Chapter x
In Darwin's Garden: an evolutionary exploration of augmented reality in practice

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Abstract
This chapter discusses the rapid developments in augmented reality and mixed reality technologies, from a practitioner's perspective of making the augmented reality sculptural work *In Darwin's Garden*. From its conception in 2012, to its exhibition at *Carbon Meets Silicon II* in 2017, the advances in augmented reality technology led to an interplay between the goal of the creators and the technological realisation of that vision. The art, design and technology involved, generated a reactive process that was mired in external influences as the accessibility to augmented reality became commercially valuable and subsequently restricted. This chapter will be of interest to anyone who wants to understand more about the possibilities, technologies and processes involved in realising mixed reality practice and about the commercial culture that supports it.

Keywords: Augmented reality • Sculpture • Extended realities • Transmediation • Embodiment • Virtuality

x.1 Introduction

The artwork *In Darwin's Garden* was developed by the artist Chris Meigh-Andrews with the collaboration and assistance of Rowan Blaik, Head gardener at Down House, and the author, a design educator and researcher at the University of Chester, UK.

Chris Meigh-Andrews' art practice considers the resonance of place, by using moving image to discuss temporality and the relationships to space, of history and natural forces. He produces site specific installations that examine spatio-temporality using technological devices. *In Darwin's Garden* explores the historical resonance of the old mulberry tree in Charles Darwin's home, Down House in Kent. The tree was there when Charles Darwin lived in the house and as Chris explained in an interview for the *Leonardo Electronic Almanac*:

> *is a living link to the past, and through that connection there is a tangible nexus with the history of ideas, to science, and to the development of theories that have profoundly shaped our sense of what it is to be human* [1]

The artwork comprises of two related works where the mulberry tree is central to the viewer's experience. In the first work, the three-dimensional structure and environment are digital; viewed on a screen or recently explored using a virtual reality headset. The second work is a physical sculptural form, with an augmented digital object at its centre.

The digital representation of the tree used in both works, was formed from photographic imagery that included a year of time-lapse photography collected from four cameras placed in the garden of Down House. This body of time lapse photography was the catalyst for the development of a digital 3D form. Chris Meigh-Andrews discussed how *"3D visualisation seemed a natural extension and progression*

from previous work, and deeply related to the fact that the mulberry tree is itself a growing, living organic structure" [1].

Fig 1. The Mulberry Tree, © *C. Meigh-Andrews 2019, reproduced by permission*

The mulberry tree is now in decline and requires human intervention through the use of man-made structures to support the weaker branches (Fig. 1). *In Darwin's Garden* uses full size facsimiles of these structures in both forms of the artwork. In the augmented sculptural form these create a physical space that the digital tree inhabits and the viewer engages with this physical space, exploring the digital form within it. The collaborative challenge was how to implement this augmented reality sculpture, combining both digital and physical elements in order to facilitate an immersive experience for the viewer.

The completely digital form of *In Darwin's Garden* is a three-dimensional structure set in an environment that can be viewed in a web browser, and more latterly this has been explored using a virtual reality headset. Within a web browser this work is viewed as a window into a digital space, seen as another reality. The viewer can move around this digital space using a keyboard or mouse, but their physical reality is separated through the implicit knowledge that the artwork is a reality contained within the screen. In a virtual reality format the viewer stands in front of the structure with the real world expunged from their sight. Virtual movement is by a hand held controller but the viewer's body does not move due to hardware and safety restrictions. The virtual reality experience is exactly that, a virtual reality that disappears when the headset is removed and the viewer returns to the real world.

These web and virtual reality (VR) implementations, while effective in their own right, do not offer what the use of augmented reality (AR) brings to the experience. Part intention, part necessity, the AR version of *In Darwin's Garden* brings an embodiment to viewing the artwork that is worthy of independent discussion. The technical journey to this augmented realisation is also of interest as the technology's rapid development posed interesting questions of remediation across realities. This chapter discusses AR and its use within a project that combined physical and digital structures, theoretical notions of digital and physical space and also details of the technical elements of AR for arts practice. There is also the relationship between practitioner and technology and the evolution that occurs over time, as both evolve while developing the project, that is an important thread running through this

chapter. My background is in industry and education, with a design practice that researches the understanding of digital space and notions of place, often working with computer animation and game engines. The approach to this collaboration was from the aspect of both designer and researcher into the possibilities of digital realities. The development of AR was, and still is, resolving the design and theoretical language needed to discuss its application. In 2011 Papagiannis likened AR to early cinema

> *…in its infancy, when there were as yet no conventions. AR, like cinema when it first emerged, commenced with a focus on the technology with little consideration to content, marked as secondary* [2].

The rapid and continued development of AR means it will take time before there are clear artistic conventions, for as Pearson states technologies are *"not developed by the artistic community for artistic purposes but by science and industry to serve the pragmatic or utilitarian needs of society"*[3]. This is reflected in the artistic development of *In Darwin's Garden*, which was at the mercy of commercially focussed technological developments. But, as Malina states when discussing art forms enabled by the computer, *"since contemporary culture is being driven by contemporary science and technology, one of the roles of the artist is as 'colonizer' of the technology for artistic end"* [4]. Chris Meigh-Andrews stated this was an extension to his previous work—it was definitely an extension to my knowledge of designing commercial applications for digital realities— so with the artistic vision discussed, we set out to explore the possibilities for an augmented sculpture.

x.2 Augmenting Reality

To augment reality is to blend another reality with a person's physical reality, so both realities are perceived as a single seamless environment. In the most common and current context the phrase 'augmented reality' is thought of as blending digital imagery with the surrounding environment. It is often discussed as a technological development and not as a theory of blending a different reality with the real world. The most identifiable forms of augmented reality are looking at a mobile phone screen and seeing digital objects blended with the live camera feed, or more recently using smart glasses that directly overlay the digital elements onto the user's field of view. Yet the theoretical concept of augmented reality relates to more than a modern digital development and has a broader historical context in art and design practice. There are studies of artworks from Hellenistic times that superimpose painted realities onto interior walls, in a form designed to create the optical experience of both artwork and real world as a single reality [5]. The scientific development of perspective during the Renaissance led artists to the development of trompe l'oeil, mixing real and painted realities. Neither trompe l'oeil nor digital augmented realities require the viewer to lose their sense of reality; both blur the optical boundaries between what is real and what is not.

Renaissance theories of perspective are important discussions for the future of AR as the Albertian perspectival system that actualised trompe l'oeil is still driving the Cartesian logic of today's computer space and subsequent digital realities. McGuirk and Summers argue that augmented reality technologies bring *"psychological and even philosophical concerns with regard to those [Renaissance] perspectival systems that underpin these technologies"*[6]. And recommend the investigation of other forms of perspective for AR such as ocular, floating point or multi-perspective forms that are less Western specific. Artists do not rely solely on Renaissance theories of perspective, so it may now be time for the artistic 'colonizers' of AR technologies to explore other theories for developing practice and as Papagiannis discusses, not just remediate the current contexts and forms of AR but break out from the current environment AR is discussed in [2].

x.3 Extended Realities

The discussion of augmented reality in its digital form must be understood in the context of other digital realities as technology continues to drive this area forward and create new forms. A catch all term used

for this area is Extended Realities, commonly abbreviated to XR. It refers to all forms of combined real and virtual environments including; augmented reality (AR), virtual reality (VR) and mixed reality (MR). If a spectrum is considered, where a real environment and a completely virtual environment are at opposite ends, then the range in between these two endpoints is where realities are mixed in different ratios. This is Milgram's Reality-Virtuality Continuum [7], a concept to aid in the creation of a taxonomy for mixed realities. The possibility is that this range may not be discrete but continuous and it has since been extended in another dimension using mediality. In order to be clear for this discussion we shall briefly consider what defines virtual, augmented and mixed realities.

Virtual reality is a completely immersive reality that replaces the user's real-world environment with a simulated one. A headset covers the user's eyes, headphones cover their ears, then visual imagery and audio immerse the user in a digital environment. There may also be elements of haptic feedback to enhance the immersion.

Augmented reality, in its digital form, is where the real world is overlaid with computer generated imagery with the intention to create the illusion of a single seamless environment. In order to avoid limiting AR to specific devices Azuma [8] stated three characteristics for AR:

1. Combines real and virtual
2. Interactive in real time
3. Registered in three dimensions

These where written before mobile phones became powerful enough to run AR technologies and so where prescient in their thinking.

Mixed reality is where virtual objects can interact with real world objects in a form where the user can act on either, or both, with them having an appropriate reaction. A mixed reality headset uses sensors to map the real objects and track their movements within the field of view so digital objects can appear attached to real objects. The headset can recognise hand movements and the user can manipulate a digital object as if it were in the real world.

Extended realities will continue to develop and so definitions may be redefined by future technological advances.

x.4 The Drivers Behind the Development of Augmented Reality

Computer driven augmented reality was first explored in 1968 by Ivan Sutherland [9] but remained a specialist area until the early 2000's when increases in processing power in affordable mobile devices enabled AR to become a viable technology with which to engage users. The development of a variety of AR software development kits (SDK's) for mobile devices meant developing AR applications became steadily more accessible to anyone who understood a certain level of coding. Companies released SDK's free to developers, but this meant the developer was locked into that company's technology [10].

An alternative to using an SDK is the use of augmented reality browsers. Developers register with the browser company and can then create AR experiences by uploading digital files to the company's cloud service. The browser will then download these files to a user's device. This business model locks both developer and user to the specific AR company and their browser technology.

The use of AR browser applications has enabled graphic designers to create printed material containing images that play video or show three dimensional objects when the reader uses the specific browser on their phone. With this development's ease of use, an array of print based AR advertising was created as a way of attracting attention to products and appealing to mobile user's curiosity to try AR experiences. The monetisation of AR as an advertising format instigated the development of an array of apps and SDK's and the developers of mobile devices took note.

Metaio GmbH was an augmented reality development company started in 2003 and used in the initial prototypes for *In Darwin's Garden*. They provided an AR web browser and development kit for programming AR applications for computers, web and mobile devices. In May 2015 it was reported that Apple had bought the company [11] and Metaio announced all products and subscriptions were to be discontinued. Developers using Metaio had to find another way to serve augmented reality experiences to their users before the deadline of December 2015. In September 2017 Apple released iOS 11, their mobile operating system for iPhones and iPads, that included support for augmented reality development. Their application programming interface (API), called *ARKit*, allows third party developers to build augmented reality applications that can take advantage of the devices functionality and processing power. The hardware developers of mobile devices where now directly supporting the development of augmented reality on their products through their operating systems.

x.5 Augmenting Art

In contrast to the evolving monetisation of AR artists had recognised the opportunities for their practice. In October 2010 Sander Veenhof and Mark Skwarek created the *WeARinMoMA* exhibition in the Museum of Modern Art (MoMA), New York. This was not an official MoMA exhibition, but as the exhibition's website states an invasion showcasing the *"radical new possibilities and implications Augmented Reality is bringing to the cultural and creative field"* [12]. Using the *Layar* augmented reality browser app [13], an internet connection and the global positioning system (GPS) on their phones, visitors where able to see digital objects inserted into MoMA's gallery spaces. Since then this form of unauthorized intervention has resulted in a range of dialogues between artists and exhibition spaces; exemplifying the conflict and opposition to traditional conventions both Pearson and Papagiannis discussed [2], [3]. MoMA is still being used in this way with the 2018 *MoMAR project* targeting permanent displays in the museum for AR artwork interventions [14]. On the *WeARinMoMA* website Veenhof and Skwarek added a cheeky *"PS The MoMA is not involved yet"* [12], and while MoMA have never responded they do now have at least one art work in their collection that uses AR, Martine Syms, *Incense Sweaters & Ice*, 2017, [15].

x.6 *In Darwin's Garden*: Producing the Digital Environment

Production on *In Darwin's Garden* started with the web based digital environment, as this was the less experimental production process. It was intended that digital elements from this web format could then be used in the creation of the second format, the augmented reality sculpture. Both artworks could be split into component parts of the tree and the supporting structure. The tree would be digital in both, but the supporting structure would be digital in the web format and physical in the AR format. The relationship between the component parts and their true to life scale to the viewer was deemed crucial to the experience.

> *…the old tree is now in its decline, with man-made structures supporting some of its branches. We would like to make full-size facsimiles of these structures to use as a foil to the virtual image of the tree and develop a work that would enable visitors to explore the tree in virtual space and time.* Meigh-Andrews [1]

The viewer of either experience should encounter a full-size tree and supporting structure. This should not be a perfect digital representation of the tree in three-dimensional space, as this would not carry the empathic connection of standing next to a living, dying tree. The viewer in this experience has to feel they are up close to a very specific mulberry tree, physically stepping around the framework supporting the old tree, getting close to the trunk and looking up through the canopy to the sky.

At the time production started there was experimental photo software, such as *Photosynth* [16], that could crowd source photos of a landmark and then build a digital photo cloud simulation of the landmark from them. This approach was a precursor to photogrammetry, now used in the 3D scanning of real

objects, where multiple photos are captured and the software extracts information from these to build an exact three-dimensional representation. An exact replication was not the intention for *In Darwin's Garden*, but a representative photographic form where the viewer builds their own mental image of the real tree through the photo cloud approach offered interesting possibilities. This format also had links to David Hockney's two-dimensional photo collages—referred to by the artist as 'joiners'—but in a three dimensional form that would be at the actual scale of the subject matter.

Using 3D modelling software, the tree structure was assembled as a photo cloud comprising of single planar shapes with a photo applied to each. These photo planes were arranged in such a way as to create the abstracted form at the scale of the real tree. The physical framework supporting the tree was modelled so as to link with the tree in a manner representative of the real-world site. The time-lapse images where placed as clouds of photo planes around the structure in locations that where spatially representative of the camera locations (Fig. 2).

Fig 2. The web-based form of *In Darwin's Garden, © A. Summers 2019*

The main technical consideration for this design approach was the quantity and quality of photographic images, more images equates to a larger file size and an increased download time. The photos included the time-lapse imagery meaning a single photo plane would contain twenty time-lapse photos, played in a looping sequence, and there were twenty photo planes for each of the four cameras. In 2012 the average speed in the UK was around 12.0Mbit/s so the first version of the app at 86Mb would take just over 1 minute to download. This was considered to be too long.

To reduce file sizes a consideration of how close a viewer will get to a single image was determined. It was expected that a viewer would be able to walk up to and into the lower areas of the tree structure. This meant that a single image in the lower section of the tree could fill the viewer's screen. Therefore, any image at this lower level must be the same resolution as the screen the viewer is using. A standard resolution, at that time, for playing a standalone application on a computer monitor was 1024 by 768 pixels.

Photo planes in the middle of the tree are at a height above the viewer's eye line so could be a lower resolution, as no single image will ever fill the viewer's screen. The photo planes at the top of the tree were bigger in scale, but fewer in number, in order to create areas of foliage and blue sky. These needed to be at the screen resolution as these would again fill the viewer's screen when looking upwards.

The author's previous design practice had explored the analysis of how trees move in the wind, applied to game environments, where wind and weather affected how a player interacts with an environment. Wind movement was explored for *In Darwin's Garden* using an algorithm to create a random direction and strength of wind. Photo planes fluttered emulating foliage in the wind and added something to the presence of the tree structure, but it was considered too much of a simulation; ironically it did not feel natural in the digital environment. On testing it was left running over twenty-four hours, only to discover an issue in the wind algorithm meant that the photo planes moved imperceptibly over time. The whole tree structure would move across the space, effectively walking out of the environment. A key development point was to remember to leave each iteration running for a reasonable length of time, as it might in a gallery situation.

Experimenting with programming the photo planes to face the viewer meant that an element of movement was present but not overpowering. As the viewer moves the photo planes overlap and intersect while rotating to face the viewer. This kept a sense of physicality and real world movement within the abstracted foliage.

In its web-based form, *In Darwin's Garden* explores space and temporality surrounding the notion of place. The viewer can see Down House in the background locating them in the space of the garden. Within that space the tree's supportive frame is treated as a physical barrier the viewer must move around; while the photo planes of the tree offer no resistance to movement and the viewer can move through them. The photo planes containing the time-lapse imagery hold the location of the real time-lapse cameras making the viewer spatially aware from the image of the garden space and the real-world tree. This web version was finalised and uploaded to the IDG web site [17] and in August 2012 presented via Leonardo Electronic Almanac's digital media exhibition platform [18].

x.7 Producing the Augmented Reality

x.7.1 Production Process

At this point in production with digital assets assembled the consideration of how to transfer the conceptual vision to an augmented reality experience began. Transmediation across forms of extended realities is not a direct process, as virtual reality offers complete immersion which brings greater levels of control over the viewer's experience than augmented reality, where the viewer can see their physical surroundings. The transmediation of *In Darwin's Garden* was not a simple transfer of digital assets; it meant overcoming technical issues while working with the dialogue between digital and physical forms, leading artist and designer on an explorative journey into the possibilities of augmented reality. Design enquiry alongside technical investigation is required for each of the component parts in an AR experience and this is a useful way to break down and reflect on the process. Those component parts are:

1. Viewing Device: this runs the app and requires a screen and camera.
2. Augmented Reality Application: to be installed on the viewing device
3. Digital Asset: to be displayed on the viewing device,
4. A Positioning Target: often an image but may also be a physical object or a GPS location that triggers and positions the display of the digital asset.

The principal for an AR app is that when launched it accesses the viewing device's camera, displaying the camera feed on the screen of the device. When the camera is pointed at a target image the app recognises this image and displays the digital object superimposed onto the camera feed. The digital

object holds a fixed spatial relationship with the target image, so when the device is moved around the target image the display shows the viewer to be moving around the digital object.

x.7.2 Viewing Device

The ability to position the work in any indoor or outdoor location was important for the development of *In Darwin's Garden*. In an indoor gallery a viewing device can be supplied with a preinstalled application. Using a specific device means any application can be fully tested to ensure it works properly. Devices can be updated and interesting developments in technology, such as advances in augmented and mixed reality glasses, can be explored.

In an outdoor context it is unlikely that a viewing device can be left securely at a site, so the viewing device has to be the mobile phone the viewer is carrying. The application will need to be developed for a range of devices and registered with the appropriate application stores. Downloading the application will be limited by the viewer's network transfer speeds and data allowance so its file size will be a factor in any viewing experience. If a person encounters the work outdoors and is not carrying a suitable device the engagement with the sculpture will only be through its physical form.

x.7.3 Application Development

To use a pre-existing augmented reality browser would mean any viewer first has to download it from the internet, then the digital object is downloaded while the browser is running. This is potentially the fastest development process and advantageously uses a proven and tested browser. But it brings in the extra stage for the viewer of dealing with the AR browser and its brand, which can act as a barrier to the process of engaging with the artwork. If an application is built specifically for the work it will contain all the information needed and is the only item to be downloaded. The disadvantage is that he application will need to be developed, tested and certified in order to be distributed by an application store. Also instructions on where and how to download any application must be visible near the installation. Augmented reality apps and SDK's for building apps are constantly being developed and improved upon but a useful starting point is *A Comparative Analysis of Augmented Reality Frameworks Aimed at the Development of Educational Applications* [19].

The decision was made to use the Metaio software tools to develop the augmented reality sculpture. This provided access to *Junaio*, a free mobile AR browser app for iOS and Android devices, along with software development kits for programming, PC, web and mobile augmented reality applications. The *Metaio Cloud* stored content online and the *Metaio Creator* software was a very good drag and drop creation system. Metaio also organised the *insideAR* conferences at the forefront of technological developments in this field. This suite of software gave flexibility in terms of choice of device, application development or a ready to use AR browser, and an offline or cloud-based approach. Metaio also supported the Epson Moverio BT-200 Smart Glasses that contain the processing power of a smart phone and the ability to superimpose the device screen upon the field of view of the user. These offered exciting possibilities for AR experiences so development of the AR form of *In Darwin's Garden* began using Metaio tools, smart devices and Epson's Moverio glasses.

x.7.4 The Digital Object

There are various forms of digital object that can be displayed using AR; a two-dimensional graphic in vector or raster form, a video file, or a three-dimensional digital object which may be static or animated. Images, text and video are two dimensional objects that can be mapped directly onto a target object to overlay it, or programmed to appear above it and always face the camera. A digital object might be 'smart' meaning it can continually access device functionality, such as GPS location, to provide a constantly updated flow of information.

In 2013 AR advertising was starting to become more common place. AR was being used to play videos over car advertisements in magazines and to show digital replicas of the advertised car [20]. Three-

dimensional objects can sit directly on or over the target object aligned to face a specific direction and also animated. A major factor in building digital objects to use in AR is file size. The larger the file size, the longer its download will be and the more likely the user will move on before the AR experience gets started. In the web version of *In Darwin's Garden* the size of the digital asset for the tree was 36Mb; this meant a minute or more download time over a 3G mobile network. To explore file size options different iterations of the digital asset where created by adapting the number of photo planes, the resolution of the photos and the number of time-lapse images in each animation. The augmented experience required a level of transmediation led by file sizes but also considering a viewer's accessibility to an internet connection, the viewing context in terms of location, and the active engagement with the augmented reality experience.

Firstly, the time lapse images were relocated to be in the tree structure amongst the images of foliage. A physical reason for this was the viewer might not be able to walk across a gallery in order to see the images as in the web version. Importantly they were now embedded in the experience of the tree, like fruit amongst the foliage. The viewer could recognise that some photo planes contain a sequence of landscape images as opposed to images of tree foliage. These became objects that draw the viewer into the digital space, so that they move in the real world around and through the physical framework. An interesting time lapse image is where a portrait of the artist appears because Chris Meigh-Andrews was working on the camera as it took a photo, this creates the chance that a viewer will encounter the artist within the AR experience.

Fig 3. The augmented digital tree structure seen to scale, © *A. Summers 2019*

In the augmented experience the backdrop photos of the house were removed because they show a fixed landscape behind the digital tree that is not there within the real world context; this would break the viewer's immersion. Instead the view only holds the digital tree and behind it the viewer's actual location appears, situating this digital form in the real landscape with the support structure. This means other viewers can be seen as part of the view, situating them in both the digital and physical realities, and true to scale against the digital tree (Fig. 3).

x.7.5 Target and Positioning

The most basic problem that limits the immersiveness of an augmented reality experience is that of registering the digital asset correctly over the target [8]. Advances in the technology needed to register a digital file in the correct position and hold it there have made a huge impact to user immersion in extended realities. Early AR systems relied solely on images, known as fiducial markers, with the developer registering each target image to display an appropriate digital file. The markers placed in the environment where often black and white block patterns which could be distinguished in terms of direction to the camera and angle of view. These attributes could then be used to place the object on the target image with the correct spatial and perspectival relationship to the camera. Developments in image

processing and camera resolution in mobile phones has meant that photographic images can now be used as targets, although contrast and asymmetry in a target image are important in order to calculate direction and angle of view.

Another positioning system used is the device's global positioning system (GPS). This is reliant on the efficiency and stability of the GPS signal and limitations occur for indoor locations where GPS information may be hard to determine. If GPS tracking is unstable then small changes in location can make the digital object appear to jump around in front of the viewer.

Metaio, then subsequently Apple's *ARKit*, can use an object as a target. This requires the AR app to know the shape of the object in order to calculate direction and angle of view. Developers create separate apps dedicated to scanning objects for use as a target.

Advances in environment recognition from camera feeds has resulted in the ability to position a digital file using marker less tracking. With this system the app recognises the planar surface in the camera view and places the digital file onto this surface. This means there is no need to prepare an environment with markers as the digital file will locate itself and move around on any flat surface in front of the viewer.

The first iterations of *In Darwin's Garden* used the GPS tracking function within the *Metaio* software to align the digital tree form within the physical frame. Using the app outdoors the digital structure jumped around due to issues of tracking and an inability to receive accurate location information. The sculpture is 5m by 3.2m and as the viewer walked around the sculpture the GPS tracking was inconsistent. When the errors in tracking caused the digital tree to move only a few centimetres this was deemed acceptable, but when the digital tree would suddenly move a number of metres it immediately broke the immersion, as it appeared to jump outside of the physical structure. Further tests in a gallery space found that some devices might not be able to receive any GPS location information. After various tests it was decided an image based target was to be used as it was the most stable form of tracking.

An issue with positioning a large digital object is the tracking of that object when the viewing device moves off the tracking image. As the viewing device pans up the tree structure the camera loses sight of the target marker and the digital structure would become unstable. This is also an issue where a digital object moves out of the field of view but the user will expect the digital object to still be there upon returning to view that part of the environment. This is commonly referred to as extended tracking and has been important in developing the possibilities for AR for dealing with more than a single digital asset in the user's environment.

During the development of *In Darwin's Garden* Metaio developed object tracking and provided an app for scanning 3D objects. A problem was the large scale of the physical structure, as this technology was geared towards scanning small objects such as toys. Experiments with scanning a smaller maquette of the physical framework worked at the scale of the maquette but it was found that this could not be scaled up to match the size of the sculpture.

A development with the Metaio software was the ability to upload a digital model of the object that could be used for tracking a real object. This proved successful in recognising the large framework, but only if the whole framework could be seen within the camera view. If the viewer was too close to the physical frame, then the tracking could not recognise a component part in order to position the digital asset. If the viewer could be directed to approach the sculpture from a certain direction, where the camera would have a full view of the structure, then this was a viable method of tracking.

The experimentations in tracking eventually led to the use of a single image marker placed in the centre of the framework as this offered the most consistent stability during the developmental stages of production (Fig. 4).

Fig 4. CAD render of the modular framework showing the circular image marker, © *A. Summers 2019*

x.8 Exhibiting *In Darwin's Garden*

In 2015 a modular framework for the physical structure was constructed. Five steel units were fabricated to hold a wooden framework together that can support the two 'A' frames that lean inwards as if they are supporting the real mulberry tree. The structure had been modelled in CAD, (Fig. 4), in order to create the necessary construction diagrams and this also meant an exact digital object file could be extracted to be used for tracking within the Metaio software.

In early November of 2015 the augmented reality sculpture was installed outside the *Chester Contemporary Art Space* for testing. The devices chosen to run the app where iPads and the Epson Moverio BT200 Smart Glasses. Using a Metaio app the iPads picked up the structures shape and the digital tree form would hold within the structure with minor stability issues. Using the Epson Smart glasses, the lower resolution camera feed proved to be able to track the object but only in good light. When marker based tracking was used the tree structure tracked with reasonable stability on both devices. Then in December 2015 Metaio revoked all licenses for their software, as they had reportedly been bought by Apple in May of that year [11]. This stopped all applications from working and there was a certain irony that *In Darwin's Garden*, acting as a form of archive for the dying mulberry tree, had itself become obsolete within three years of its conception.

There followed a period of six months testing other SDK's and apps as commercial products competed to fill the gap in the market left by Metaio. The SDK from Vuforia was used to create a marker based tracking system for *In Darwin's Garden,* but the possibilities of object tracking where not available.

Fig 5. Using the iPad holder to view *In Darwin's Garden, © Wrexham Glyndwr University 2019, with permissions.*

In September 2017 *In Darwin's Garden* was installed as part of the *Carbon Meets Silicon 2* exhibition at the Oriel Sycharth Gallery, Wrexham. For this installation the smart eye glasses where not used as these could not be secured at the site. Instead iPads where placed in specifically designed plywood holders that slot into charging stations. These holders where robust, having handles at both ends to allow two hands to hold the device (Fig. 5). They were designed to give confidence in handling the device and remove the fear of holding, or dropping, an expensive electronic device. This appeared to change the nature of the user interaction as users where more confident holding these larger objects. The users were quick to step into the physical space and interact with the digital elements and each other. The interconnection between the physicality of the real world and the nuances of the digital world appeared to be enhanced by giving the viewer confidence in their handling of the device required to engage with the digital reality.

x.9 Conclusions

Throughout the development of *In Darwin's Garden* there has been the need to react to the advancements of augmented reality technology, as well as the disappearance of that technology when it became commercially valuable. This shifting dialogue between technology and artwork raises interesting questions of transmediation and archival. Do we keep developing an artwork until the technology facilitates the vision, or accept current technological limitations and compromise that vision? *In Darwin's Garden* is complete, yet for each new installation it is expected that the digital assets will need to be embedded in new devices because of software and hardware developments.

In its gallery iteration it became apparent that there is an embodiment which occurs between the viewing device and user that facilitates a more complete interaction with *In Darwin's Garden.* This embodiment is inherent in the physicality of holding the plywood iPad holders with both hands and moving around and through the sculpture as these devices appear to push the digital foliage out of the way. This may be in part due to the true to life scale of the digital element that facilitates a tacit understanding within body movement and the path the viewer takes exploring the digital tree. This embodiment between user and viewing device may also be due to the connection we have with our personal smart devices. We are confident in positioning ourselves and our smart device in order to get the best photo. Subsequently we

have a familiarity with the spatial connection between a camera view and targeting objects of interest within it.

The smart glasses used in developing *In Darwin's Garden* where found to have a narrower field of view than human vision, meaning a frame appeared to clip the edges of the digital tree. This broke viewer immersion, as the frame appeared to float at a constant distance away from both viewer and object. As this technology develops to allow wider fields of view this disconnect should reduce, but in this instance these devices did not facilitate a truly immersive experience for the AR sculpture.

In the end it was the physicality of holding a framing device in a form where the user can twist and angle it with their body, hold it out or look in close, adapting the screen view to their preference, that was found to be the most intuitive form for the exploration of an augmented sculpture of this size. Personal smart devices can facilitate this intuitive exploration, so for external installations of *In Darwin's Garden* it will be important for viewers to download the application in order to engage with the experience using a familiar device.

In conclusion there has been a constant tension between developing the augmented artwork, utilising technological advances, and adapting to setbacks as access to technology was withdrawn. With each advance there was a temptation to be led by technology, but the transmediation of the vision, not the application of technology, was the essential driver throughout the development process.

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