Towards Gamified Decision Support Systems: In-game 3D Representation of Real-word Landscapes from GIS Datasets

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Abstract: It is increasingly acknowledged that urban and landscape planning processes need to incorporate stakeholder input and feedback. To this end, decision-makers have been implementing a range of decision support systems (DSSs), such as using geographic information systems (GIS) or 3D renderings of designs to help better explain the advantages and disadvantages of proposed designs. In addition, urban and landscape planning DSSs have also incorporated gamification (the use of game features and mechanics in non-game environments) to provide interactivity whilst providing an engaging experience. In these contexts, using 3D renderings of real-world environments can be a powerful tool for aiding in the democratisation of planning decisions. However, the creation of large-scale 3D models representing real cities or landscapes is limited by time intensive manual methods. This is compounded by the fact that under our current rapidly changing environment, landscapes and urban areas are likely to alter in appearance within short periods of time. It is therefore imperative that 3D renderings of real-world environments can adapt to these changes. Here, we propose methods of using GIS datasets to automatically generate in-game worlds reflective of the real-world and how these 3D models can be used to engage citizens in planning decisions.

Keywords: Gamification; 3D visualization; LiDAR, GIS

1 Introduction

Environmental changes and anthropogenic pressures are having a profound effect on cities, landscapes, people and nature, including significant risks to built infrastructure and human health (HOBBIE & GRIMM 2020). It is therefore increasingly acknowledged that urban and landscape planning processes need to incorporate stakeholder input and feedback to maximise benefits for people and the environment. However, traditional top-down approaches to planning can often miss opportunities for input and have unintended consequences for residents such as green gentrification or increased rates of crime. This problem can be further compounded in underprivileged areas where community voices may not always be heard given the complexity of meaningfully engaging all relevant stakeholders (SCHINDLER & DIONISIO 2021).

To better democratise decision making, governments and planners have been implementing a range of decision support systems (DSSs) to engage communities. Here, DSSs can be any tool used to help better explain the advantages and disadvantages of proposed designs to citizens, such as using geographic information systems (GIS) or 3D renderings of designs (ZHANG & MOORE 2014). However, many DSSs only allow for citizens to provide feedback on a set of static choices, e. g., preference between a range of premade 3D models or photomontages. To better elicit the wants and needs of stakeholders, DSSs should allow for interaction and meaningful input from the user and provide the ability to change a design or proposal. To this end, urban and landscape planning DSSs are starting to use gamification (the

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use of game features and mechanics in non-game environments) to provide such interactivity whilst still providing an engaging process. These gamified DSSs are promising, though their widespread use is hindered by the time intensiveness of manually creating 3D models for planning and design decision making. To overcome this, we propose methods of using GIS datasets to automatically generate in-game worlds reflective of the real-world. In the following sections we provide background on current practices of gamification and decision support systems as well as challenges for developing future DSSs. We then propose methods for the automatic creation of 3D models from GIS datasets and conclude with a discussion of how these methods can facilitate stakeholder engagement in design and planning processes.

2 Gamification and Planning Decisions

2.1 Current Practices

A range of gamified DSSs including text-based, 2D and 3D games have been designed to engage and educate citizen on planning decisions. For example, the game 'MiniLautern' (POLST et al. 2021) educates players on the impacts of altering mobility habits (e. g. reducing parking spaces) via a text driven narrative. Other DSSs allow players to interact with and edit maps and models under a set of goals. For example, 'Community Circles' (THIEL et al. 2019) allows planners to post proposals to an interactive map of a local community while citizens post suggestions via comments and images on an interactive map. 'land.info' (LINDQUIST & CAMPBELL-ARVAI 2021) takes this one step further and allows players to interact with 3D models of real-world vacant lots to minimize flooding and increase social-cultural benefits. Though 2D and text-based games can provide a strong platform for education and engagement, games that utilise 3D renderings of real-world environments provide realistic and immersive environments that tend to be more engaging for users. For example, games representing real-world locations and games using virtual reality (VR) technology may better motivate players by providing a greater sense of connectedness to the in-game "place" and increase citizen buy-in to the planning process (GNAT et al. 2016, VAN LEEUWEN et al. 2018).

2.2 Challenges for Future DSSs

3D models used for planning and design DSSs are often generated using computer-aided designs (CAD) or manually by human designers. 3D models for DSSs can also be generated through GIS datasets, though they often lack the realistic engagement of more advanced technologies (ZHANG & MOORE 2014). The creation of CAD and human-designed 3D models are often limited by higher associated costs and time-intensive methods (GNAT et al. 2016). Furthermore, while previous research has used remotely sensed data to manually create 3D models, the process can still be time intensive for example when using terrestrial laser scanning (SPIELHOFER et al. 2017). These limitations mean that generating 3D models are often only feasible for smaller local-scale studies. This is problematic, as DSSs need to represent a range of spatial scales to accurately communicate the planning implications to stakeholders (BAI et al. 2018).

Creating large-scale 3D representations of real-world environments is further complicated by environmental and anthropogenic pressures such as climate changes impacts on landscapes. Under projected scenarios both natural and rural landscapes and urban areas are likely to undergo rapid changes. Landscapes may experience large topographic change through increased frequency of natural hazards, or changes to hydrological systems such as rivers drying up or more frequently flooding (HOBBIE & GRIMM 2020). Furthermore, urban areas may rapidly change due to damage from natural hazards, or rapidly increasing unplanned housing from climate migrants (HOBBIE & GRIMM 2020). It is therefore important that DSS games can quickly depict these changes through novel approaches that are faster than current manual creation methods.

3 Methods: Potential Uses of GIS Datasets

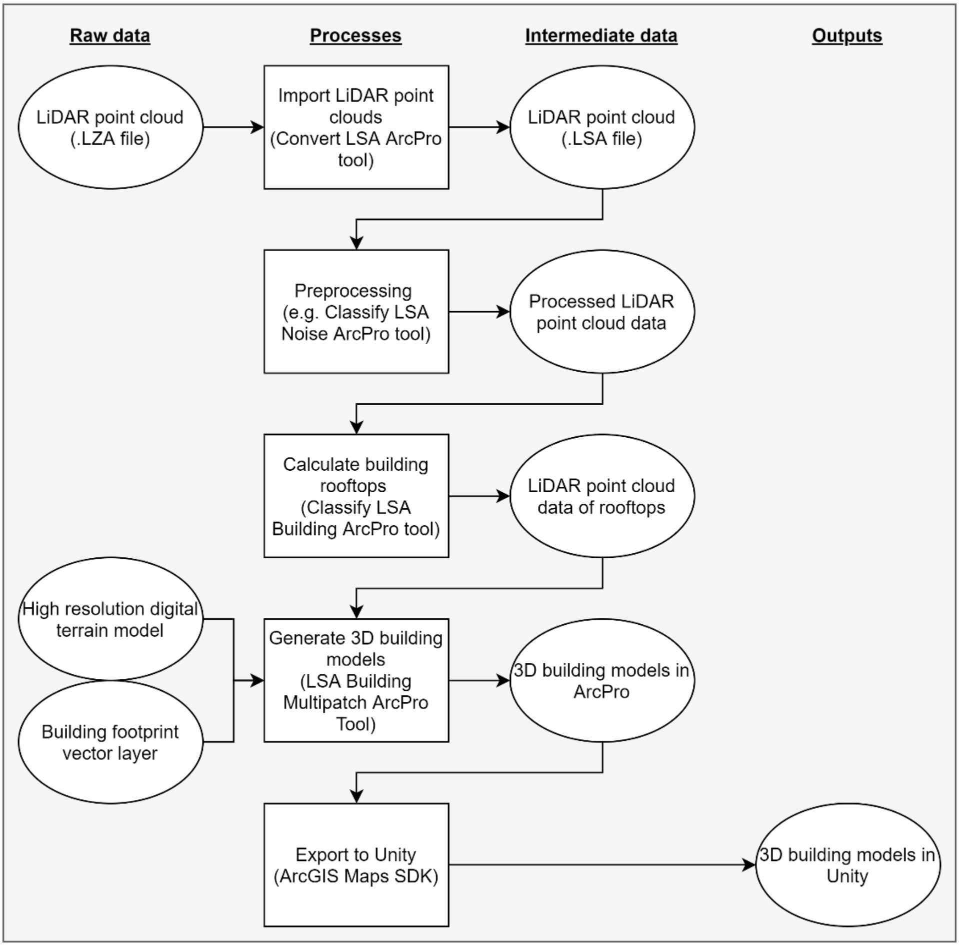

Fig. 1: Workflow and data required for automatically generating 3D building models in the Unity game engine from remotely sensed data

To demonstrate a rapid methodology for creating 3D models, we present a workflow that automatically generates 3D buildings from LiDAR point cloud data for the city of Ann Arbor, Michigan, USA (Figure 1). LiDAR point cloud data for all areas within the Ann Arbor city limits was obtained through the United States Geological Survey (USGS) national map downloader (apps.nationalmap.gov/downloader). LiDAR point clouds are a collection of data points that store information such as the real world XY coordinates and the 3D Z coordinate. These 3D point cloud data can be processed to generate 3D models of buildings (KULAWIAK & LUBNIEWSKI 2020). The point cloud data was imported into ArcPro (ESRI 2021) as a .LSA file. ArcPro provides the functionality to automatically classify building rooftops from the point cloud data. Once extracted the building point cloud data can be combined with a building footprints vector layer and a digital terrain model (DTM) to generate 3D models of the buildings.

To facilitate the implementation of these 3D models and other spatial data within gamified DSSs, we used the ArcGIS Maps software development kit (SDK) for Unity. The SDK enables GIS layers to be imported from JSON files. The data imported in Unity is used to generate the meshes that correspond to the 3D models from ArcPro, keeping all the relevant metadata such as the real world XY coordinates of the buildings. Once imported into Unity these 3D models can be incorporated into games that allow for users to interact with the models and the surrounding environment. These models can be implemented into a range of games including computer-based games, mobile applications or virtual reality worlds that use head-mounted displays (Figure 2).

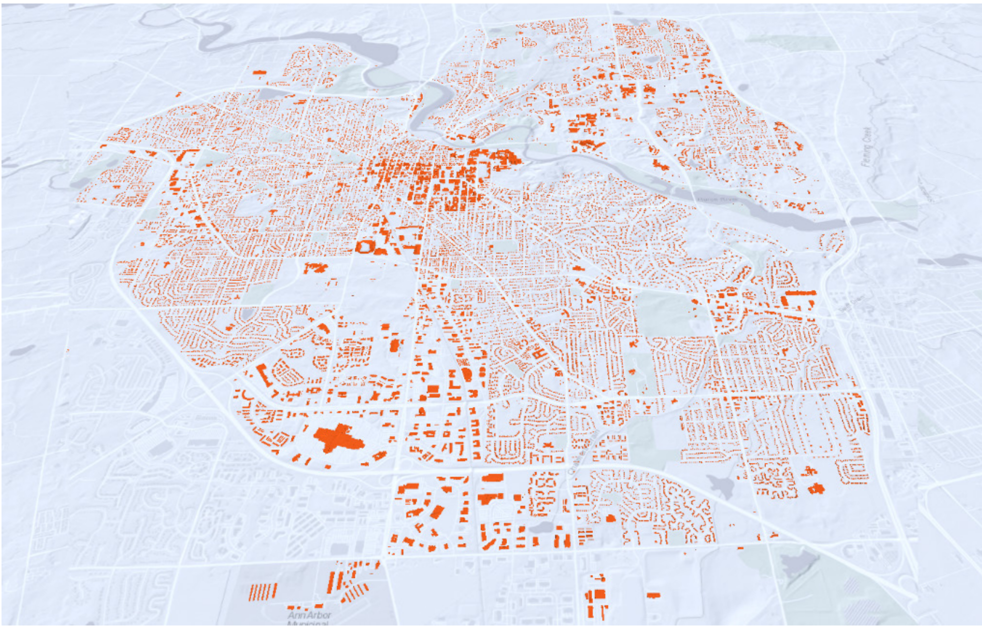

Fig. 2: Overview of all buildings in Ann Arbor generated using remotely sensed data in the Unity environment

To further improve realism in the real-world environment other conditions and objects should be replicated as accurately as possible for example topography, landcover and trees. The ArcGIS Maps SDK provides functionality for adding in a base map image as the ground layer for the in-game environment. The SDK also allows for an elevation layer to be imported which is used to create the in-game topography. Within the Unity engine the imagery layer can be draped onto the terrain layer to provide realistic looking landscapes. Realistic in-game terrain from satellite imagery can also be imported into Unity from open-source software such as R (R Core Team 2021). For example, the R package 'terrainr' (MAHONEY 2021) provides the functionality to download orthoimagery and elevation data from a range of sources and render these in the Unity environment at a 1:1 scale representative of the true environment (Figure 3).

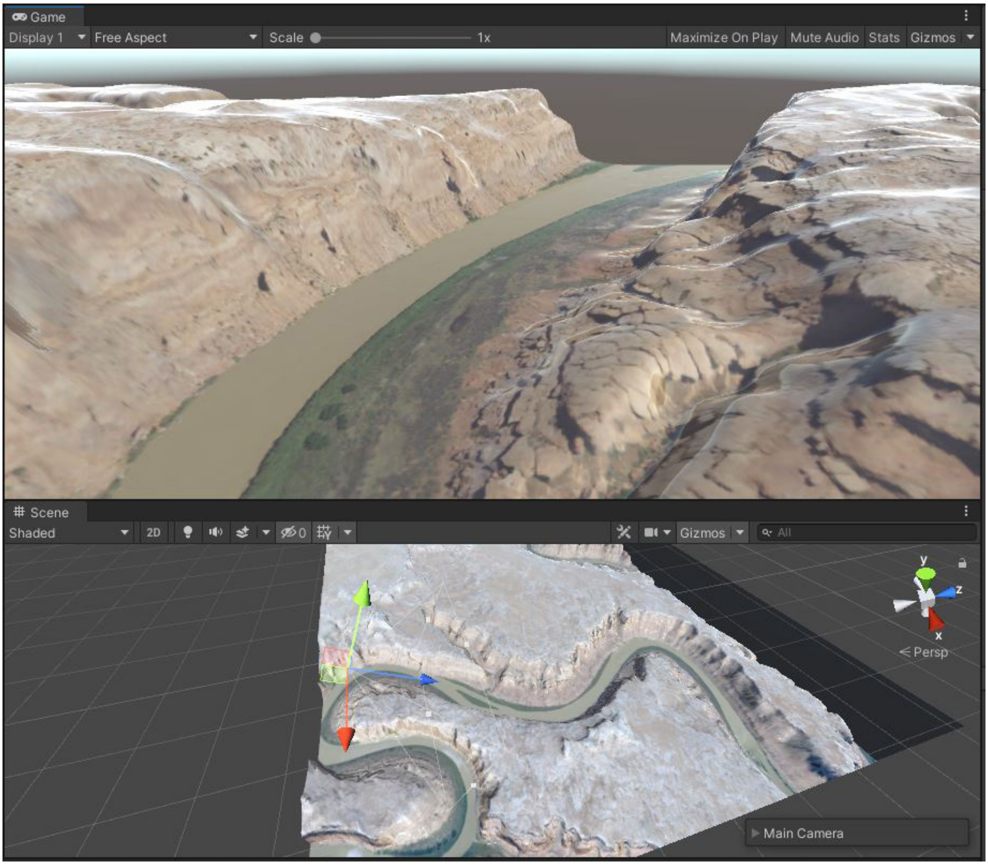

Fig. 3: Example of realistic terrain generation in Unity from the 'terrainr' R package

Some cities and regions have detailed GIS datasets for environmental or anthropogenic object locations (e. g., trees and roads). For example, one could use a tree inventory dataset to extract the latitude and longitude of different tree species, which can then be rendered alongside the SDK data within the Unity environment using prefabricated tree models. If city wide georeferenced datasets for objects do not exist, it would also be possible to manually collect geospatial coordinates of other objects, such as benches and streetlights, and populate the world with prefabricated models using the same process (ROUT & GLAPERM 2021).

4 Discussion

The addition of interactive features such as allowing users to add, remove and modify objects in editable areas could further increase citizen engagement in urban and landscape planning processes (GNAT et al. 2016). Shapefiles representing boundaries could be used to delimit the playable areas, such as within an urban park that has been earmarked for a proposed development. Previous research has shown that some stakeholders can become disorientated in games representing real-world locations with 3D models (LINDQUIST & CAMPBELL-ARVAI 2021). To overcome this a more advanced game could use boundary datasets to allow stakeholders to easily travel and 'play' where they want. Boundary data could allow players to enter an address within a prompt (e. g., their home) and be teleported to the locations. Players could then edit that area as defined by the GIS layer. By coupling automatically generated real-world locations with the ability to alter and design these areas, this gamified approach moves beyond current practices and allows planners to give citizens additional flexibility and freedom in providing feedback into landscape designs.

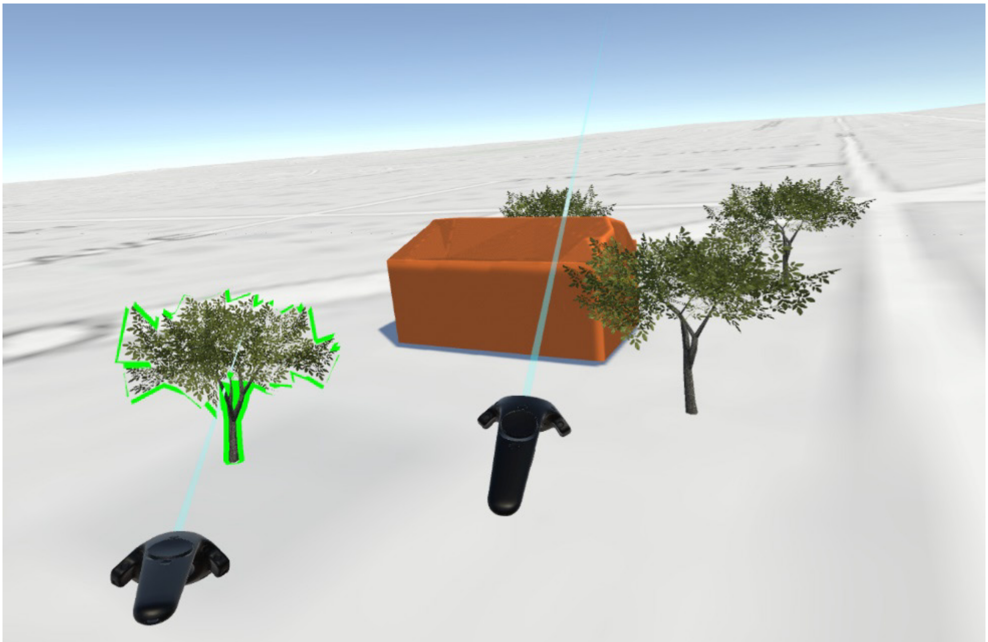

Fig. 4: Example VR application: redesigning tree locations on a residential property

By allowing users to interact with the 3D models in a meaningful way we can better elicit the wants and needs of citizens (XU et al. 2017). Depending on the game design and DSSs needs, the 3D rendered models presented here can be individually edited within a game environment by the players through multiple methods. For example, the game can be designed to allow players to move and edit objects using a mouse and keyboard if playing on a computer, by clicking and dragging with their fingers on touch screen devices or through using game controllers such as those for virtual reality (Figure 4). Moving, adding, removing, or physically changing models (e. g., creating new buildings, applying different textures or altering their shapes) allows for players to assess, in real-time, the visual impacts of their changes. Games can build on this and provide users additional real-time feedback on their decisions based on visualisation of these measures' underneath 3D renderings. For example, adding values to the models (e. g., carbon storage of a given tree species; pollution potential of cars; flooding potential of hydrological systems), games can provide players numeric feedback on the environmental, economic and social impacts of their changes (LINDQUIST & CAMPBELL-ARVAI 2021). This additional informational element can provide clarity to citizens about the potential real-world impacts of development choices and can help foster their long-term engagement in the planning process (GALEOTE et al. 2021).

Additional data can be collected about the players' game experiences and actions may also be useful for informing planning decisions. For example, pre-game and post-game questionnaires can be used to investigate how players' attitudes and opinions change or develop over time. LINDQUIST and CAMPELL-ARVAI (2021) used questionnaires to gauge whether participants believed that their in-game designs aligned with specified environmental targets such as flood management. In-game passive actions can also be recorded to elicit information about players' opinions. For example, it is possible to record the user's in-game movements and examine the length of time players stay in different areas as a proxy for areas of interest (BAUŠY et al. 2021).

5 Conclusion and Outlook

The methods presented here provide an automated workflow that can be applied to generating realistic 3D models of real-world locations, from site scale to entire cities. The outlined methods can also be beneficial compared to traditional methods as the data required to generate them is often freely available (depending on the location) and require a relatively short amount of time to update the 3D model as new data is acquired. Automating the processes of generating a realistic in-game world makes DSSs flexible and more easily applied across multiple spatial locations and scales. The flexibility also means that the game can be rapidly adapted to any short or long-term environmental changes.

The use of the Unity game engine, coupled with GIS data imported via the ArcGIS Maps SDK or other software, is advantageous in other DSSs designs contexts. LiDAR generated buildings and change detection has generally lacked an interactive element for users to date, e. g., static images or a video walk through of the generated landscape (e. g., SPIELHOFER et al. 2017, HAYEK et al. 2019). By incorporating this method of 3D generation into Unity, planning DSSs can be designed to allow for a wide range of interactions from the users, helping to provide richer information given different goals and aims (XU et al. 2017). The additional realism and presentation of the real-world locations can help to foster continued engagement from citizens through the planning process (GNAT et al. 2016, VAN LEEUWEN et al. 2018, GALEOTE et al. 2021).

We acknowledge that there are currently some limitations to these methods compared to manually designing each building, such as the lower realism in the rendered textures. However, the applications of additional methods and algorithms to the processing of point cloud data can further improve the realism in LiDAR generated building models (KULAWIAK & LUBNIEWSKI 2020). For example, though not explored here, ArcPro also provides all the necessary tools for adding real-world photographs as a realistic texture for the 3D model. This is however limited by the need for a photograph of all sides of a building and therefore may be better suited to games focused on specific buildings. Future work therefore should aim to assess the usefulness of these large scale automatically generated models. Furthermore, studies should continue to evaluate the level of realism required to create engaging game environments for citizen participation in real-world planning scenarios in the face of a rapidly changing environment.

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