is outlining the animal by a semilucent blurry stroke and flash by expanding and shrinking back. This may be less disturbing than the wheel around the animals' head. From distraction limitation point, this is subtle enough to remind just in perfect extent.

In addition, the animal movements also may cause the unsteady of the camera when users try to follow them with their phones. Even leave out this, the virtual objects may have troubles on following the animals smoothly, or even cause the unclear of the information around them. At that time, the less information follows, the easier it is to read the rest on a more static position like the side menu and information board.
3.3.5 Engagement Level

I have mentioned some of the principles in distraction and enhancement, these two parts can be categorized as engagement level, which is about what kind of roles the AR system play and how much the virtual elements being manipulated in the process of visiting in the zoo. It is summed that visitors come to the zoo to experience with bare eyes and bodies, and they take out their phones for AR function till they want to learn more information, and angles. However, there is no promises that every visitor would explore in this order. That is why the whole system designed to be as integrate as the in-person experience when they are holding the phones all the time. Like mentioned before, the indicators appear not immediately. Instead, they appear after the visitors holding their phones and move them around for 10 seconds.

However, when there are no animals in the display area, presenting a virtual animal figure doing as same thing as the real animal do is enhancing the visiting experience. There is a popular gorilla exhibition in the Franklin Park Zoo with many toys inside, like the balls, the swing chairs, etc. I only remember those toys after twice visit without seeing the gorillas. If I could watch how those gorillas playing with the toys, there wouldn’t be any pity with that visit and may encourage me to visit earlier next time to watch the real gorillas.
3.4 The visual languages for Zoo

Based on the stated challenges in the previous sections, I picked an appropriate system from a few concepts. I took photos of the lions with a range of behaviors from different angles and positions through several visit to the Franklin Park Zoo. These materials are enough to support the comprehensive design explorations. The application is use circle to point out the lions in the exhibition. The one closer to the view is circled in solid stroke, while the further one who is hiding behind the tree being circled in stroke with 60% opacity. I abandoned the idea of using button wheel to circulate the lions for two reasons: The buttons are inaccessible when the lions are too far or too close; and the thickness of the button wheel causes unnecessary blocking issues.

In this platform, the trigger of the information board is located on the right side of the screen in semi circles. The bigger button in the middle shows the current information being presented while the two smaller buttons suggesting the wheel is rotatable to get different information board (Figure 34).

Figure 34. Side Menu.
Meanwhile, what kind of information that could be expected is suggested by the icons on the buttons. The information board shows the interpretation of the current animal behaviors referring to human emotions and feelings by default, in order to bring up the empathy. In addition, from the observations in zoos, visitors care about what animals are doing at the moment and the reasons behind it. It is also common to see parents try to explain the animals’ behaviors to children by using similar human behaviors and emotions. Of course, such interpretations should be built upon zoology and related science. There will be further discussion on the pros and cons in chapter 4.3.

Back to the default setting, the screen shows the interpretation of the current animal gestures because it is the main advantages of adopting AR technology into the zoo, the instantaneous, on the one hand; on the other hand, it is based on the human-animal empathy. Moreover, the other basic, un-real-time information are presented on the signs all around the zoos and aquariums, even though many of the sign designing is barely satisfactory. Besides using AR to ample the instantaneous and empathy, it could show basic information better.

In order to present the information logically in front of the visitors, my AR system employs three-level technique – from the current individual information to the general individual information, then to the species information. For example, the first level could be how much food the lion eats today; the second level could be where did this lion get found in the world; and the third level could be where are the distribution of the Africa Lions. There are three main reasons for this technique. First, zoos use social media to tell stories about their animals as a branding strategy. They give animals names and tell interesting events happened on the individuals. By doing this, they are emphasizing the individual difference to impress the potential audiences and starting to build the connection between these potential audiences with the animal stars. Besides, in the typical “Zookeeper Talks” links, zookeepers tell stories about the individuals, the relationship between the social animals’ herd, and tells characteristics of each animals. For instance, when I was doing research in gorilla exhibition in Franklin Park Zoo, the zookeepers told me how smart the little Joe is and he likes sitting quietly and observing people. While his aunt, the alpha in the herd, prefer to help the zookeeper organize the other gorillas like setting them back to the cave every evening. Afterwards, I saw a mother holding
her son and pointing at little Joe saying, “look, this is little Joe, how calm is him and he is staring at you”. This is the connection mentioned above, the one deepens the visitors’ impression and understanding, therefore, transfer into the empathy since the early age of the human.

Second, from the AR-on-the-small-screen point, this hierarchy of information presenting is one of the advantages of the digital devices, comparing to the spreading all information when the scale and range is fixed. This hierarchy leads the visitors to enjoy the desired flow which is created for enhancement through combining the essential goal of zoo visiting – connect with animals deeply and comprehensively - with the expectation from the zoo, the empathy and awareness.

Third, the individual information distinguishes the specific animal from the rest in their species. The first information we are normally asking about is the name when we meet new friend. The correspondence of the events and the names help with the memory. It is also a good start of referring during introducing and communication when the visitors want to tell the interesting events happened in their zoo visiting to the family, friends, and colleagues. Story sharing is the byproducts mentioned before, as well as the process quality in the service quality theory (Gronroos 2000).

In the designed screen, the information ring to the right shows seven aspects: feature, emotion, diet, geolocation, human comparison, endanger level, and the family tree (Figure 35). In order to match the multiple reading levels of audiences, the system is primarily relay on visual visualization – using images instead of much text.
Under the “Feature”, the first level of information board shows the individual lifestyle or habit, like Dinari lifts his paws up when the ground is freezing. In the second level, tells the species features or the fun facts, like lions sleeping over twenty hours a day and taking the prey from hyaenas in the wild. In the “Emotion” section, the lions’ behavior is linked with human emotions. For example, according to the zookeeper, lions pace around if they feel stressful. At that moment, the information board will have an emoji on it and quote as lion’s first-person perspective: “So many people are watching me, Stress, Stress, Stress”. When the audience roll the ring to browser the “Diet” part, the first board says what this lion ate or will eat today according to the zookeeper’s schedule (Figure 36).

The schedule also has the feeding time as well. For visitors, watching animals eat could be fun. A notification helps them arrange their visiting to fit the feeding time, which transits smoothly within the diet section. Thus, when visitors are viewing the diet section, a notification will automatically appear for a few seconds on the top, saying “Welcome dropping by at 2 PM, when zookeepers give them snacks and answer questions”. The second level shows the weekly diet schedule by date and amount (Figure 37). The icons represent the menu. In the third level, the icons showing what preys Africa lions have in the wild (Figure 38).
Figure 36. First level in Diet.

Figure 37. Second level in Diet.

Figure 38. Third level in Diet.
Under “geolocation” tag, the first level information board presents the lions’ current location in a bird eye view perspective, ideally. (This information absolutely requires technology to support, but this thesis is focusing on the design possibilities). The under-viewing and observable lions are marked separately with different opacities in visualization. The second level provides the location of where the lion was obtained in the wild or other animal preserve institution. On the third level, the visitor gets to know where African Lions live in the wild on a map.

In the “Human Comparison” section, the first level displays the appearance of a general lion as shown in Figure 39, an outline of the lion and the body data like length, weight, and life span. Visitors get a comparison of a human and the lion within the same data measurements in the second level (Figure 40).

Figure 39. The Appearance of a General Lion.

Figure 40. The Comparison of Human and Lion.
In the “Conservation Status” section, the first level shows how vulnerable this species is while the second level tells instructions of how to make a move in daily life to protect the animals as a normal citizen. It is as simple as donating any change or posting lion stories online. When the information wheel scrolls into the “Family Tree”, the visitors see a diagram which shows the genic relationship of these two lions in the Franklin Park Zoo and where to trace their relatives, in the wild or at other conservation institution. If this information is unavailable, this section also presents the story of how the zoo obtained this animal. For example, Dinari and Kamaia were transferred from Dallas.

While visitors are in the zoo, some notifications will appear to assist visitors to be aware of the interesting events happening all around the zoo, like the diet alert mentioned above. They may have the chance to fully take advantage of their current trip to rearrange their tour to see the peacock spreading its feathers or to feed the reindeer. When some special animal behavior occurs, a notification will appear at the top of the screen broadcasting it together with the navigation option. It will make a better experience for visitors to enjoy the activeness of the animals as much as they deserve. One interesting thing happened during my research in the Franklin Park Zoo: I saw people running to the lions’ exhibition when they heard roaring. It demonstrates the positive potential of this design insight.

In addition, the design includes a switching function in which visitors can change view between animals located in the same area. For instance, when the camera points at a lion, a dynamic dot indicating the location of the other lion on the edge of the screen.
3.5 The onsite test in Franklin Park Zoo

3.5.1 Test Preparation and process

The system talked in 4.4 is transferred into an interactive low fidelity prototype via Sketch, which can be used on the phone as a mock up prototype in InVision APP. The prototype of the application is designed to be used horizontally, with the buttons to be tapped to switch screens. Besides, adopting the procedures of usability testing, first introduce the testor and ask the basic information of the testees like the age and expertise level with the smart phones. Next, ask them to try the prototype and complete a few tasks while testor observing and taking notes. Last, explain the issues they meet during the trial and get feedback, as well as the confirmation of some of the behaviors during the trial.
3.5.2 Test Result and analysis

The test was ongoing in the Northeastern Studio and Franklin Park Zoo with four users, based on the procedures in 4.5.1. Testee one is observed tapping the map of the distribution of the Africa Lions around the world while exploring the geolocation section. He explained that he was expecting the bigger view of that map and fully detailed description of it. Testee number two is a female in her 20s, who is quite familiar with the gestures of smart phones. She tried to roll the wheel menu, which indicate she is expecting such rolling switch effects. She said, “This is pretty cool, I would buy this if you finish it. The interaction of the information is so new”. However, she questioned the emotion part with concerning that the emotion is subjective compared to the other objective information about the animals. Thus, she expected some distinguish between those two kinds. Testee number three, a 45-year-old employee from Franklin Park Zoo, who talked about the emotion part as well. He thought the prototype is not precise by using “Boring”. He said, “They (the lions) seldom get bored.” After explaining some of the fun facts of the lions, he suggested of talking to the zookeeper for better interpretations of the animals’ behavior. “The interaction part is great, the kids are gonna love it”, he said. The testee number four, a male in his 20s, who is observed swiping the screens and repeedly tapping the name tags. He found three level information board, but he wandered at the moment for a while, seems like thinking next move. After the post interview, he said he was expecting switch the lions by tapping the name tag when he figured out there are two interactable lions. With no changes on the information board between switching, it seems like that there are no connection between the information board and the lions. He also described his confusion while exploring the diet section. Does the first page indicate the lions had 8 pounds beef and 4 pounds human today (Figure)? Besides, he said he didn't notice the disabled side menu when lions getting closer at all. “Why not let users choose to read the information or not? Instead of you designed it this way?” says he. In addition, he hoped the application can reserve the camera function of zoom in and zoom out because he is worried what if the lions do not get closer during the visiting.

According to all the feedback gathered from the test, there are following improvement direction. First, the real-time interpretation about animal behaviors need more precise data and evidence from
scientific zoology field to keep the objective consistency. Second, the button on the information board to read level information is hard to access or see. It is also difficult to discover there are multiple levels of information beneath, not to mention the unlabeled card need users to guess the meanings for each one. For instance, the third level of the Diet section could be improved by adding a title saying, “Diet In the Wild”, together with the name of the prey (Figure). Moreover, a more narrative card can be provided as an overlay when users click the specific item on the information board. Third, in order to solve the disconnection of the objects and the side menu, change the effects of spreading the menu as popping up when name tag get tapped. There would not be problems with distraction as long as the spreading menu triggered with the users wish.
Discussion

4.1 The Augmented Reality design system

In the design of Augmented Reality applications, not only do the virtual entities in the display need to be considered in front of the recipient, but also the physical objects. Their interactions are not limited to digital, but also real-world interactions. Other important variables that influence the design decision are audience, as individuals or as groups; the inter-relation of the objects like shadowing or splitting; the moving status of the elements in the view; the distance between the audience and the observed world, the application of the virtual elements in dimensions; the engagement level of the audience; the visibility of the virtual elements like the colors and opacity; and the Augmented Reality Tools like phones or goggles. Each of these aspects could be divided into sub-aspects as shown in the table 3 on the next page.
<table>
<thead>
<tr>
<th>Aspects</th>
<th>Sub-aspects</th>
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<td>Audience</td>
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<td></td>
<td>Group</td>
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<td>Object</td>
<td>Separate</td>
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<td>Block</td>
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<td>Phones</td>
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<td></td>
<td>Goggles</td>
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4.1.1 Audience

When considering delivered tangible or intangible products, the audience comes first. People either come in a group or alone. They behave differently in different scenarios, especially in public exhibitions like zoos. Visitors who come alone spend more time observing and taking photos while a group of people spend more time discussing and sharing thoughts during their visit. Based on observations, when it comes to interacting with the facilities, individuals are often less engaged than groups due to the social situation where they may feel embarrassed because they feel like other people in groups are staring at them instead of focusing on the devices. The limited number of interactive devices means that if one person is interacting with the device, other people have to wait to engage with it. Furthermore, some interactive devices are single-user controlled, which might make the user feel like they are being observed by others while they are with the device. In this case, the user cares about the others’ reactions and feelings while he/she is exploring the device without fully being immersed in the desirable experience.

However, the AR design on small devices limit these strange moments to some extent by concentrating the interaction individually even in the public space. In that circumstance, the audience feels more in control and comfortable. The freedom of engagement with the device in any amount of time or intensity encourages the audience to participate more.

Phone-based augmented reality, however, is not an entirely solitary experience. A small group of people are benefited by the small screens in a relatively core. Unlike the audiences for the drama or the show, which provide the experience to the public in same quality, the visitors come to the zoo usually visit in relatively small group. There are typical scenarios when in a family, father holds the device and show to the two-year-old, who cannot hold and interact stably, the interaction on how to get the three-level map showing the lions’ position in the exhibit, in the zoo, and in the wild. Or a person finds the hidden feature of information being disabled while lions are too close in order to let the audiences enjoy the observing opportunity ideally, and then show that to the other members in the group through his/her own device.
4.1.2 Object (The space relations between objects)

Similarly, animals live in group or alone as well. As we all know, many of them are passive or even invisible to the visitors during the daytime, which is opposite to human habit. When animals live in group, they have different relations between each other. Sometimes, social animals, like elephant, play together while solitary animal stays alone. These relations create the potential of distance between individuals and distance between audiences and animals. This section focuses on the space relations between objects, in this case, animals. In 4.1.4 the distance section discusses the interval between human and animals. I will use “Separate”, “Touching”, and “Block” to describe these space relations. The term “Separate” means the individual objects act respectively with no physical interaction. “Touching” is when the outline of the objects is next to each other even partly overlap with no much difference in visual size while “Block” means the objects is one in front of another.

Objects in the real world that are close to each other can create a problem of overlap in AR. When two animals are separated, which means no touching in outlines, there is no overlapping problem in usage no matter what styles of the information display. However, the designers need to cautiously pick the symbols to have similar characteristics in visual languages, as much as possible, like all use circular style to be categorized as a group. At the same time, the shape characteristics are more representative than the color and the opacity ones. In the first prototype, I used the white button wheel and the white arrow with same opacity to distinguish the being observed lion under focus and the observable but currently hidden lion. The useful feedback I got from the small group pre-test is the inconspicuousness of the arrow – barely noticed by the testees without prompting. Some people said they reckoned that arrow was pointing at a rock, because it is obvious that wheel shows the information for lions while arrow shows something other than lions, for example, rock.

In Touching and Block situation, two objects may overlap from the perspective of phones, which is flat like two dimensions view to some extent. The button wheel of one animal possibly obstruct the body even eyes of the other animal, which obstructs the primary goal of watching animals in person. This goal should always be kept in mind in discussion and design.
According to the analysis above, I designed a set of abstract illustrations to demonstrate the relations and principles of elements, including spatial relationships, in virtualization and reality. The background is full of greens in a lot of shade which are extracted from the real photo taken in the Franklin Park Zoo under many light/weather circumstances. The irregular shapes are used to express the complexity and unrecognition of the animal exhibit environment. The orange enneagrams in the middle represent the objects which are intentionally picked complex shapes inspired from the lions’ mane, because the lions are not only the target of the case study of this thesis, but also very popular in the zoos. The third column in the Table 4 pictures two objects. One is a close primary lion circled by solid ring, the other circled by dot ring in same color and stroke. In Separate situation, the rings are scaled to the objects according to the size, while the rings cut to make objects visible in Touching situation. When objects block, the front object and ring counted as a group to cover the behind group- the other object and its ring. After all, there is no good view for the further one in this situation.

<table>
<thead>
<tr>
<th>Object</th>
<th>Seperate</th>
<th>Touching</th>
<th>Block</th>
</tr>
</thead>
<tbody>
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<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
<td><img src="image3.png" alt="Image" /></td>
</tr>
</tbody>
</table>

Table 4. Illustrations for Object Aspect in AR Design Space.
4.1.3 Status

Animals move or keep still. Status shows the speed of objects – again, in this case, animals- changes under circumstances, from zero to some nonzero number. The information follows the animals since it is tightly tied to specific individuals in limited space. The virtual elements showing such information stays relatively still with the animals. Even when the animals not moving, the virtual elements pulse in a small area in order to attract audiences. On the whole, the elements remain the same relative positions with the animals.

In the table 5, dynamic means the animal moving speed is greater than zero while static means animals not physically changing position, keeping the moving speed at zero. Like stated in 4.1.2, using the same complex background to mark the different status of the objects with the unsure visual language like opacity and dot lines. The Dynamic illustration has three rings and objects on the movement track. These groups of rings and objects show three relative positions of virtual elements and animals. On the contrary, animals do not change the position in Static status while the virtual elements are changing the scale which are represented by two dot rings for two conditions in the illustration.

<table>
<thead>
<tr>
<th>Status</th>
<th>Dynamic</th>
<th>Static</th>
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<tbody>
<tr>
<td></td>
<td><img src="image" alt="Dynamic Illustration" /></td>
<td><img src="image" alt="Static Illustration" /></td>
</tr>
</tbody>
</table>
4.1.4 Distance (The distance between human and objects)

Visitors move for better perspective while the objects move in the environment, which causes the complicated distance scenarios. When the objects locate at extreme distance, the virtual elements need to narrow the display area or hide functions to ensure the integrate experience. The distance categorizes as far, middle, and close, which indicate the interval between audiences and the objects. In the table 6, the far and the close objects only have identity dots showing their presence. The dots are not always appearing above the objects; they will subtly adjust position according to the objects' relation to the edge. The full ring and the identity dots present while the objects in the middle. The switch between different distance is dynamic as the keyframes demonstrated in Figure 41-43.

Table 6. Illustrations for Distance Aspect in AR Design Space.
Figure 41-43. Keyframes of Ring Switching Process.
4.1.5 Dimensions

Dimension is discussing about the relationships of objects width, length, and depth with the space. Phone-based applications today have a solid understanding and the skills necessary to design the height and width for 2D platforms, but in AR, the third dimension, depth, matters. The consideration of depth means a plane is not always face against us directly, it may sidle or face with an angle. But is that a distorted flat surface?

When people hold their phones, there are real world (the environment and part of the body like arms and hands), phone (acting as AR view device and control device at the same time), and the perspective inside the phone in their sight range. These things may create a disconnect experience compared with the AR goggles. Meanwhile, the virtual objects are relatively static in the human perspective because there is a arm length between the eyes and the phones. This distance leads to the ignorance of the spheral distortion. Therefore, inside the phone-based AR design, the spheral bend is unnecessary and the special feeling can be created only by distorting in depth linearly.

In the illustration (Figure 44), the translucent trapezoid shows the information card with angle in the space. According to the perspective principles, the diagonal plane looks like trapezoid from two-dimensional view. In the Figure 45, when visitors move to the left, the right plane turns back to the rectangle since it located at a absolute position in the space.
Figure 44. Illustration of Normal Dimension Aspects.

Figure 45. Illustration of Dimension Stretch After Movement.
4.1.6 Engagement

The engagement level has two parts, distraction and enhancement. The interaction is one of the advantages of Augmented Reality. With the multi-level information, users get encouraged from the content perspective; with the gamified effects, users get encouraged from visual engagement perspective; with the interpretation and the notification, users get encouraged from empathy perspective. Even the disabled functions are methods to encourage users. It is designed to encourage them focus on the real world instead of the virtual objects. The alternate experience of reality and virtuality balances the enhancement comprehensively, and level up the engagement consequently.
4.1.7 Visibility

In the aspects of visibility, the color and opacity float up. As zoos simulate the natural environment as much as they can, the background in the zoo is basically the low saturate yellowish and greenish range (Figure 46). The color choice of the virtual object needs to be strongly contrasted or bright for readability. White with shadow can work both on dark and light environment. However, in the far view under sunny days, a large area would be bright in the phone view. A translucent black background can distinguish the text on it for this situation.

Through the test on opacity, from 60% to 90% contribute to the clear readability. The translucent information card needs to be seen through the space behind and also thick enough to hold the icons and text.
4.2 Application in other AR contexts

This system works well in the zoo according to the feedback from the interviewees. Thus, this system also has the ability to serve the similar environment. One of the main differences of this research is that this system is dealing with the dynamic environment which include the moving animals (The exhibition filed and the animals can be seen as the environment because they are different than the adding on virtual objects). A large amount of the Applications in the markets work with the fixed space, in which the moving parts are people holding their phones. Furthermore, those applications keep static after the virtual objects placement during the most of the scenarios. Therefore, this AR system not only adapts to the static scenarios, but also the ones contains changes.

The dynamic environments include the space involve humans other than zoos. For example, the parks have people jogging, walking dogs, and flying kites; the streets have people walking and cars dashing. This system could work with the city, which include the buildings and moving cars. The information about buildings will stick to the location while the information about cars follows. However, the car moves way much fast than the animals in the exhibitions, which may lead to unreadable information card change. In this situation, a speed slow or a pause function may benefit audience to read and explore the selected cars.
4.3 The Mutual Improvement of AR and Empathy

This AR system contains interpretations of the animals’ behaviors, which help to build the basis of empathy construction, understanding. Like the world-famous quotation from Freeman Tilden: “Through interpretation, understanding; through understanding, appreciation; through appreciation, protection” (Tilden, Dickenson, and Craig 1957). This system also adopts the technique of comparing the human to the animal which helps the audiences to link the animals’ attributes to theirs. This is another dimension of empathy construction. Built upon Tilden’s idea, the empathy forms in the following process presented in the Figure 47.

The visitors perceive the animals’ behavior and understand by their knowledge or through the interpretation from zoos. Some techniques help with analogizing human and animals, especially through the AR camera when visitors see themselves presented equally with animals. Due to the difference of the cognition and cultural background, people may identify animals’ emotions based on the “interactions between dispositions of animals and contextual factors”, or view them “as the direct unfolding of animal dispositions” (Su, Koda, and Martens 2018). All kinds of visitors possess the ability to perceive emotions, no matter how they achieve the final understanding of the similarity, which leads to empathy appearance.

Data is embedded in all kinds of ways. The choice of technology correctly helps to reveal the hidden truth by telling the story in a perceivable way. Traceback to chapter 3.4, the human comparison section works strongly on linking animal features with humans. AR serves as such a way in this scenario. More importantly, however, the storytelling strategy is beyond the choice of technology. The layout of the information which helps the analogy process matters.
Bibliography


