Dundee University TouAR

The effects of Narrative Generation methods (based on Augmented Reality Interactions) on overall User Experience

Kaloyan Marshalov
University of Dundee
Dundee, UK
kvzmarshalov@dundee.ac.uk

ABSTRACT

Storytelling is amongst the oldest human art forms. It is one of the main methods people use in order to understand an environment and communicate personal experience. The increased popularity of digital entertainment has given birth to Interactive Storytelling (IS) - a narrative technique in which the plot and discourse of a story are not predetermined. Traditionally, digital interfaces are used to interact with such systems. The rapidly emerging field of Augmented Reality (AR) aims to combine the virtual and the real and achieve a novel level of immersion. However, the effect of AR interactions on dynamic storytelling is still unclear. An Augmented Reality tour around the University of Dundee campus was built in order to better understand the users' perceptions when using such applications. The tour presents historic information related to the institution through a selection of AR activities. The impact of the narrative generation methods is examined in a user study, for which participants were asked to report on their experience when using the application. An evaluation of User Experience was done using both qualitative and quantitative techniques. The results of this study demonstrate the positive impact that this novel form of IS interactions can have on the overall immersion and engagement with narrative tours. A discussion of the implications of these results highlights the main considerations that designers need to make when creating AR storytelling experiences.

1 INTRODUCTION

Storytelling in its various forms is amongst the oldest artistic human expressions. Narratives are an integral part of human media, including novels, theatre, movies and video games. Humans use this medium in order to understand an environment and communicate personal experiences. While oral storytelling is perhaps one of the earliest manifestations of this field, the opportunities created by focusing on Interactive Storytelling (IS) have resulted in increased interest in this area from both research and commercial aspects [8].

Interactive storytelling differs from traditional stories in that the plot of a story is not predetermined. Instead, comprehensive stories get constructed based on a user's interactions, allowing for a unique user experience. Because of its relatively young age as a research area, many aspects of it remain unexplored [35]. Recent efforts from the field attempt to provide structure to the topic of Interactive Narratives [12, 22, 24, 32], allowing future work to be based on quality concepts. The examples of such research provide guidance on the best practices when writing an interactive narrative [12], how to then transfer it to a Mixed Reality medium of storytelling [22] and the measures and questionnaires which designers can use to asses their system [24, 32]. Defining such concepts is a big leap in progress towards better-informed design and theory work.

An area that has fully embraced interactive narratives is video games. For example, action games like Mass Effect [1] or entirely story-driven ones like The Stanley Parable [2]. The gaming medium is a perfect playground for IS, as the player has complete control over their actions. Video games have begun expanding outside of their traditional context and into Mixed Reality. These forms of entertainment in which the real world is mixed up with the virtual are a fantastic vehicle for improving the intractability and immersion of a story [48]. The popularisation of Mixed Reality as an entertainment medium means that an entirely new category of research is needed, in order to explore the new interaction techniques [44]. Efforts can also expand past the fictional and into the factual world [12].

Historically, some of the key technical limitations of Mobile Augmented Reality have been associated with the high computational and energy demands, as existing hardware was simply not powerful enough to cope with complex rendering and computer vision algorithms [16]. Recent trends in mobile phones see some of the largest manufacturers putting their most advanced camera and processor chips into their lowest-priced devices [7, 9]. This opens up opportunities for Augmented Reality applications to become more mainstream, as the powerful hardware is able to reach a broader audience of both users and developers. It is, therefore, necessary to explore how Augmented Reality can be applied across various domains.

The central question that this paper is focused on is the impact of a Narrative Generation method of storytelling, based on Augmented Reality Interactions, on overall User Experience.

1.1 Study Contributions

The paper contributes to the existing knowledge about Narrative Generation techniques when used in conjunction with Augmented Reality. This novel combination of two research areas focuses on interactions that alter discourse as opposed to the means of authoring a narrative. It does so by exploring more than just location as an AR storytelling interaction, but also object-based activities. The resulting application presents methods for creating a non-fictional narrative tour using modern tools and frameworks. An alternative approach to testing indoors has been used for a User Experience evaluation. The research presents the findings through a mix of quantitative and qualitative analysis.

2 RELATED WORK

The ultimate goal of any Interactive Storytelling (IS) system is to create a world in which the user's actions result in a cohesive and engaging story. In order to support development in this area previous work has examined, and defined, the goals that IS designers should consider [45]. In general, story plots are created from a subsection of predefined elements which can be combined in order to determine the discourse of the story [30, 31, 40]. Creating an engaging narrative means re-arranging discourse based on users' inputs to the system. Integrating interactions within a story should be seen in two ways. On one hand, the interaction should be a driving factor of the story. However, the choices offered need to be well related to the plot in order to simulate our choices in real life.

A challenge exists in designing new interactions that can fit within an IS narrative. The nature of Augmented Reality is such that it lays between the virtual and the real world. This can result in messy experiences by designers that try to tackle the multi-layered structure of user interface components and information on screen [14]. Within a storytelling setting, interactions also need to get offered frequently enough, in order to fight the feeling of being a spectator rather than an actor within a story [45]. Working in tune with these factors results in an increased narrative immersion, in which users start to feel part of the virtual world [51].

2.1 Narrative Generation

The design of a story is usually initiated by the decision of a narrative form. Current literature identifies three main types of plot: epic, dramatic and epistemic [45]. An epic plots take the point of view of the hero and follow them through a set of challenges until an ultimate goal is reached. A great example of this category are the Grant Theft Auto games, in which players are free to advance the story on their own by roaming around the world and doing quests, which all work towards the characters' final goals. Dramatic narratives follow the progression of interpersonal relations and their impact on the story. Narratives like the one in Detroit: Become Human rely on players to form emotional bonds to the characters, which are then tested throughout the story, as their decisions often lead to life or death situations. Epistemic narratives aim to engage the user in a mystery, in which they have to induce and deduce facts as the story unfolds. The game L.A. Noire does this well by having players investigate crime scenes and do interrogations, however, the quality of their detective work determines how much of the story gets revealed.

Having selected the narrative form, further progress in interactive narrative design requires the writing of the story. It has been suggested that stories can be split into fragments, which need to be carefully examined in order to identify the relevant concepts within them and their meaningful connections to other fragments [31]. Other research demonstrated the role of storytelling artefacts (such as letters, quest items and newspapers) in enriching narratives in video games [30]. These often provide information about the story world and its characters, while further engaging the players in the narrative. Several studies have documented the pillars around which the discourse of a story is built [40, 49]. Narrative constraints try to reduce the number of errors and convolutions of a story by identifying the necessary events of the plot, alongside the final goals of the narrative. A narration agent can then process these constraints (anchor points) and decide if they should be intertwined. User input can also be mapped to anchor points, thus altering discourse.

The nature of interactive storytelling is such that sometimes unpredictable events can emerge. The systems should, therefore, be designed with that in mind, allowing the unexpected interactions to still have an effect of the storyline. Such moments can be predicted when analysing the structure of the narrative for potential inconsistencies [39, 42]. In the cases where these unforeseen interactions come from the player [42], the system could implement a "catch-all" scenario, in which an NPC executes the task at hand and advances the plot. A more sophisticated approach has the story manager identify future inconsistencies and repairs them before they are reached [39]. A preventative approach can also be taken. Certain parts of a story could be structured in a way which allows the user to interact with them, however, these interactions have no effect on the outcome of the particular plot point [52].

An emerging area of research is happening around location-based narratives. Evidence of this can be found in the recent attempts to create a writer's toolkit when designing such narratives [33, 37]. The current literature suggests focusing on factors that disrupt the user experience, alongside pragmatics and aesthetics when writing location-based stories. The structure of these narratives is another topic of research. Spierling and Kampa outline a story and plot structure, intended for use with mobile devices in museum tours [50]. Other research suggests the correlation between location and time when structuring the plot of a story [47].

The majority of studies in Interactive Storytelling focus on Narrative Generation and the algorithms which author plot and discourse. There are some common approaches when building a choice-based narrative [4]. Although a heavily branching tree structure might seem like the most obvious approach, they often result in short storylines and risk the players missing out on a lot of the content. Lengthier narratives are usually constructed by either linearly or cyclically rejoining branches into a small selection of pivotal events. The focus of most interactive storytelling work is focused on experimenting with these structures and the way they can guide discourse. Much less is known about interactions, the way they are classified and their role in stories. Furthermore, there exists little evidence of the role of Augmented Reality Interactions in Interactive Storytelling systems. Location appears to be the only interaction to receive a good amount of focus in literature.

2.2 Augmented Reality Interactions

Augmented Reality applications aim to combine the virtual and physical world into one, increasing the immersion of the user in their environment. The increased popularity of mobile devices has naturally led to a surge of interest in AR. Special care needs to be taken as they can oftentimes seem very messy in their efforts to combine the physical and virtual in order to be "here and there" at the same time [14]. They can have advantages over traditional media as well by using tactile-visual interfaces, like for example the ability to "look around" a panorama picture on top of being able to use swipe gestures. A major interest of this field has been the interactions themselves. Literature suggests the division of AR interactions into two categories [10]:

- **Tangible Interactions** refer to interactions based on physical contact with an interface. These interfaces come with the major advantage of being intuitive to use, as the virtual objects are directly mapped to the physical manipulation [13]. Research suggests a further division to touch-based (touch-screen controls) and device-based (the device's sensors) interactions [27]. A limitation of these interactions, however, is that users can only interact with visible objects.
- **Intangible Interactions** refer to interfaces that separate the user from the physical object. While they increase user engagement, a drawback of these is the lack of haptic feedback [27]. Literature further divides intangible interactions [10] into marker based[27] and marker-less [13**?**] .

Other work attempts to establish the strong concepts of the field by examining the configuration, non-verbal interactions in physical space, and non-verbal interactions with digital and physical objects [22]. The ability to track movement through space, map the surrounding environment, recognise and categorise physical items, and alter the degree of immersiveness of digital objects has been recognised as essential for Mixed Reality narratives. This information is then utilised for location awareness and recognition of voluntary movement as an interaction. Furthermore, the use of freehand gestures and fingertip rays needs to be considered for near space and far space interactions with the digital world.

While the obvious method for achieving location-based interactivity would be through GPS tracking, it has been demonstrated that a Context-aware indoor AR is possible [18]. Real-world markers, coupled with inertial navigation can help track the user's location indoors. Most modern mobile phones have barometers, which can further increase the accuracy of these interfaces [34]. Another aspect of locations is their relationship with the story [11]. The Augmented Reality application can be either Reinforcing, Re-skinning or Reminiscent. Reinforcing is a technique by which the narrative of both a physical and a digital environment are improved by combining them together. An example of this is playing historic footage on a battlefield site. Re-skinning is a similar strategy, however, the physical world is completely ordinary and unrelated, relying on the virtual content entirely. Computational understanding of the real world plays a large role in these applications, as they are not always situated in a fixed environment. Reminiscent techniques aim to link personal experiences to the narrative, rather than well known historic facts. An example of this would be audio log files, which are played out on specific locations.

Kim further expands on the idea of time and location-based experiences by including object-based and user-based events as parts of a larger context-immersion concept [29]. Time and location can contribute to engagement after a careful design consideration of the context and constraints of interactions. Object-based immersion heavily depends on the mobile hardware and modern object-tracking algorithms in order to create various connections between the objects. User-based experiences take advantage of the highly networking capabilities of mobile phones by facilitating user communication between devices within AR applications. These three aspects describe the mobility, relationship and interaction measurements of augmented experiences, which can be useful when assessing context-immersion.

Designing Augmented Reality applications comes with its own set of challenges when looked through the lens of User Experience. The rapid advancements in technology result in users being unaware of available services, struggling to find the value in them or simply finding them too cumbersome and challenging to use [17]. De Sa and Churchill also suggest the use of video prototyping in order to obtain the best user feedback possible. Furthermore, there exists research that provides a detailed look at a user's expectations when engaging with mobile AR [36]. A shortcoming of similar work is that the narrative is often overlooked as a factor. Such an effort is made by Grinder-Hansen and Schoenau-Fog, outlining the storytelling design factors that influence the user experience [25].

2.3 User Experience

While User Experience (UX) is highly subjective, efforts are made to develop frameworks for understanding the factors that affect it [32, 43, 51]. One of the well-established models is that of Roth et al. [43]. They identify the key experiential qualities of interactive storytelling systems - curiosity, suspense, aesthetic pleasantness, self-enhancement, and task engagement. Other efforts in objectively measuring an Interactive Story can be seen in the PC3 framework [32]. It proposes Process (actions that can be executed), Content (plot and discourse), Control (ability to alter Content), and Context (intended purpose) as the defining qualities of interactive systems.

Some of the reasons Mixed Reality is chosen over other storytelling mediums is the increased immersion and feeling of agency when experiencing a narrative. However, research on immersion suggested that more is not necessarily better when it comes to enjoyment [15]. Other work suggest that the feeling of agency can be similar between branching and linear stories [20]. Furthermore, there is evidence that the classical approaches of Virtual Reality are not necessarily the most engaging form of media [38].

Perhaps the best way to evaluate an Interactive Storytelling system is to examine the user's desire to continuously engage with the application. This is further examined by Schoenau-Fog [26], who's research suggests that engagement can be defined as a player's pursuit of objectives, accomplished through activities, which result in a feeling. Further research aimed to evaluate engagement in real-time by using an emerging narrative [46]. Other work suggests measuring immersion in Augmented Reality applications [23, 24]. Georgiou and Kyza present a questionnaire for location-based applications, by applying well-established game theory [15] to an augmented reality setting. The questionnaire measures a user's engagement, engrossment and total immersion. The authors argue that these categories can further be divided into interest, usability, emotional attachment, focus of attention, presence and flow.

2.4 Research Questions

Based on the above, and in consideration of the effect that Augmented Reality will have on the development of Narrative Generation, we present the following research questions:

RQ1 What are the effects of Augmented Reality interactions on Narrative Generation?

RQ2 How is User Experience affected by Narrative Generation techniques, compared to traditional storytelling?

3 METHODOLOGY

The evaluation of the system was done by asking participants to do a mock tour of the campus using the application installed on a testing device. The entirety of the testing was done indoors, in a single room with a cleared out elongated path, as some of the interactions required walking in a straight line. The users were able to "navigate" to different buildings by verbally indicating that to the researcher, who changed the GPS coordinates of the device remotely. These changes in the experiment were necessary due to government restrictions on public movement at the time of testing. The originally intended format of the experiment can be found in Appendix D.

3.1 System Description

An Android application was created using Unity as the development environment. The Augmented Reality Interactions were built using the ARCore SDK. All mapping related functionality was created using the Mapbox SDK while SQLite was used for data storage. The system itself can be split into two main parts - a Mapbox map interface and an ARCore augmented reality interface. A Unity application manager handles the communication and redirection between the two interfaces with the aid of the SQLite database.

1) Mapbox map interface: The Mapbox map interface (Figure 1.A) is responsible for providing users with GPS-based information and mapping. It consists of a map and two types of markers: device marker and point of interest marker. The former represents the real-world position of the user, while the latter represents the locations at which interactions are possible. On startup, users are prompted to navigate to one of those markers, which unlocks the location-specific AR interactions and the ability to chose a route. Once a route is chosen, only the relevant markers are displayed and the suggested directions for the whole tour. The option to change path is available at locations which are a part of more than one path. Path and Location-specific information is retrieved from the SQLite database through SELECT queries. A User Interface button is available to toggle between the mapping and augmented reality interactions.

2) ARCore Augmented Reality interface: The ARcore augmented reality interface is responsible for handling all AR interactions of which there are 4 available:

1) Select Path: Surrounds the user with select-able images, corresponding to one of the paths (Figure 1.B);

2) Portal: Allows the user to walk through a door into a room full of objects related to the location (Figure 1.C);

3) Photo Sphere: Places the user in the middle of an old 360 photograph of the location (Figure 1.D);

4) Pedestal: Places a pedestal that presents information about the location with pictures, videos and objects (Figure 1.E).

Interactions 2), 3) and 4) require the detection of a surface for anchoring, while interaction 1) is anchored to the device itself. Each location has a predefined set of interactions available, with specific data loaded as a prefab into the Unity scene. Further information about the development methodology, design decisions and software tools is presented in Appendix A.

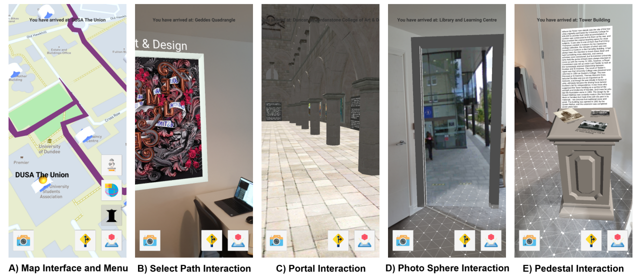

Figure 1: A) Map interface displaying points of interest on an Art & Design path and the available interactions for DUSA The Union. B) Image interaction associated with Art & Design path. C) Inside an Art Gallery Portal on the Art & Design path. D) Door towards a Photo Sphere. E) A Pedestal showing historical information and old photographs of the Tower Building.

3.2 Design

The tour around campus is designed around 4 paths, related to the main teaching categories at the university: Life Sciences, Formal and Applied Sciences, Social Sciences, and Art & Design (Figure 2). Each path consists of between 8 and 10 points of interest, making up an undirected graph with a total of 26 nodes and 37 edges. Each point of interest represents a building with some historical significance to the university. 11 of the nodes are hubs, meaning that they are a part of more than one path. Each node has at least one of the following interactions available: Photo Sphere, Portal or Pedestal for a total of 35 unique Augmented Reality experiences. A mixture of text, photographs, videos and 3D models are used in each interaction.

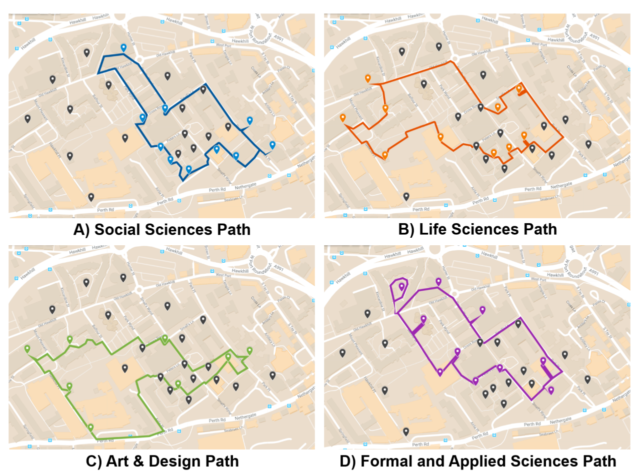

Figure 2: The four available paths

Each evaluation began with an explanation of the purpose of the study through an information sheet, followed by an informed consent form. Having agreed to take part, the participants were briefed on the potential health risks when taking part in the study. Each participant was then given a short overview of the User Interface, after which they were handed a mobile phone with the application. At the start, the application prompts the users to navigate to one of the points of interest, in order to begin the tour. There are no restrictions on the starting point of the tour, which allows for a complete narrative agency. They can then complete a "Select Path" interaction, which places them on one of the predefined routes. The users can then explore the available interactions for each building. Each node can only be visited once, with hub nodes offering the option to select a different path. While there is a suggested travel route between locations, participants are free to visit the points of interest in any order. The study also attempts to do A/B testing using the storylines by utilising two separate application builds. The first one offers three of the four paths and allows the participants to freely alter between them. The second application build restricts the users to the fourth path. A different fixed route was used for each participant. This is all done in order to compare narrative generation techniques to predetermined storytelling, as participants cannot change discourse in the second application. Participants were given up to 30 minutes to navigate the first scenario and up to 10 minutes to navigate the second.

After completing the tour participants are asked to complete an Augmented Reality Immersion Questionnaire [24], which consists of 21 questions using a 7-point Likert scale. The range of options are from Completely Agree to Completely Disagree and aim to evaluate the engagement, engrossment and total immersion of the system. Participants then take part in a semi-structured interview aiming to gain an overall understanding of UX, using the measures presented by Roth et al. [43]. An interview guide was used, built around a skeleton of their dimensional model. The five dimensions of storytelling were dispersed across three categories: Technology, Story and Experience. The optimal task engagement ("flow") dimension was broken down into Engagement, Attention, Familiarity and Fatigue. An extra subsection regarding the User Interface was added as well, aiming to gather more information about the aesthetic pleasantness of the storytelling. Finally, participants are asked to provide further comments on their experience, should they have any. All conversations were recorded, transcribed and anonymised. Further analysis of the interviews and the questionnaire is made in the Results section.

3.2.1 Materials, Equipment and Setup. Experiments were carried out in a single room in which an elongated path was cleared out, allowing for greater freedom of movement when using the Augmented Reality Interactions. Solely the author and the participant were in the room for the duration of the experiments, ensuring minimal distraction throughout. All testing was done in the morning in order to maximise light levels indoors, which helps with surface detection.

The two versions of the application used for the evaluation were installed on a Samsung Galaxy S10 Plus phone. The device was set on maximum screen brightness, screen timeout of five minutes and full media volume. A GPS mocking application was also installed and allowed to run as a foreground service [3]. A Huawei Matebook 13 (2019) laptop was used by participants to read information sheets, sign digital consent forms and fill out the questionnaire after testing. The laptop was also used by the author to remotely change the device's location by issuing commands to the GPS mocking application through a Telnet connection from a PuTTY terminal. A notebook was used to record the sequence of locations and keep track of start and end times for each part of the testing. An antibacterial spray and paper towels were provided for each participant in order to disinfect the devices between use.

3.2.2 Participants. A total of 3 participants took part, all aged 22 (Male = 1 and Female = 2). None of the participants reported any experience with Augmented Reality applications. Two of the participants were students at the University of Dundee. Both students were in the School of Medicine.

4 RESULTS

The sequence of visited points of interest, as well as any changes to the tour path, was logged for each participant in a notebook and digitalised after testing. The appropriate colour-coded information is added to each results file. The outcomes of the Augmented Reality Questionnaire were stored in a spreadsheet and later used for calculating the measures of AR immersion [24]. All interview sessions were recorded, transcribed, anonymised and annotated by the author before analysis. Data was then sectioned out according to the main parts of each session (testing, questionnaire and interview). The segments were combined in order to facilitate the analysis of each area. Although efforts were made to remain impartial during data collection, both participants and author are closely related, which can result in a slight bias in the resulting information.

4.1 Tour Paths

An overview of the key metrics related to each participant's behaviour while exploring the application is presented in Table 1. A visualisation of each route is shown in Figure 3. Although participants were not required to walk between nodes in real life, none of them managed to visit all points of interest while testing within the allocated time frame. This indicates a potential for a very long real-world experience. In addition, only one participant (P1) visited all four paths during testing, while three of the buildings (Fleming, Harris and Peters) were not visited by any of the users. This could be related to participants' tendencies for visiting nodes out of the suggested order. Although the number of nodes visited on a static route seems relatively low, this is caused by the fact that participants have already seen most of the hubs on the route in their previous interactions.

Further analysis of the data reveals that on average participants visit 73% of a route before deciding to select a different path. This is a much higher percentage than the second longest trail of 44%. Interestingly, two of the participants completed the majority of a selected path at the start of testing. The same participants explored only three of the routes.

Measurement	P1	P2	P3
Time Spent on dynamic route (min)	26	27	28
Time spent on static route (min)	10	8	7
Nodes visited in dynamic route	13	9	11
Nodes visited in static route	3	3	4
Nodes visited before first change of route	4	5	8
Most nodes visited on a single uninterrupted route	7	5	8
Nodes visited out of the suggested order (for dynamic route)	2	3	4
Total visited nodes	16	12	15
Total visited paths	4	3	3

Table 1: Tour Path Data

4.2 Augmented Reality Immersion Questionnaire

The questionnaire results were collected and calculated according to the original authors' guidelines. The statements within are built around a 7-point Likert Scale, with responses ranging from 1 - Completely Disagree and 7 - Completely Agree. The scoring of the questionnaire involved a primarily reversal of the results of two of the statements, namely "I found the AR application confusing" and "The AR application was unnecessarily complex". The levels of immersion and their components were then individually calculated for each participant. Table 2 presents the obtained results.

Engagement: Participants reported a high level of Engagement (AVG = 6.29) when using the application. This result validates any further analysis, as it is the first stage of immersion. The data indicates that an augmented reality tour with a dynamic storyline is aligned with the participants' preferences and is a style of storytelling that they are interested in. It also demonstrates that the users had high expectations, which were met by the application. The high Interest score (AVG = 6.58) further amplifies the meaning of the measurement. Although still high, a lower Usability score (AVG = 6) highlights imperfections in the controls and the feedback from the application. While a high measure of Engagement means that the software covers all the basics for immersion, users need to form a further emotional bond in order to feel motivated to continue using it.

Engrossment: In this second stage of immersion, participants report a further feeling of involvement. Engrossment has a similar score to Engagement (AVG = 6.28) indicating a well-constructed application with an engaging story, interesting interactions and high visual fidelity. The lower Emotional Attachment score (AVG = 5.78) suggests that the contents of the story itself are not enough to generate a strong emotional response. The benefit of that, however, is that the feeling of being "emotionally drained" is not something that the participants are likely to experience. A strong emotional response usually results in an increased immersion due to users being more invested in the story. Despite the lower score, the Focus of Attention was still reported to be quite high (AVG = 6.67), demonstrating that the Augmented Reality Interactions by themselves are well suited for high user engrossment. This is explained by the nature of AR applications as they mix the real and the virtual world. Traditional measures of focus aim to asses the levels of complete disengagement from the physical surroundings. The same metric in an AR context is a user's ability to mute any distractions from their surroundings (such as noises or passerby). However, a high Focus of Attention score is associated with a slight degree of risk, as potential health hazards in the physical world might be unnoticed. Once fully engrossed, participants can move towards being completely captivated by the application.

Total Immersion: This is the optimum level of immersion, during which users reach a sense of presence in the virtual world. The lower overall score of Total Immersion (AVG = 6) hints that there are some underlying issues with the testing setup. The high Flow score (AVG = 6.33) illustrates a full absorption in the activity. By contrast, a lower Presence measurement was recorded (AVG = 5.75). The building blocks of that score are empathy and atmosphere. As already discovered at the previous level, there is a slight lack of emotional attachment to the application, which could be attributed to the non-fictional storyline. This means that there is simply not enough material for participants to feel empathy towards. The second factor of atmosphere takes the makeup of the experience (story, interactions and visuals) and considers its relevance to the environment. The physical space plays a large part in generating a good atmosphere, as it is the "stage" for AR interactions. Due to indoor testing, participants have noted the absence of a relevant environment for the available implements. This feedback has been common between participants in the informal conversations.

Score	P1	P2	P3	AVG
Engagement	6.63	6.5	5.75	6.29
Engrossment	6.84	6.34	5.67	6.28
Total Immersion	6.86	6.43	4.71	6
Interest	7	7	5.75	6.58
Usability	6.25	6	5.75	6
Emotional Attachment	6.67	5.67	5	5.78
Focus of Attention	6.67	7	6.33	6.67
Presence	6.75	6	4.5	5.75
Flow	7	7	5	6.33

Table 2: ARI questionnaire results

4.3 Semi-Structured Interview

The initial transcripts of the interviews were expanded with additional information describing objects which were brought up or hinted at, but not explicitly mentioned by the respondents. The text files were then split into three sections, corresponding to the general structure of the interview guide. Each section was then analysed for any patterns, recommendations or observations from the participants in the study.

Technology: All participants provided mostly positive comments about the aesthetics of the application. In response to the question '*How visually appealing did you find the application?*', the users responded with '*it is very realistic, a lot of detail*' (P2) and '*On the whole I'd say it was — quite well done, at least in terms of visual aesthetic*' (P3). One of the participants (P3) noticed that the Photo

Sphere images used had some slight deformations '*the buildings in the 360 view that kind of appeared to bend*'. The participants did not think that there were any elements in the visuals that were out of place. Questions about the icons and the overall visuals of the interface also received positive feedback, with P3 stressing their appreciation for the Path Selection by stating '*It was very clear, even if you were not trying to read what it is attached to, the icons themselves kind of pointed you in the right direction anyway*'. The same user also reported their enjoyment of the Pedestal interactions '*I thought they were really well done*'. Unfortunately, none of the participants reported any previous experience with Augmented Reality and were therefore unable to compare the application to anything else.

The functionality of the interface was also examined through questions like '*Was the interface easy to use?*', '*Were the gestures accurate?*' and '*Did you have any issues understanding the controls?*'. The majority of the responses to those questions were positive, with one interviewee reporting on the learning curve of the software by saying '*I was like "where do I click", "do I click anything", but after I figured it out it was really easy*' (P1). Another participant reported on a similar topic and said '*the ones that you can use were highlighted well*' (P2) when asked if the interface was straightforward. One participant noted that '*the statue ones [Pedestal Interaction] did not work and some of the items moved around when you tapped it*' (P2), while another expressed a negative feeling in stating '*It was kind of frustrating every time you get closer to a point of interest and it would just disappear*' (P3). Although these can be associated with the limitations of the technology, P3 attributed their issues to '*being stuck inside*'.

Story: A feeling of curiosity and constant engagement was expressed by all participants. This positive feedback could be analysed in two ways. The first comes from the point of view of the story itself. One participant did not want to miss out on a specific path before the end of testing and noted that '*I went for something I was more interested in like the Old Medical School*' (P1). In contrast, another user chose to explore the Art & Design buildings '*purely out of curiosity, because I do not interact with them on a daily basis*' (P3). The second way to analyse curiosity is by examining the interactions themselves. P1 reported that they were looking forward to a specific interaction by saying '*I wanted the little things that you could read and watch [Pedestal interactions], but I did not normally get them*'. Some negative comments emerged from the question '*Were there any interactions that you tried out and did not yield any results?*'. Every participant reported that at least one of the interactions did not load, however, no one expressed any negative feelings as a result of that. Although a couple of users felt disconnected from the virtual world, reporting that '*I was more kind of a bit annoyed when I had to click it again because I hit a wall*' (P1) and '*I did find it harder trying to figure out how to stick to a path*' (P3), these pains were attributed to them being indoors while testing.

There were no significant reports of feelings of stress, suspense or a pressure to make the "right" decision. When asked if they felt an emotional attachment to the story, P2 replied with '*not particularly*', while P3 said that they felt '*a weird sense of belonging to the story unfolding*' and that it was '*nice to find out more of the history of different parts surrounding campus*'. P1 theorised that the feeling is built over time and that perhaps in '*first year you would have been a bit more detached because it is brand new*'.

Experience: The interviewees reported feeling fairly engaged by the tour and confirmed that it was worth exploring. Two themes emerged from the answers to the question '*Would you do the tour and would you change your path?*'. P1 said that they would try to '*pick buildings that I have not seen before*', while P3 reported that they would like to have '*looked at more of the other faculties other than Life Sciences*'. These responses indicated a desire to return and explore new buildings. On the other hand, P2 talked about returning to already visited nodes in order to '*go into more detail in some places ... the DJCAD one was interesting ... all the paintings and the art on the wall — and all the information*'. The same participant said '*I could not see it because I could not walk as far*' (P2), suggesting that the physical space was not enough for that particular interaction. None of the participants expressed any major issues with loss of attention, except for getting distracted when '*looking to see where I was going*' (P1). There were no reports of any fatigue or a need for a break when using the application.

In all cases, the informants reported a positive learning experience, mainly focused on '*information about the history*' (P2). One of the respondents shared that '*I do not think it is accessible*' (P1) when talking about the history of Dundee, while another said that '*reading some of the history did put things into context*' (P3). A common view between participants was that Augmented Reality as a medium of dynamic storytelling sits somewhere between movies and video games. The experience was described as '*more involved than a movie*' (P3) and classified as something that it is '*completely different because most are just 2D and are not interactive*' (P2). P1 further elaborated that when watching television '*you just sit there and it happens*' while the application had a more dynamic style of storytelling and contains '*different elements of "no, I want to chose a different path", "I want to go to this building"*'. P3 commented that one difference from traditional video games is that '*there was no set objective apart from "if you want to explore, go explore"*'. Another participant thought that '*compared to games ... would be less interaction*' (P1), however, there was no negative impact on their enjoyment and they found it '*personally more entertaining*' (P1). The perceived immersion was also commented on, with one interviewee stating that '*it feels like you're there more, then just looking at a screen*' (P2), suggesting that the physical and virtual worlds were combined well.

4.4 Summary of Results

A mix of quantitative and qualitative measures reveal insights into user perceptions when using Augmented Reality for location-based Narrative Generation. Although the study was done indoors, the results of the Tour Path data suggest the real length of an outdoor tour, alongside a measure to the level of completeness for each path. The Augmented Reality Questionnaire results indicate the high level of immersion that participants experienced while using the application. This is further expressed in the Semi-Structured Interviews, during which users reported on their feelings of engagement. Special care needs to be taken when designing the Augmented Reality interactions, the constant avoidance of potential health hazards can also result in a break of immersion. The style of Narrative Generation allows users to explore story lines relevant to their interests in a more involved and entertaining manner than traditional media.

Figure 3: The route that each participant took with static path A) Life Sciences (Orange); B) Social Sciences (Blue); C) Formal and Applied Sciences (Purple)

5 DISCUSSION

5.1 Augmented Reality as a Narrative Generation technique

(RQ1) **What are the effects of Augmented Reality interactions on Narrative Generation?**

Very little was found in literature on the way Augmented Reality interactions can be used in Narrative Generation techniques. Evidence exists of location-based dynamic storytelling [53], however, object-based and user-based interactions [29] are less prevalent in research. Furthermore, a common theme of current literature appears to be a focus on the story rather than the interaction [28, 31], meaning that there is much room for the topic to grow as a research area. The appropriateness of Augmented Reality design recommendations [23] when used for Narrative Generation has also not been explored.

The results of this study show that there is a very high degree of immersion for the particular setup. Considering immersion as a factor of good storytelling and one of the goals of Narrative Generation [41], it could be therefore argued that Augmented Reality has a positive impact as a technique of altering the discourse of the story. With this particular application being built around non-fictional storytelling, it shows that AR can be a great medium for presenting historical or other factual information. Designers of location-based experiences can take advantage of the novelty factor of the interactions to keep users constantly engaged, ensuring that users remain focused on the activity and complete it in its entirety. A note of small caution here has emerged from the results as there were reports of an initial barrier because of the novelty, as users had to figure out how to best use the interactions.

It is possible to hypothesise that one way of giving users a head start can be by following good design recommendations for both the user interfaces and the content [5, 23]. Although the questionnaire results had an imperfect Usability average, this can be attributed to the later reported malfunctions of the software. This result is also likely to be related to the lack of any significant input or haptic feedback from the application, outside of a vibration when a point of interest has been reached. It has been suggested before that realistic renderings are a necessary element for immersion and a stylised world could be the optimal solution in a mobile setting [21]. This does not appear to be the case in this study, as the simpler interfaces and objects were not reported to have a negative impact on aesthetics and interviewees still found them to be very visually appealing. This is a significant finding for developers, as it means that the use of low poly objects does not negatively impact the experience when using mobile AR.

The results of this study are also in line with previous work [23, 29] in finding that the context and locality of interactions are key in Augmented Reality storytelling. This relationship can be explained by the fact that all participants reported on the negative implications of doing the tour indoors. Most users described issues with inadequate physical space or simply wished to be present at a real-world location.

5.2 Effects of dynamic storytelling

(RQ2) **How is User Experience affected by Narrative Generation techniques, compared to traditional storytelling?** There are various methods of interactive storytelling [4] with various levels of complexity. Some research describes a method of scattering information in the world and relies on the user to piece it together [30, 50], while other efforts describe methods that support emergent narrative [31, 53]. It is possible that the results from this study underestimate the true effect of Narrative Generation, as the study is built around real-world exploration, rather than a specifically generated narrative. However, it can be argued that a simpler interactive storytelling technique facilitates the interpretation of results after incorporating Augmented Reality into the application.

In contrast to other studies [28], this research on dynamic storytelling is not bound to any user personas but instead is driven entirely by the user preferences in a particular moment. There are benefits and drawbacks to this approach. While it does allow for a complete narrative agency, its implementation should be carefully considered for each use case. As Keil et al. suggest, museum exhibitions are carefully designed for a seamless experience, which suggests that a complete autonomy over discourse would be undesirable. The findings of this study should be therefore considered only in scenarios in which the order of storytelling cannot be detrimental to the overall experience.

Initial interpretation of the results can lead to the assumption that the narrative generation techniques did not majorly contribute to the discourse of the story. This hypothesis can be explained by observing the patterns in the tour data, which reveals that most participants explored the majority of one singular path at the beginning of the tour. The low number of nodes visited out of the suggested order can wrongfully be attributed to users simply following the path and not really caring about their route, only changing it when reaching the final nodes of the current one. Further analysis of the interviews reveals that the Narrative Generation techniques did in fact have a positive contribution to the User Experience. Participants reported following primarily the routes that are closely related to their personal interests and in some cases talked about returning to a node and exploring it further.

One unanticipated finding was that people wanted to explore the history of buildings that misaligned with their interests. It can thus be suggested that the Narrative Generation techniques can play a role in generating curiosity, by including additional information to a path and thus encouraging participants to change the discourse of the story. This is a rather useful result, as it has important implications for developing very diverse storylines which encourage exploration.

It can be difficult, however, to explain this result. One possibility might be related to participants wanting to see more Augmented Reality interactions. It is, therefore, possible that these results can be attributed to the novelty factor of AR. A stronger interpretation of the results would be possible after testing with users who had prior experience with Augmented Reality storytelling.

6 CONCLUSION

The present study was designed to determine the effects of Narrative Generation storytelling techniques, based on Augmented Reality, on overall User Experience. The paper set out to evaluate the following two questions:

RQ1 What are the effects of Augmented Reality interactions on Narrative Generation?
RQ2 How is User Experience affected by Narrative Generation techniques, compared to traditional storytelling?

The necessity for this research was motivated through a review of literature related to dynamic storytelling, augmented reality interactions and user experience evaluation techniques. The experiment outlined was designed around split testing and built upon existing assessment criteria [24, 43]. An evaluation was done through a user study involving 3 participants. A purpose-built application was created to fit the requirements of the research.

The findings of this study suggest that the use of Augmented Reality software can result in an increased immersion when used in conjunction with Narrative Generation techniques, ensuring a constant level of engagement. However, the novelty factor of interactions can be confusing for some, which further increases the importance of following good design practices. Another finding on the benefit of AR is the increased engrossment in the story world, assuming that designers pay attention to the context and locality of interactions. The study also strengthens the idea that dynamic storytelling contributes positively to User Experience by allowing people to explore the aspects of a narrative that are most interesting to them.

6.1 Limitations

The results of this study are subject to certain limitations. The two main weaknesses of this research are the small sample size and the testing environment for the experiment. An interpretation of the results from the split testing is therefore difficult, as the comparison between trials would be highly variable. All of these negatives are related to the present government restrictions on public movement. The method of the study was identified to be the best option considering the difficult circumstances. Nevertheless, the conclusions of this work should be used with caution, as results might differ with a larger sample size of participants using the application around the university campus.

None of the participants reported any prior experience with Augmented Reality applications. Users outside of this demographic might have a different perception of the interactions, as there would be no novelty factor to their experience. Another drawback is that all participants were closely related to the researchers, which could have resulted in biased feedback. A more rigorous experiment, which includes a larger selection of the population, would result in more concrete findings.

One other limitation of the study is the relatively simplistic method of Narrative Generation. While other research in the area is more focused on dynamic authoring, this work examines the interactions that can change the discourse of a story. These results may therefore not be applicable to a more complex storytelling application, however, they can serve as a starting point for future research.

6.2 Generalisations and Future Work

Augmented Reality narrative experiences were shown to be highly engaging for users that had no previous background with the technology. Participants found the storytelling method to be novel and entertaining, showing preference in using it for historic-based learning. The findings of this research display the benefits of adopting novel technology when designing walking tours.

There is a range of possibilities for future work with this study. The experiment should be repeated using the initially planned setup and with a larger sample size. Extensions of this work can also be undertaken in the following areas:

More complicated Narrative Generation methods: Further research should attempt to develop a more complicated storyline using Artificial Intelligence. Possibilities for narrative authoring can be seen from a purely storytelling perspective, such as the choices made in a role-playing game. A Narrative Generation engine could be purpose-built for the task of telling a brand new story. A different approach, such as the one by Dow et al. [19], can re-purpose existing dynamic storytelling software and attempt to include Augmented Reality interactions.

An extended array of Augmented Reality interactions: A more complex narrative structure would provide an opportunity to explore a wider variety of Augmented Reality interactions and their effect on interactive storytelling. Location-based authoring is a possibility [53], as well as time-based and user-based [29]. Intangible interactions using hand gestures is another area of Augmented Reality that should be explored. A future study investigating emotions as an interaction through facial recognition would be very interesting.

Other applications: This study focused on a non-fictional story, which opens up an opportunity for future work to explore the implications of a fictional narrative. Further research is needed on dynamically generated AR narratives in order to better understand its alternative uses. A look into educational or industrial training applications can develop a deeper understanding of the real benefits of the technology.

Driving factors to User Experience: Immersion was the main quality explored by the questionnaire used in the study. Future work can attempt to identify other assessment methods, which would provide a broader understanding of the User Experience. Personal interest was identified as the driving factor behind a participant's choices in this study. More research is needed in order to identify other influences on a user's decisions.

ACKNOWLEDGMENTS

The author would like to express his gratitude to Dr Michael Crabb for his continuous support throughout the project, as he was instrumental to the success of this work. His fantastic guidance and advice are reflected in the final result. The author would also like to thank Caroline Brown from the University of Dundee Archive Services for providing all of the tour's historical data and Yiannis Georgiou from the Cyprus University of Technology for elaborating on the use of their Augmented Reality questionnaire. A final set of acknowledgements goes to all participants that agreed to take part, the creators of all models and textures and everyone else that offered support throughout the project.

REFERENCES

[1] 2007. Mass Effect Video Games - Official EA Site. https://www.ea.com/en-gb/games/mass-effect
[2] 2013. The Stanley Parable: Ultra Deluxe. https://www.stanleyparable.com/
[3] 2016. MockGeoFix – Apps on Google Play. https://play.google.com/store/apps/details?id=github.luv.mockgeofix&hl=en_GB
[4] 2016. Standard Patterns in Choice-Based Games. https://heterogenoustasks.wordpress.com/2015/01/26/standard-patterns-in-choice-based-games/
[5] 2019. ARCore Elements - Apps on Google Play. https://play.google.com/store/apps/details?id=com.google.ar.unity.ddelements
[6] 2019. The Double Diamond: A universally accepted depiction of the design process. https://www.designcouncil.org.uk/news-opinion/double-diamond-universally-accepted-depiction-design-process
[7] 2019. Pixel 3a. https://store.google.com/gb/product/pixel_3a
[8] 2020. ICIDS Interactive Storytelling - ARDIN. http://ardin.online/conferences/icids-interactive-storytelling/
[9] 2020. iPhone SE - Technical Specifications. https://www.apple.com/uk/iphone-se/specs/
[10] Loubna Ahmed, Salma Hamdy, Doaa Hegazy, and Taha El-Arif. 2015. Interaction techniques in mobile Augmented Reality: State-of-the-art. In *2015 IEEE Seventh International Conference on Intelligent Computing and Information Systems (ICICIS)*. IEEE, 424–433. https://doi.org/10.1109/IntelCIS.2015.7397255
[11] Ronald Azuma. 2015. 11 Location-Based Mixed and Augmented Reality Storytelling. (2015).
[12] Nicole Basaraba. 2018. A Framework for Creative Teams of Non-fiction Interactive Digital Narratives. In *Interactive Storytelling - 11th International Conference on Interactive Digital Storytelling, ICIDS 2018, Dublin, Ireland, December 5-8, 2018, Proceedings*. 143–148. https://doi.org/10.1007/978-3-030-04028-4_11
[13] Mark Billinghurst, Hirokazu Kato, and Seiko Myojin. 2009. Advanced interaction techniques for augmented reality applications. In *International Conference on Virtual and Mixed Reality*. Springer, 13–22. https://doi.org/10.1007/978-3-642-02771-0_2
[14] Jay David Bolter, Maria Engberg, and Blair MacIntyre. 2013. Media studies, mobile augmented reality, and interaction design. *interactions* 20, 1 (2013), 36–45. https://doi.org/10.1145/2405716.2405726
[15] Emily Brown and Paul Cairns. 2004. A grounded investigation of game immersion. In *CHI'04 extended abstracts on Human factors in computing systems*. 1297–1300. https://doi.org/10.1145/985921.986048
[16] D. Chatzopoulos, C. Bermejo, Z. Huang, and P. Hui. 2017. Mobile Augmented Reality Survey: From Where We Are to Where We Go. *IEEE Access* 5 (2017), 6917–6950. https://doi.org/10.1109/ACCESS.2017.2698164
[17] Marco De Sá and Elizabeth F Churchill. 2013. Mobile augmented reality: A design perspective. In *Human factors in augmented reality environments*. Springer, 139–164. https://doi.org/10.1007/978-1-4614-4205-9_6
[18] Buti Al Delail, Luis Weruaga, and M Jamal Zemerly. 2012. CAViAR: Context aware visual indoor augmented reality for a university campus. In *Proceedings of the The 2012 IEEE/WIC/ACM International Joint Conferences on Web Intelligence and Intelligent Agent Technology-Volume 03*. IEEE Computer Society, 286–290. https://doi.org/10.1109/WI-IAT.2012.99
[19] Steven Dow, Manish Mehta, Annie Lausier, Blair MacIntyre, and Micheal Mateas. 2006. Initial lessons from AR Façade, an interactive augmented reality drama. In *Proceedings of the 2006 ACM SIGCHI international conference on Advances in computer entertainment technology*. 28–es. https://doi.org/10.1145/1178823.1178858
[20] Matthew William Fendt, Brent Harrison, Stephen G. Ware, Rogelio E. Cardona-Rivera, and David L. Roberts. 2012. Achieving the Illusion of Agency. In *Interactive Storytelling*, David Oyarzun, Federico Peinado, R. Michael Young, Ane Elizalde, and Gonzalo Méndez (Eds.). Springer Berlin Heidelberg, Berlin, Heidelberg, 114–125. https://doi.org/10.1007/978-3-642-34851-8_11
[21] Jan Fischer, Dirk Bartz, and Wolfgang Straber. 2005. Stylized augmented reality for improved immersion. In *IEEE Proceedings. VR 2005. Virtual Reality, 2005.* IEEE, 195–202. https://doi.org/10.1109/VR.2005.1492774
[22] Joshua A Fisher. 2016. Strong Concepts for Designing Non-verbal Interactions in Mixed Reality Narratives. In *International Conference on Interactive Digital Storytelling*. Springer, 298–308. https://doi.org/10.1007/978-3-319-48279-8_26
[23] Yiannis Georgiou and Eleni A Kyza. 2017. A design-based approach to augmented reality location-based activities: Investigating immersion in relation to student learning. In *Proceedings of the 16th World Conference on Mobile and Contextual Learning*. 1–8. https://doi.org/10.1145/3136907.3136926
[24] Yiannis Georgiou and Eleni A Kyza. 2017. The development and validation of the ARI questionnaire: An instrument for measuring immersion in location-based augmented reality settings. *International Journal of Human-Computer Studies* 98 (2017), 24–37. https://doi.org/10.1016/j.ijhcs.2016.09.014
[25] Arne Grinder-Hansen and Henrik Schoenau-Fog. 2013. The Elements of a Narrative Environment. In *Interactive Storytelling*, Hartmut Koenitz, Tonguc Ibrahim Sezen, Gabriele Ferri, Mads Haahr, and Digdem Sezen (Eds.). Springer International Publishing, Cham, 186–191. https://doi.org/10.1007/978-3-319-02756-2_23
[26] Schoenau-Fog Henrik. 2011. The Player Engagement Process - An Exploration of Continuation Desire in Digital Games. In *DiGRA &#3911 - Proceedings of the 2011 DiGRA International Conference: Think Design Play*. DiGRA/Utrecht School of the Arts. http://www.digra.org/wp-content/uploads/digital-library/11307.06025.pdf
[27] Wolfgang Hürst and Casper Van Wezel. 2013. Gesture-based interaction via finger tracking for mobile augmented reality. *Multimedia Tools and Applications* 62, 1 (2013), 233–258. https://doi.org/10.1007/s11042-011-0983-y
[28] Jens Keil, Laia Pujol, Maria Roussou, Timo Engelke, Michael Schmitt, Ulrich Bockholt, and Stamatia Eleftheratou. 2013. A digital look at physical museum exhibits: Designing personalized stories with handheld Augmented Reality in museums. In *2013 Digital Heritage International Congress (DigitalHeritage)*, Vol. 2. IEEE, 685–688. https://doi.org/10.1109/DigitalHeritage.2013.6744836
[29] Mi Jeong Kim. 2013. A framework for context immersion in mobile augmented reality. *Automation in construction* 33 (2013), 79–85. https://doi.org/10.1016/j.autcon.2012.10.020
[30] Toke Krainert. 2014. Storytelling Artifacts. In *International Conference on Interactive Digital Storytelling*. Springer, 113–124. https://doi.org/10.1007/978-3-319-12337-0_11
[31] Silvia Likavec, Ilaria Lombardi, Alberto Nantiat, Claudia Picardi, and Daniele Theseider Dupré. 2010. Threading Facts into a Collective Narrative World. In *Interactive Storytelling*, Ruth Aylett, Mei Yii Lim, Sandy Louchart, Paolo Petta, and Mark Riedl (Eds.). Springer Berlin Heidelberg, Berlin, Heidelberg, 86–97. https://doi.org/10.1007/978-3-642-16638-9_12
[32] Brian Magerko. 2014. The PC3 Framework: A Formal Lens for Analyzing Interactive Narratives across Media Forms. In *Interactive Storytelling*, Alex Mitchell, Clara Fernández-Vara, and David Thue (Eds.). Springer International Publishing, Cham, 103–112. https://doi.org/10.1007/978-3-319-12337-0_10
[33] David E. Millard and Charlie Hargood. 2016. Location Location Location: Experiences of Authoring an Interactive Location-Based Narrative. In *Interactive Storytelling*, Frank Nack and Andrew S. Gordon (Eds.). Springer International Publishing, Cham, 419–422. https://doi.org/10.1007/978-3-319-48279-8_40
[34] Kartik Muralidharan, Azeem Javed Khan, Archan Misra, Rajesh Krishna Balan, and Sharad Agarwal. 2014. Barometric phone sensors: More hype than hope!. In *Proceedings of the 15th Workshop on Mobile Computing Systems and Applications*. ACM, 12. https://doi.org/10.1145/2565585.2565596
[35] Janet H Murray. 2018. Research into interactive digital narrative: a kaleidoscopic view. In *International Conference on Interactive Digital Storytelling*. Springer, 3–17. https://doi.org/10.1007/978-3-030-04028-4_1
[36] Thomas Olsson, Else Lagerstam, Tuula Kärkkäinen, and Kaisa Väänänen-Vainio-Mattila. 2013. Expected user experience of mobile augmented reality services: a user study in the context of shopping centres. *Personal and ubiquitous computing* 17, 2 (2013), 287–304. https://doi.org/10.1007/s00779-011-0494-x
[37] Heather Packer, Charlie Hargood, Yvonne Howard, Petros Papadopoulos, and David Millard. 2017. Developing a Writer's Toolkit for Interactive Locative Storytelling. https://doi.org/10.1007/978-3-319-71027-3_6
[38] Emilee Patrick, Dennis Cosgrove, Aleksandra Slavkovic, Jennifer A. Rode, Thom Verratti, and Greg Chiselko. 2000. Using a Large Projection Screen As an Alternative to Head-mounted Displays for Virtual Environments. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '00)*. ACM, New York, NY, USA, 478–485. https://doi.org/10.1145/332040.332479
[39] Richard Paul, Darryl Charles, Michael McNeill, and David McSherry. 2011. Adaptive Storytelling and Story Repair in a Dynamic Environment. In *Interactive Storytelling*, Mei Si, David Thue, Elisabeth André, James C. Lester, Joshua Tanenbaum, and Veronica Zammitto (Eds.). Springer Berlin Heidelberg, Berlin, Heidelberg, 128–139. https://doi.org/10.1007/978-3-642-25289-1_14
[40] Julie Porteous and Marc Cavazza. 2009. Controlling narrative generation with planning trajectories: the role of constraints. In *Joint International Conference on Interactive Digital Storytelling*. Springer, 234–245. https://doi.org/10.1007/978-3-642-10643-9_28

[41] Mark Owen Riedl and Vadim Bulitko. 2013. Interactive narrative: An intelligent systems approach. *Ai Magazine* 34, 1 (2013), 67–67. https://doi.org/10.1609/aimag.v34i1.2449
[42] Mark O Riedl and Andrew Stern. 2006. Believable agents and intelligent story adaptation for interactive storytelling. In *International Conference on Technologies for Interactive Digital Storytelling and Entertainment*. Springer, 1–12. https://doi.org/10.1007/11944577_1
[43] Christian Roth, Peter Vorderer, and Christoph Klimmt. 2009. The Motivational Appeal of Interactive Storytelling: Towards a Dimensional Model of the User Experience. In *Interactive Storytelling*, Ido A. Iurgel, Nelson Zagalo, and Paolo Petta (Eds.). Springer Berlin Heidelberg, Berlin, Heidelberg, 38–43. https://doi.org/10.1007/978-3-642-10643-9_7
[44] Rebecca Rouse and Evan Barba. 2017. Design for Emerging Media: How MR Designers Think About Storytelling, Process, and Defining the Field. In *Interactive Storytelling*, Nuno Nunes, Ian Oakley, and Valentina Nisi (Eds.). Springer International Publishing, Cham, 245–258. https://doi.org/10.1007/978-3-319-71027-3_20
[45] Marie-Laure Ryan. 2008. Interactive narrative, plot types, and interpersonal relations. In *Joint International Conference on Interactive Digital Storytelling*. Springer, 6–13. https://doi.org/10.1007/978-3-540-89454-4_2
[46] Henrik Schoenau-Fog. 2011. Hooked! – Evaluating Engagement as Continuation Desire in Interactive Narratives. In *Interactive Storytelling*, Mei Si, David Thue, Elisabeth André, James C. Lester, Joshua Tanenbaum, and Veronica Zammitto (Eds.). Springer Berlin Heidelberg, Berlin, Heidelberg, 219–230. https://doi.org/10.1007/978-3-642-25289-1_24
[47] Henrik Schoenau-Fog. 2015. Adaptive Storyworlds. In *Interactive Storytelling*, Henrik Schoenau-Fog, Luis Emilio Bruni, Sandy Louchart, and Sarune Baceviciute (Eds.). Springer International Publishing, Cham, 58–65. https://doi.org/10.1007/978-3-319-27036-4_6
[48] Roy Shilkrot, Nick Montfort, and Pattie Maes. 2014. nARratives of augmented worlds. In *2014 IEEE International Symposium on Mixed and Augmented Reality-Media, Art, Social Science, Humanities and Design (ISMAR-MASH'D)*. IEEE, 35–42. https://doi.org/10.1109/ISMAR-AMH.2014.6935436
[49] Mei Si, Zev Battad, and Craig Carlson. 2016. Intertwined Storylines with Anchor Points. In *Interactive Storytelling*, Frank Nack and Andrew S. Gordon (Eds.). Springer International Publishing, Cham, 247–257. https://doi.org/10.1007/978-3-319-48279-8_22
[50] Ulrike Spierling and Antonia Kampa. 2014. Structuring Location-Aware Interactive Narratives for Mobile Augmented Reality. 196–203. https://doi.org/10.1007/978-3-319-12337-0_20
[51] Nicolas Szilas and Ioana Ilea. 2014. Objective Metrics for Interactive Narrative. In *Interactive Storytelling*, Alex Mitchell, Clara Fernández-Vara, and David Thue (Eds.). Springer International Publishing, Cham, 91–102. https://doi.org/10.1007/978-3-319-12337-0_9
[52] Huaxin Wei. 2011. Structuring Narrative Interaction: What We Can Learn from Heavy Rain. In *Interactive Storytelling*, Mei Si, David Thue, Elisabeth André, James C. Lester, Joshua Tanenbaum, and Veronica Zammitto (Eds.). Springer Berlin Heidelberg, Berlin, Heidelberg, 338–341. https://doi.org/10.1007/978-3-642-25289-1_43
[53] Jon Womack and William Freeman. 2019. Interactive Narrative Generation Using Location and Genre Specific Context. In *Interactive Storytelling*, Rogelio E. Cardona-Rivera, Anne Sullivan, and R. Michael Young (Eds.). Springer International Publishing, Cham, 343–347. https://doi.org/10.1007/978-3-030-33894-7_35

A SYSTEM DESIGN

A.1 Design Decisions and Alternatives

Augmented Reality applications can be created for a variety of software and hardware. Because of the nature of walking tours, a mobile phone was chosen as the most appropriate vehicle for the application as it is lightweight and highly portable, resulting in a lesser strain on the users. The rapid advancements in sensors, cameras, processing power and graphics hardware have spurred the development of a variety of mobile AR tool kits, which offer an improved understanding of the visual world. Modern SDKs offer features such as plane recognition, lighting estimation, face meshing and augmented images, with more recent efforts focusing on the social aspect of mobile applications by implementing cloud functionality. For the purposes of this research three of the main frameworks were considered, namely ARKit, ARCore and Vuforia. ARCore was chosen as it is the only one that is freely available for non-iOS applications (due to the cost of the Apple Developer Program). The framework is available for Android and Android NDK, as well as Unity and Unreal. Unity was chosen for the development environment as it provides a wide variety of integrated tools and assets. It also has a large community behind it which can help with any undocumented issues. A decision was also made to use plain ARCore instead of ARFoundation, which expands upon the framework and enables multi-platform builds. A drawback of the latter is that it is an incomplete implementation of ARCore and updates of the main framework would not be immediately available.

A part of the study are location-based interactions, which necessitates the use of mapping tools. Mapbox was selected for this, as it provides a Unity SDK and its free tier limits are high enough for the purposes of the project. An alternative would be the Google Maps services, however, recent changes to their pricing plans would make the project very costly. An enterprise budget would make Google's Unity SDK the perfect choice, as it is built for immersive location-based games.

The final major requirement consideration is related to the choice of a database. A traditional SQL database on a remote server can be a valid solution, however, it would require a constant internet connection. Instead, an integrated SQLite database was used for storing information about routes and points of interest. Modern mobile phones usually have a large storage capacity, which negates the negative aspects of a built-in database.

A.2 Development Methodology

The design of the application was done through a series of brainstorming exercises. The basis of the activities was rooted in the ideas behind BDC's Double Diamond methodology [6]. The first goal of the framework is to help designers understand the available problems in depth and generate a set of challenges on which to focus on by exercising divergent thinking. To do so, a large set of research papers related to Augmented Reality and Narrative Generation was examined and analysed in order to define the topics that are not prevalent in literature. Some of the identified problems include a need for a tailored experience when using Augmented Reality; a lack of understanding of the role of interactions in Narrative Generation; a small number of applications that use AR interactions when altering discourse; a lack of research on user experience when using narrative generation applications and how static and dynamic stories can compare to each other.

The second goal of the framework is to motivate a variety of solutions to the identified problems and take focused action in order to solve them. This was done by examining the capabilities of the leading Augmented Reality SDKs, their features and their shortcomings. The design recommendations and example projects were also explored. Small prototypes were created using the frameworks as a proof of concept, which later resulted in a fully implemented solution in the final product. The source material for the tours was also identified at this stage, after a series of conversations with the Dundee University Archives. The points of interest were selected according to their historic significance and the specific paths were designed around the main categories of teaching within the institution.

The specific requirements for the application were a result of the needs of the study and the research experiment. A Gantt chart was created at the start of the development phase (Figure 4), which guided the progress for both the report and the application. The development of the software was done using agile methods, stretched across 5 sprints. The length of each one was between 7 and 16 days. Each sprint was initiated after a meeting with the project supervisor when a selection of features was chosen to be implemented in the following weeks. The product backlog was implemented as a set of GitHub issues, which were used in Basic Kanban projects. A mixture of paper and digital prototypes was used when designing new features. Design guidelines and recommendations [5, 23] were followed where possible for all aspects of the application. Small bug fixes were also implemented after user testing, ensuring that all models load properly.

The implementation and testing were completed using Unity version 2019.2, Visual Studio 2019 and Sourcetree (connected to a GitHub repository). A full description of all the software and hardware used can be found in the following subsection. Subsequent meetings with the project supervisor acted as a sprint review and sprint planning. Full description of each sprint is presented in Appendix B. The full evaluation of the software was done through the user testing presented in the main report.

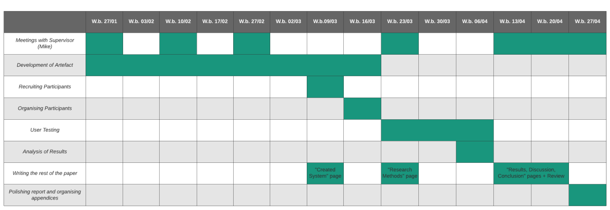

Figure 4: Gantt Chart for the development phase of the project

A.3 Tools and Software

A.3.1 Unity 3D. Version 2019.2.20f1 was used as the game engine for the project, as it was the one compatible with the latest version of Google ARCore.

A.3.2 Visual Studio 2019. The main IDE used throughout development, used for all coding and some debugging through ADB Logcat.

A.3.3 DB Browser (SQLite). Used to access the raw SQLite file for most the simple data management. Some data entry was done directly through this tool.

A.3.4 Google ARCore. Version 1.15 was used as it is the most recent one, implementing the largest array of AR functionality. Some of the assets and code from the example applications were used in this project.

A.3.5 Mapbox. Used the SDK for Unity (version 2.1.1). It is the framework that handles all mapping. Some of the assets and code from the example applications were used in this project.

A.3.6 Sourcetree. Used as a git GUI for easier access to the git repository. Extra branches were used to separate the testing builds from the final one.

A.3.7 GitHub. Hosts all files associated with the project, including ethics forms and testing results. Also served as a project management tool through issues and Kanban boards.

A.3.8 PuTTY. Used for a Telnet connection to the testing Android device. Issued commands directly to MockGeoFix.

A.3.9 MockGeoFix. The mocking GPS application installed on the Android device, which was used to change the location data.

A.3.10 Mendeley. Used to keep track and organise research papers throughout the writing of the report. Separated into Narrative Generation, Augmented Reality and User Experience sections.

A.3.11 Overleaf. A LaTeX editor used to write the report and keep a history of all changes.

A.3.12 Google Forms. Used to implement the Augmented Reality Immersion questionnaire, which was filled out by each participant during testing.

A.3.13 Microsoft Word. Used during data collection for organising and collating results.

A.3.14 OneNote. The main tool for taking notes throughout the project, contains all minutes from meetings with the supervisor, alongside other data about the tours.

A.3.15 Paint3D. Used to create the figures in the report.

A.3.16 Google MyMaps. Used for the route figures in the report and to extract the latitude and longitude of the points of interest.

A.4 Acquisition of New Knowledge and Skills

A wide range of new skills were acquired throughout the duration of this project. The writer had no previous experience with the Unity engine, which necessitated a large section of time to be dedicated to learning it. Another gap in knowledge was the Augmented Reality framework. The novelty of the software means that it is not a common resource in personal projects or a part of the academic curriculum. AR also brings a specific set of design requirements which had to be learned prior to development. Other professional skills such as version control, debugging and prototyping were further improved because of the project.

Academic writing was another major lesson stemming from this report. The author was introduced to the structure of research papers and the methods for both reading and producing that style of writing. Creating an evidence-based, cautions, precise and detailed report has been the focus of this work, which will be a great experience for future work. Conducting professional user evaluations and reporting on results are also examples of great lessons learned throughout.

B DEVELOPMENT SPRINTS

Sprints were managed and tracked using GitHub's Projects feature. Each Project was set up using a basic Kanban board with a To Do, In Progress and Done sections. Issues were created for each major step of development and were labelled with at least one of the following:

- Application - main features of the software project
- Ethics Submission - tasks involved with the submission
- Narrative Generation - writing and development of the story
- Report - writing tasks for the research paper
- University Archives - scheduling communication with the university archives and following up tasks
- User Testing - setting up and testing the application
- Other - issues that fit into none of the above

The goals of each sprint were identified with the help of the project supervisor at the start and discussed and reviewed in the following meeting. Some software development was done outside of the sprints, implementing minor changes to the projects prior to testing and submission.

B.1 Sprint 1

Start Date: 10th of February 2020
End Date: 26th of February 2020
Duration: 16 days
Goals: The main intention of the first sprint was to build the foundation of the application. The main goals revolved around building a backlog of issues; creating a working Portal and Photo-Sphere interaction; mapping out the points of interest on campus and expanding the Literature Review of the report.

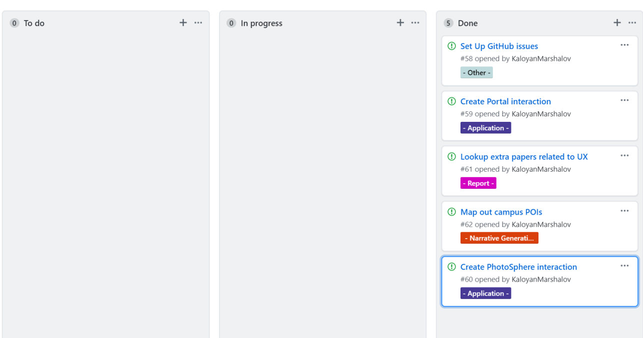

Figure 5: Kanban board for Sprint 1

Outcomes: An initial array of issues and labels was created. The majority of the new tickets were only related to the current sprint, with some being added for future implementation.

The Unity project was set up and ARCore was added to the build. A portal and a photosphere interaction were developed, in-line with requirements. A couple of popping bugs were identified at this stage. The cause of the issues was identified through testing in various conditions. The root of the problem was associated with two factors: low light conditions and close proximity of the testing device to nearby walls. Neither of the causes could be addressed in future work due to time constraints.

The first draft of relevant buildings was also created. The points of interest were placed on a Google MyMaps project and a route was identified (Figure 6). This mapping project was used and iterated upon in later sprints.

The extensions of the literature review resulted in an extended definition of the testing methodology.

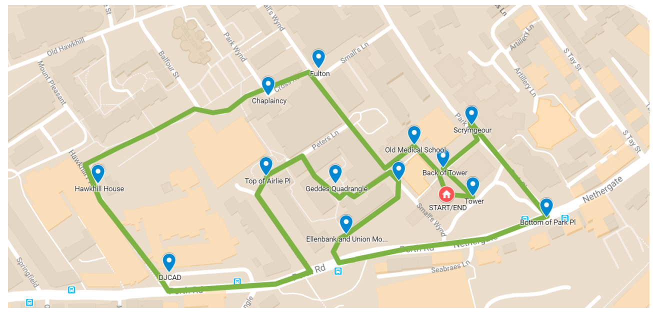

Figure 6: First draft of the tour path

B.2 Sprint 2

Start Date: 26th of February 2020
End Date: 11th of March 2020
Duration: 14 days
Goals: The main objective for this sprint was to transfer the identified points of interest from the previous one onto an interactable map inside the application. The Select Path scene was also a necessary implementation in order to begin the development of an application manager. Mapping out the routes within was also attempted in this sprint. Extra work was carried out on the report as well.

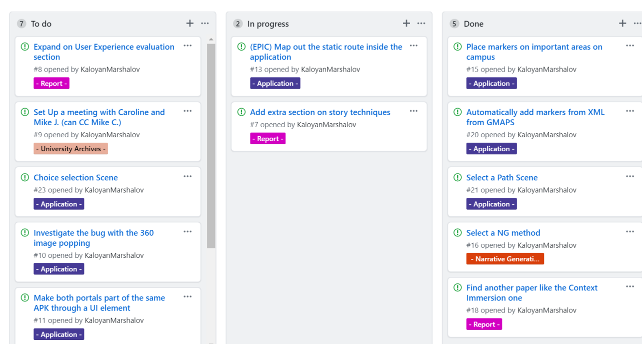

Figure 7: Kanban board for Sprint 2

Outcomes: The majority of the development time in this block was spent setting up and configuring Mapbox to work with the Unity project. The lack of documentation associated with the SDK resulted in a lot of time spent reading and understanding source code. Once set up, an XML file was downloaded from the MyMaps project from which all of the coordinates were loaded into the application. A paper prototype was developed in order to gain an understanding of the overall structure of the map interface (Figure 8).

The spawning of the nodes on top of the map appeared straightforward at first, by simply using the following method:

```
AbstractMap.GeoToWorldPosition(Vector2d latLong, bool
     queryHeight);
```

It would convert the latitude and longitude of a point of interest into Unity coordinates, relative to the map GameObject in the scene. The nature of the SDK is such, that these coordinates needed to be changed on each Update() cycle of the engine in order to account for the map scroll. This became apparent after examining one of the examples that come with the framework.

A major issue that was continued in the following sprint was the addition of routes on the map. One of the Mapbox examples suggests starting a Unity Coroutine which makes a request to the Mapbox servers for Walking directions and updates the map every second. There are, however, two issues with this approach and its suitability for the project. Firstly, a GET request every second is an expensive operation both from a performance and a monetary point of view. Secondly, the lines drawn on the map would change dramatically when scrolling or zooming in on the objects. The issue was left uncompleted and was picked up in the next sprint.

The Select Path interaction was also developed in this sprint. It is the only Augmented Reality scene that does not require a surface, as the pictures are placed in relation to the Player Object. Thanks to the way Unity and ARCore work, the images would be placed at a constant distance from the Camera and will always be out of reach, but would still move as the device rotates. An example from the most recent version outlines the process of switching scenes:

```
Ray ray = ARCamera.ScreenPointToRay(touch.position);
RaycastHit hitObject;
if (Physics.Raycast(ray, out hitObject))
{
    string pathName = hitObject.transform.Find("Text")
    .GetComponent<TextMesh>().text;

    GameObject.Find("FrameContainer").Destroy();
    Manager managerScript =
         GameObject.Find("Manager").GetComponent<Manager>();
    managerScript.currentRoute =
         dataService.getRoute(pathName);
    managerScript.switchScenes();
}
```

B.3 Sprint 3

Start Date: 11th of March
End Date: 27th of March
Duration: 16 days

Goals: This was the most productive sprint from a features point of view. The entire duration of this block was focused on the application with the Application Manager taking a priority. The routing of the previous weeks was to be continued, as well as a complete User Interface, a SQLite database and a transition between

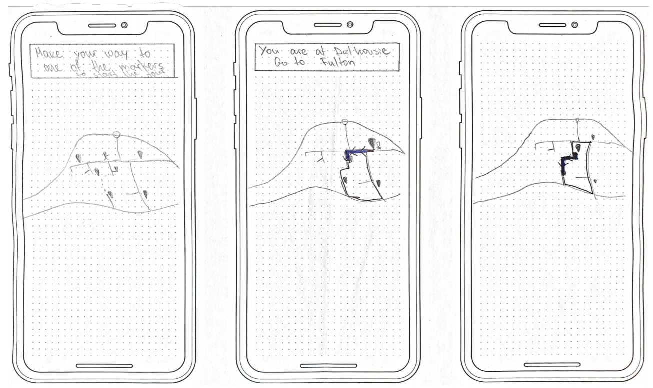

Figure 8: Paper prototypes of the Map interface

interactions. The Kanban board for the sprint is available under the "Week 10 Meeting" Project in the GitHub repository.

Outcomes: One of the first implemented features was the SQLite database. The application uses it to store information about routes and points of interest, while also keeping track of visited nodes. A database diagram is shown in Figure 9. The DBMS was chosen for its simplicity and small footprint, as the application did not need for a complex database on a remote server. Three tables were created: PointOfInterest, Route and POI_Route with the last one being a joining table. Due to SQLIte limitations, integers columns were used instead of boolean ones, as the language does not support the data type.

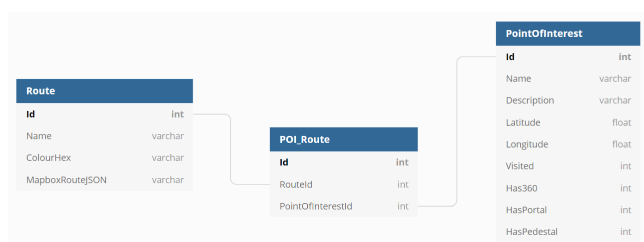

Figure 9: SQLite Database Diagram

The work from the previous sprint on drawing the paths onto the map was continued. The constant Mapbox server communication was omitted and instead, the path for each route was requested once, with the JSON response being saved in the database. The data was then referenced in the original method, with the coroutine updates only redrawing the paths.

The development of the Application Manager was another important aspect of this sprint. It is responsible for handling the communication between scenes and updating the User Interface accordingly. An example of its use can be seen when querying for the markers to spawn on the map:

```
Route currentRoute = GameObject.Find("Manager")
    .GetComponent<Manager>().currentRoute;
if (currentRoute != null) {
```

```
    pointsOfInterest =
        dataService.getPointsOfInterestForRoute(currentRoute);
} else {
    pointsOfInterest = dataService.getPointsOfInterest();
}
```

The logic involved in reaching a node was also implemented. A helper class is used to calculate the Haversine distance between two points. It is used to check the current location of the device with the spawned nodes on the map.

```
int distance =
    (int)DistanceCalculator.calculateDistance(locationLatLong,
    locationsOnMap[i]);
```

Being near a location makes the corresponding AR interactions available by using flags in the database. A paper prototype was used to identify the overall design of the interface and the positioning of the buttons (Figure 10). A more recent iteration moved the "Select Path" button from the top left corner to the bottom right, as that makes it more reachable using one hand.

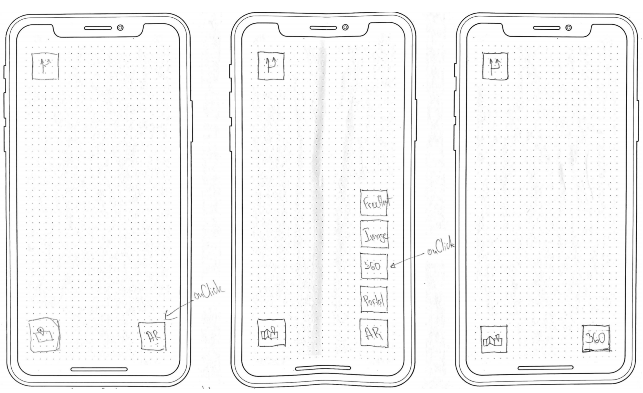

Figure 10: Paper prototypes of the User Interface

B.4 Sprint 4

Start Date: 27th of March 2020
End Date: 3rd of April 2020
Duration: 7 days
Goals: Having completed the tasks involved with creating an Application Manager, the goals for this sprint expanded to adding an additional Pedestal interaction and then adding the information that gets displayed on each node. Some minor bug fixing was also assigned to this sprint, as well as making preparations for the user testing. A second ethics submission was made during this block, which delayed the experiment by another week.

Outcomes: Work in this sprint began with fixing issues from the previous commits. The colours defined for each path did not work as expected on the testing device. This was due to a change in material order on deployed instances, which resulted in the wrong texture being changed. Other issues were associated with the improper toggling of the Camera/Map buttons, which was a result of a simple error in a conditional statement. Finally, the tooltips above map markers were made to disappear when clicked again.

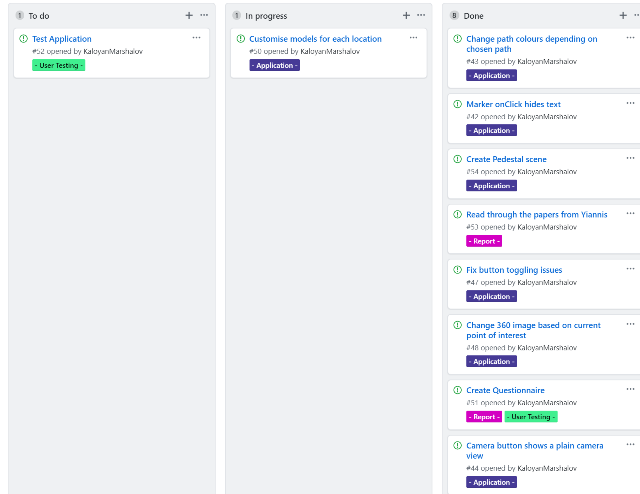

Figure 11: Kanban board for Sprint 4

A major addition to the application was the new Pedestal interaction. It uses a model of a gallery pedestal on which images, models, videos and text can be presented. This interaction was made for buildings with a lesser significance than others, as it could only fit a small amount of information. Each node had its own arrangement of the object which was saved in a Prefab. This strategy was followed for the Portal interactions as well in which pictures and objects were placed inside a 3D model of a Renaissance building. The Photo Spheres followed a similar strategy, with 360 images changing the inside texture of a sphere object. The customisation of models for each point of interest was not finished in this sprint and was continued in the next one.

All three of the interactions were getting loaded at runtime after a check of the corresponding database flag. Storing boolean data for the availability of interactions was necessary because of the way the Unity engine works. While it is possible to check for the existence of a file in the Assets folder, it is not possible to determine if a Prefab is available. A possible workaround could be to try to load the Object in a try-catch block. That would, however, produce unnecessary complications, as the User Interface code would have to load Prefabs which it doesn't need and would, therefore, result in a weaker code cohesion.

The task unrelated to software development was to prepare for user testing by creating the online questionnaire and organising all of the materials for the study. Device GPS mocking was tested out and a list of commands was written for the purposes of speeding up testing. Google Forms was used to create the survey and a test run of the application was done, in order to ensure that the study is ready.

B.5 Sprint 5

Start Date: 3rd of April 2020
End Date: 15th of April 2020
Duration: 13 days
Goals: There were no major software development goals for this final sprint outside of finalising the application by adding in

the last few interactions. User testing was intended to happen in this time frame which was unfortunately held up by an ethics re-submission. A larger focus began to be placed on the report during this period.

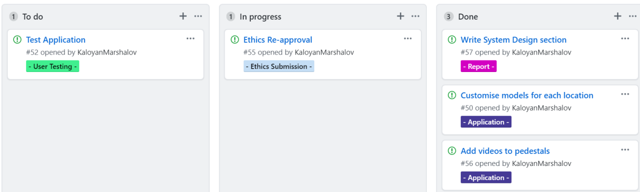

Figure 12: Kanban board for Sprint 5

Outcomes:

The work for this sprint began with work on a second ethics application, as it was necessitated due to the changes made in the study. Once completed, efforts were focused on adding in the last remaining Prefabs. Videos were also added to Pedestals, which were made from an old video provided by the University Archives. The two separate builds were made and the testing device was prepared for user evaluations. The differences in the two testing applications were very minor. The dynamic instance had one path deleted from the database, including its relationships in the POI_Route table and any Point of Interest which is only available for that route. The static instance did not make any changes to the database, but instead hard coded the route and disabled the Select Path button:

```
currentRoute = dataService.getRoute("Formal and Applied
    Sciences");
GameObject.Find("SelectPathButton").SetActive(false);
```

The rest of the work done during the sprint was in expanding the report, namely the System Description and the Methodology sections.

C LEGAL, ETHICAL, PROFESSIONAL AND SOCIAL ISSUES

C.1 Summary of Legal Issues

Considerations for the legal handling of information have been made throughout the testing and development of the application. Special care is taken to safely and securely store anonymised data from user testing. All resources used in the project are for educational purposes only and are owned by their respective owners. All copyrights belong to them. No images, models or videos have been used without permission and proper citation, recognising the intellectual property to all third party work. The use of the Unity engine ensures that no open format models can be downloaded. The study was appropriated to be in line with the most up-to-date COVID-19 restrictions.

C.2 Summary of Ethical Issues

Ethical approval was obtained from the Dundee University School of Science and Engineering Ethics Committee. Two submissions were made, with the second being necessitated by the change in the experiment structure due to the restrictions on public movement. Participants were selected from within the same household, as no other options for physical interaction were available at the time of testing.

C.3 Summary of Professional Issues

The British Computing Society Code of Conduct was followed throughout the project in order to ensure a high level of professional integrity. An outline of professional practices for design, development and testing have been laid out throughout the report. Professional tools, frameworks and programming languages were used for development. A list of creators of the resources used has been included in the GitHub repository.

C.4 Summary of Social Issues

Social inclusion practices have been followed throughout, taking care to ensure the proper level of usability and accessibility of the application. The result of the tour has been to expose the digital artefacts to a broader audience, which might not otherwise have access to it, thus increasing the reach of the information presented.

D INTENDED METHODOLOGY

The original plan for the experiment involved a walking tour around campus using the application installed either on a testing device or on the participant's personal mobile phone (should it cover the minimum requirements for running the Augmented Reality framework). The users would be able to walk between nodes in order to progress the tour. An additional "Select Next Building" button would have been added, which would display a suggested walking route to that node. This feature was omitted from the current application, as it would not have been useful for the participants in the study.

D.1 Design

The design of the application, routes and available interactions would have remained identical to the ones outlined in the main report (§3.1 and §3.2). The intended evaluations would have been carried out the same way, except for two minor changes. First, the risk evaluation for outdoor testing is different from the one for indoor testing. Participants would have been briefed on the caution they need to exercise when crossing roads, walking on busy streets or during bad weather. The full risk assessment is part of the first ethics submission and is linked in Appendix I. The second change to the evaluation involves an extended time frame for testing. Users would have been restricted to using the application for no longer than 90 minutes, meaning that the first part of the study would have been done for no longer than 65 minutes and the second one for no longer than 25 minutes. The rest of the evaluation would have been done inside one of the labs in the Queen Mother Building.

D.1.1 Materials, Equipment and Setup. Experiments would have been carried out outside, within the Dundee University campus. Participants would have been followed around, in order to ensure their safety, as necessitated by the Risk Analysis.

Applications would have been installed either on the user's device or on a testing Samsung Galaxy S10 Plus phone, set on maximum screen brightness, screen timeout of five minutes and full media volume. Additional logging of exact coordinates of users would have been implemented when using the testing device, in order to facilitate data analysis. There would have been no need for an additional GPS mocking software on the devices.

D.1.2 Participants. Participants would have been identified through convenience sampling. There would have been no inclusion/exclusion criteria and users would have been approached using email and social media channels. The sample size for the work would have been no larger than 20 participants.

E CRITICAL EVALUATION

Overall, the project fit well withing the defined timeline and covered all of the requirements throughout. The initial plan of completing the Literature Review section in semester 1 and following up from that in semester 2 was followed with positive results. The structure of the report was also well suited to describe the work done in the main body and provide additional information in the appendices. This resulted in the writer being more comfortable with the style of research papers and provided him with valuable experience in academic writing.

There were a couple of aspects that could be improved upon in future work. For example, the definition of hypothesis prior to testing could have been useful, as it would provide better guidance for the semi-structured interviews. The development of the application could also have been sped up through tutorials for each of the major frameworks. Time should be allowed for this when sectioning out the project timeline in future Gantt charts. Despite that, the author is very happy with the quality of the final product.

E.1 Project Problems and Difficulties

One of the obvious issues towards the end of the project was linked to the global efforts to combat the COVID-19 virus. This led to a series of delays in testing and restricted the number of participants that could be recruited. A full breakdown of the changes made to the project because of the virus is available in Appendix M.

Other difficulties in development were related to the lack of documentation for the Mapbox SDK. Although the framework provides a wide array of functionality, the majority of it is undocumented and its proper usage is unclear. The only real way of using the SDK was to study the source code of the examples and the framework itself. There were also other incompatibility issues between Unity and ARCore, as only specific versions were able to be used together.

F SOURCE CODE

Available on the following link: GitHub repository or inside the folder named "Application" of the project submission. The directory "Application/Assets/Portal" contains the majority of the written source code, while the other folders contain the frameworks for the project.

G USER MANUAL

Available on the following link: User Manual or inside the folder "Appendices/User Manual" of the project submission.

H MEETING MINUTES

Available on the following link: Minutes or located inside the folder "Appendices/Meeting Minutes" of the project submission.

I ETHICS SUBMISSIONS

Available on the following link: Ethics or inside the folder "Ethical Approval" of the project submission.

J MID-PROGRESS REPORT

Available on the following link: Mid-progress report or located inside the folder "Appendices/Mid-Progress Report" of the project submission.

K PROJECT FEEDBACK FORM

Available on the following link: Feedback form or located inside the folder "Appendices/Project feedback form" of the project submission.

L PROJECT LOGBOOK

A combination of commit history, OneNote pages and scans of a physical notebook are available on the following link: Development Logs or located inside the folder "Appendices/Project Logbook" of the project submission.

M COVID-19 STATEMENT

Available on the following link: COVID statement or located inside the folder "Appendices/COVID statement" of the project submission.

N STUDY MATERIALS

Consent form, Information sheet and Informal conversation guide are all part of the Ethics submission in Appendix I. The Augmented Reality Questionnaire is available on the following link: ARI Questionnaire.

O USER TESTING RESULTS

The anonymised and collated results from the user testing are available on the following link: Testing Results or located inside the folder "User Testing" of the project submission.