Where the Wild Things Will Be: Adaptive Visualisation with Spatial Computing

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Abstract: Augmented Reality is increasingly being used as a tool for education and communication. However, applications tend to be limited to a single-use case, due to the complexity of adapting in-situ visualisations to different environments and topographies. In this paper we propose a novel adaptive visualisation workflow designed to embed large-scale visualisations with temporal dynamics within arbitrary environments, using dynamic spatial mapping. We build a generic parameterised method to create interactive, explorable visualisations of progressive environmental augmentations. We demonstrate how this system could be used to simulate a simplified rewilding visualisation for use in education and stakeholder participation, allowing participants to explore potential ecological changes in-situ.

Keywords: Augmented Reality, visualisation, spatial computing, occlusion, rewilding

1 Introduction

The United Nations General Assembly has recently declared 2021-2030 the decade of eco-systems restoration (UNITED NATIONS 2019). Rewilding has been proposed as one path to achieving the ambitious vision of a restored level of biodiversity by 2050. Rewilding is a progressive approach towards nature restoration, which aims to restore complex ecosystems while minimising human interventions (LORIMER et al. 2015). The widespread acceptance of afforestation efforts will need innovative public policy solutions, backed by public under-standing and support (SANDOM & WYNNE-JONES 2019). This is achieved by a communica-tion strategy that involves affected communities in decision making as well as outreach ac-tivities that inform the wider public about the outcomes of interventions, potentially including opportunities for nature experiences such as guided tours through the area in question.

Visualisation plays an important role in stakeholder participation (LANGE 2011). Since the early before-and-after visualisations of Humphry Repton (REPTON 1980), we have used de-velopments in visualisation technology to improve the communication of the effects of pro-posed landscape interventions. Augmented reality (AR) has been used since its inception, as a method to enrich visualisation and communication techniques. Recent developments in AR hardware has led to a resurgence of AR applications in landscape architecture (GOUDARZNIA, PIETSCH & KRUG 2017, HAYNES, HEHL-LANGE & LANGE 2018, SORIA & ROTH 2018, TOMKINS & LANGE 2019), however realistic occlusion has been a barrier to the effectiveness of on-site visualisation (LI et al. 2018).

Realistic occlusion without environmental understanding is a difficult task in AR application development. Marker-based AR is one widespread technique, which requires detailed mod-elling and laborious spatial calibration ahead of time to get convincing results, leading to either site-specific single-use applications without environmental occlusion (GOUDARZNIA et al. 2017, SORIA & ROTH 2018), or more generic applications with no interaction with the surrounding environment (TOMKINS & LANGE 2019, 2020).

Haynes et al. (2018) have demonstrated an innovative, yet time-consuming manual approach to roughly mapping the spatial profile of an area using primitive shapes to create simple occlusion geometries (HAYNES et al. 2018). While this approach is feasible for small areas, its application would be problematic for complex or larger natural environments, and entirely unsuited to free exploration. These limitations pose a problem in harnessing the immersive power of Augmented Reality visualisation to affect change in large scale projects, such as the Rewilding Britain Initiative (SANDOM & WYNNE-JONES 2019), which are spread across many sites, or in projects with undefined sites, such as you find in outreach and education programs.

Site-specific outcomes are heavily influential in the acceptance and success of rewilding endeavours (CEAUSU et al. 2019), severely limiting the transformational role of single-use applications across multi-site projects. If AR is to play a role in large scale projects, we need an approach which can be applied to sites in which the environment is unknown in advance. The development of spatial mapping in wireless AR headsets may offer the chance to develop applications which work with the local topography, without prior knowledge, applicable across multiple sites without spatial recalibration.

To assess the ability of the latest AR hardware to address these limitations, we must adapt the way we build AR experiences, moving away from the visualisation of specific interventions, to building adaptive visualisations through procedural generation reactive to the immediate environment. We introduce the Adaptive Visualisation Workflow to dynamically visualise landscape augmentations, through a user-guided exploration process, constrained by pre-defined parameterized stages, which adapt to the local topography. By defining a set of simplified temporal stages to approximate the progression through the natural succession of plant recolonization of human-dominated landscapes (BILLINGS 1938), we show an example of how this generic visualisation engine could be used to explore a phenomenological visualisation of the rewilding process in-situ. With this work, we aim to let people experience the evolution of their wild spaces, learning not in a lab, but upon the very land concerned.

2 Methods

For this project, we have created a new Augmented Reality application for the wireless Microsoft HoloLens 2 headset. We built our application within the Unity Game Engine, using the Mixed Reality Toolkit (MRTK) Spatial Mapping library to build and interact with a continuously maintained spatial mesh of the world around the user. The dynamic mapping process ensures that no prior knowledge of topography, nor prior modelling of the intervention is required. To maintain a generic application, our experiences are designed by configuring a set of independent visualisation stages akin to snapshots in time, which are incorporated into the Adaptive Visualisation Workflow, as explained in section 2.1.

2.1 The Adaptive Visualisation Workflow

To create our AR experiences, we follow an adaptive visualisation workflow, driven by the interplay of user exploration, local topography and a configuration based scenario, shown in figure 1. The adaptive visualisation workflow aims to frame how we build AR experiences which explore procedurally generated scenarios in response to the immediate environment, using the on-site dynamic mapping process shown in figure 2. We create experiences which

can be used across sites, yet capture the underlying traits determined by pre-configured parameterisations, such as species variety, prevalence, density and dynamics.
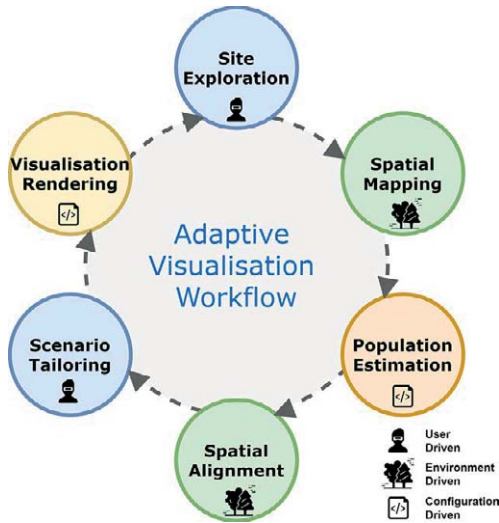
Fig. 1:
The continuous loop of the Adaptive Visualisation Workflow, driven by the interactions of the user, the immediate environment and the pre-defined scenario configuration parameters

During the experience, while wearing the headset, we begin the cyclic workflow. As the user explores, through walking and casting their gaze around, we build up a spatial mesh of the environment, as shown in figure 2. The spatial mapping is restricted to approximately 3 meters range from the participant, ensuring exploration is a key process to create larger-scale visualisations. With all newly mapped areas, we use a set of the pre-defined stages, to calculate how many new assets (for example, tree species) should be visualised, and of which types. We then spatially align the new visualisations such that they are embedded in the natural undulations of the generated mesh, as shown in figure 3. With each stage calculated, the scenario is then pruned to show only the assets required in the current stage. Finally, the results are visualised with the headset. This is an autonomous process, with the only user input being exploration, and the explicit commands to change the currently displayed stage.
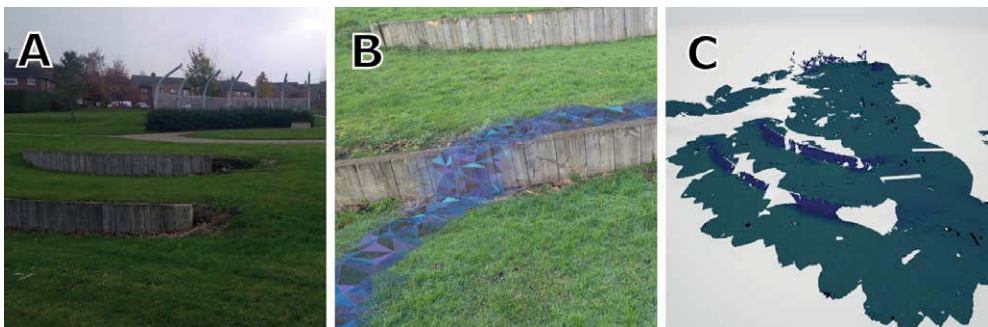

Fig. 2:   On-Site Dynamic Spatial Mapping Process. (A) A multi-layered urban green space with complex geometry. (B) The dynamic mapping process visualised as seen through the HoloLens 2. (C) A snapshot of the 3D spatial mapping mesh of the urban green space captured during a short walk, exported and rendered after the session.

2.2   Defining a Visualisation Stage

The Adaptive Visualisation Workflow is a procedurally generated process, which is adapted to a specific scenario through the configuration of distinct stages. Stages consist of a user-defined set of groups, or layers, which interact through their average density. Each associated item within a group contains a 3D representation, and their associated relative prevalence within the group, as shown in figure 3. All assets within a group share an average density estimation, as such, stages which combine species with different dynamics, such as pioneer trees and undergrowth, should be represented as different groups within a stage. In our example, stages represent the temporal progression of natural plant succession seen in the recolonization of unmanaged land (BILLINGS 1938), with each stage including distinct tree groups, and undergrowth groups.

The spatial distribution of items within a group is determined by iteratively adding models as the space is mapped, ensuring the global density of items within one layer remains consistent with the average density configured for the group. Individual items within a group are picked at random, with respect to their respective prevalence. For example, varying the density and prevalence of species across succession stages can approximate the changing underlying make-up of forest biomass through time. An example configuration, as shown in figure 4, demonstrates a simplified progression of plant succession which can be adapted for specific sites and stages as required. Each stage after the first contains two groups, one for the undergrowth (annual, perennial and shrub dynamics), and one for the tree species dynamics.
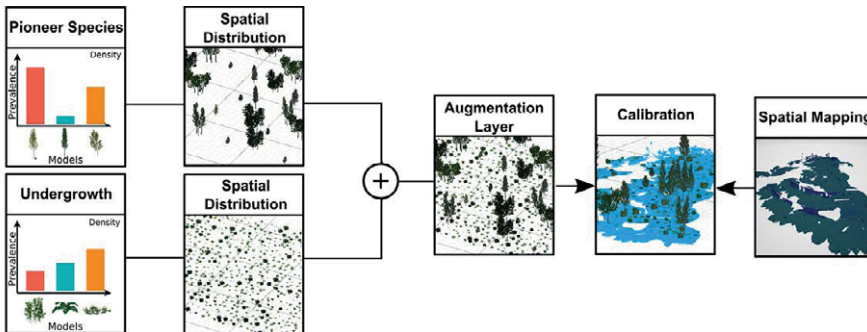
Fig. 3:   Procedural generation of augmentations for a single-stage, build from two distinct groups configured with different species, prevalence and group-level densities

As stages are defined by a probability distribution through asset prevalence, each run of the experience will create different variations on the scenario. Choosing to represent the distribution in terms of prevalence and density of species groups enables a flexible way to configure experience to approximate group dynamics. Parameters could be taken from theoretical model predictions or site-specific measurements. Assets are free to be any set of objects which can be rendered in Unity, including 3D models, billboard models and animated models such as wildlife. In this example, we use the highly detailed European Vegetation resource pack, from the Unity Asset Store. Stages can be progressed using a simple set of voice commands giving audio feedback, which are less prone to environmental interference than holographic user interfaces. As such, the only interface to the participant is the augmentations themselves.
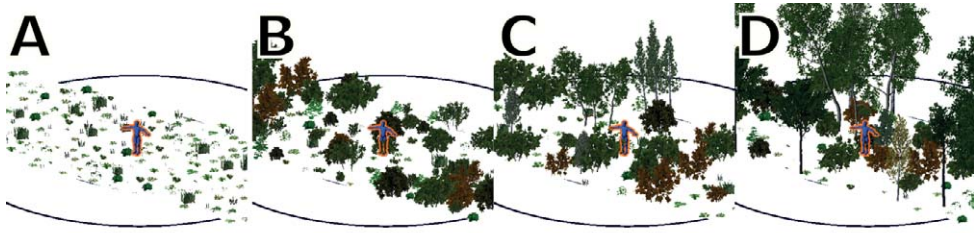
Fig. 4: An example configuration of stages to approximate plant successional stages. (A) annual & perennial plants and grasses, (B) shrubs, (C) Early pioneer and (D) Mature Pioneer species.

3   Results: Visualising Passive Rewilding for Education

Rewilding in the European context often emphasises a passive ecological approach to rewilding (SANDOM & WYNNE-JONES 2019), relying on the natural process of ecological succession for land management. Rewilding can occur in a variety of settings, and spatial scales, from urban green spaces to abandoned agricultural landscapes (PRIOR & BRADY 2017). Here we apply the Adaptive Visualisation Workflow to develop a proof-of-concept application to determine the applicability of our approach to enhancing educational opportunities for nature experiences, such as guided site tours in outreach. To achieve this, we use our procedural visualisation engine to visualise a phenomenological configuration of plausible local outcomes of natural plant succession, reminiscent of the unguided afforestation seen in the passive approach to rewilding.
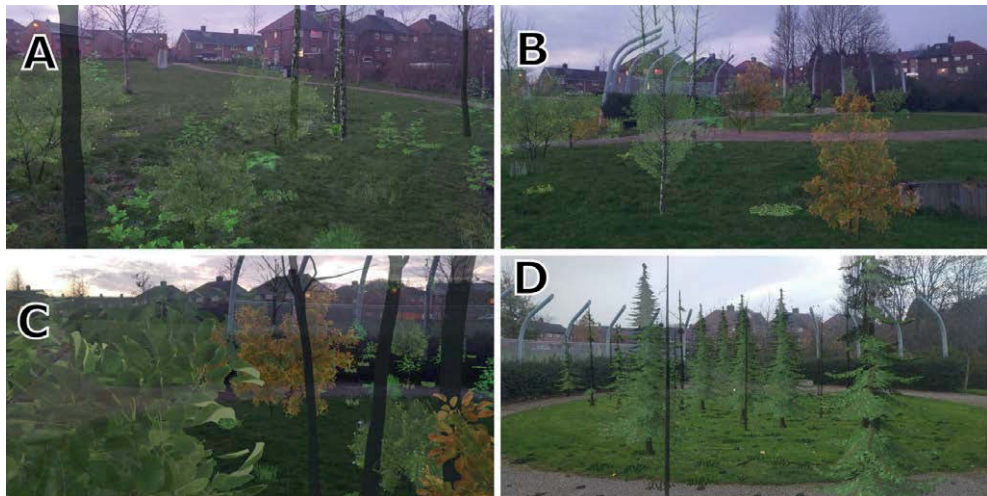
Fig. 5: Examples of successional visualisations in an urban green space, taken through the HoloLens headset. (A) Augmented mature pioneer Birch trees and shrubs alongside established real trees, (B) Early pioneer species and shrubs, (C) Close up experience of the shrub augmentations, (D) Alternative Pine dominated configuration.

We define a simplified 4 stage progression, annuals and perennials and grasses, shrubs, early pioneers and established pioneers inspired by the natural progressions found in BILLINGS, (1938), shown in figure 4. We represent the stages of pioneer succession as two separate stages, to smoothly capture the growth of the pioneer species from early colonisation to maturity. Each stage contains primary species, and residual species, such as undergrowth, showing the gradual reduction in species prevalence as the habitat becomes less favourable.

In this configuration, we focus on a section of European grasses, shrubs and tree species based on what is present in the local area, mainly birch, oak and maple. Indicatively, we included the locally prevalent perennials, horsetail (*Equisetum arvense*) and dandelion (*Taraxacum*). Each simulation will result in a different experience, reflecting the spatially stochastic, but generally predictable stages of natural succession (BILLINGS 1938). Each outcome is shaped by the profile of the land itself, the path the participant has taken to explore the area, and how they have chosen to experience the progression of stages.

Figure 5 shows 4 examples of the visualisations created by the HoloLens, with figures 5A, 5B and 5C showing the primary configuration based on a Birch dominated succession progression. Figure 5A shows a possible pioneer stage, in conjunction with a small area of exploration. We see the addition of several larger Birch trees, with smaller shrubs, and newly established maple saplings interspersed. Areas near the boundary of exploration can leave an abrupt gap in the augmentations. In contrast, figure 5B shows the early stages of pioneer growth, with augmentations present for ~30 meters in advance of the user. Figure 5C shows the visual effect of walking through the dense shrubbery, including the level of detail available with close up inspection. Unfortunately, we found that the visual efficacy of the HoloLens is strongly affected by direct sunlight, as such these pictures were taken in the late afternoon.

To create visually appealing tree models, leaves are generally created with translucent materials, allowing the light behind to subtly influence the appearance of the leaves. While this produces excellent visualisations in general, when capturing the images from the HoloLens, this results in reduced visual definition. In contrast to this, Figure 5D shows a configuration using more rudimentary models of pine trees. In this case, the materials are solid and non-transparent, leading to a clearer image, but less realism. In all cases, due to the additive nature of the HoloLens, there will always be some degree of transparency, with 100% occlusion of the environment impossible.

4 Discussion

In this paper we aimed to explore the applicability of an untethered headset based Augmented Reality for displaying, exploring, and interacting with changes in the immediate environment, to address the drawback of single-use site-specific AR applications which are unsuited to larger project goals. We have proposed a new Adaptive Visualisation Workflow, which enables us to formulate the visualisation process in terms of the continuous interactions between the user and the environment using a procedural visualisation engine. This approach avoids many site-specific requirements, such as mapping and calibration in advance, while remaining generic enough configure the engine to produce a large range of desired scenarios.

The visualisation engine is model-independent, designed to spatially contextualise the predictions of theoretical models, real-world measurements, or tailored scenarios (KUULUVAI-

NEN 2016). This allows users to visually experience representations of various scenarios in-situ, a key benefit for communication of complex and widespread interventions (CEAUSU et al. 2019).

As the visualisation engine is constrained by the parameterization of the experience, the accuracy and rigour of the visualisations are largely dependent on the initial configuration. This allows for experiences which range from general-purpose scenarios designed to visually communicate the general principles and ideas of complex subjects, such as in our Rewilding use-case, to more rigorous site-specific visualisations which would require detailed knowledge about the ecosystem (soil, plants, animals, localization, climate, etc.), which would be encoded in the parameterisations of the stages, species, prevalence, density and progressions of the stages, a simple example of which is shown in figure 3.

In section 3, we demonstrate the capability of creating spatially widespread and complex visualisations which arise entirely in a closed loop of interactions between the participant, and the environment. In order to assess the applicability of the Adaptive approach to visualisation in communication exercises, we built a proof-of-concept application aimed at communicating the phenomenological process of natural species succession associated with the passive rewilding process, to illustrate the conceptual afforestation process of an urban green space using locally prevalent species. For this paper, we have presented results from an urban green space, however, this approach is equally applicable to larger open areas. We show that the dynamic spatial mapping can successfully augment an environment, without prior knowledge of site topography. This workflow could largely eliminate the barrier of dynamic occlusion found in other spatial communication tasks, such as small-scale flood visualisation, and support novel applications of in-situ visualisation. With the initial technological barriers of generic in-situ visualisations in place, further investigations will be continued to capture specific data-driven model predictions in a spatial visualisation.

We found that the HoloLens creates an effective medium for free exploration of augmented natural landscapes. However, in its current iteration, the hardware does present some significant limitations. Primarily, effective use of the hardware is hampered by bright sunny days, as the over-saturation of natural light limits the ability to see visualisations clearly. This is not an issue with hand-held AR devices, and as such an effective communication strategy may still require both hand-held and headset AR until the hardware improves.

5   Conclusion

Augmented reality has been used as a tool to enhance communication and education since its inception, focusing on handheld AR devices in recent years. However, in this instance, we demonstrated a headset-based experience that is both embedded in the natural world and, like rewilding, applicable to a large range of sites, from small urban green spaces, to open abandoned farmlands, without prior topographical knowledge.

We have proposed a new Adaptive Visualisation Workflow designed to support generalised AR applications, with the widespread applicability required for large, multi-site projects and educational applications. We find that while the HoloLens 2 hardware is extremely capable in terms of mapping environments in real-time, and has the necessary computing power to perform such experiments, the environmental requirements, such as low light levels pose the biggest issues in creating an effective and widely applicable experience in this current device.

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