Digital Twin Builder for Urban Planning Interim Report

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***Abstract*—Digital twins have been increasing in use and can be applied to improve urban planning applications to help users visualise what is in an urban area. Eagle Technologies are interested in using Esri software to create digital twins of New Zealand cities. This project aims to develop an application that can build digital twins from data about feature locations, and use these digital twins to create plans for urban development. This application will also display data about urban heat islands, which are areas where heat gets trapped by the materials and morphology of urban areas. Information about the distribution of urban heat islands will help urban planners reduce this effect. The project is currently halfway through development, with methods of displaying a 3D model of Wellington being developed. The second half of development will involve urban plan creation functionality.**

***Index Terms*—GIS, urban planning, digital twin, urban heat islands, New Zealand**

I. Introduction

Geographical Information Systems (GIS) are commonly used in tools to support urban planning and development [1]–[3]. 3D visualisations of areas are helpful for urban planners to become familiar with areas and improve their mental image, as well as helping complex assessment tasks [4]. A digital twin of a city can be used to display important features such as trees and buildings with high accuracy in 3D space. Interest in using digital twins to record the state of cities is increasing [5]–[7]. Collecting the data required to create a digital twin can be a very intensive and time consuming process [6], [7]. This project investigates methods of generating digital twins based on information gathered from satellite images and LiDAR scans. These models are then to be integrated with tools to assist in creating plans for urban development. Another benefit of this tool will be the ability to overlay information that can inform urban planning decisions. The development of this project is based on the following research questions.

Research Question 1: How can an application transform feature location data into a 3D model to aid visualisation and development planning?

Deep learning models have been used to interpret satellite images and plot points of interest. This data can easily be used to show locations of these points on a map. Visualising how this interacts with elevation and understanding the scene is difficult from a 2D representation. An interactive, 3D visualisation of an area and the existing features of interest could be used by designers and councils to plan developments. This project aims to investigate the development of such an application.

Research Question 2: How can the application be extended to overlay information about urban heat islands?

The Urban Heat Island (UHI) effect is where urban areas are commonly higher temperatures than rural areas because the morphology and materials of a city trap heat [8]. The New Zealand Government's national adaptation plan for climate change contains an article on UHIs and the associated issues [9]. This project will investigate ways to display UHI data to help urban planners identify problem areas and how to improve them.

This project is currently halfway through development, and this interim report describes the current status of the project. In Section II, the context of the project and industry partner is described. In Section III, a summary is given of similar work that has been done in this area. The design, implementation and development progress is described in Section IV. The plan for the entire project is laid out in Section V. The results and progress are summarised in Section VI. A list of tools used is given in Appendix A

II. Background and Objectives

This project will be developed by an individual student in partnership with Edward Wong from Eagle Technologies, and supervised by Ben Adams from the University of Canterbury.

Eagle Technologies represent Esri Technology in New Zealand and the South Pacific. Esri develops solutions using GIS, location intelligence, and mapping. This project will be built using ArcGIS, Esri's web based mapping software (Appendix A).

Eagle Technologies have trained some deep learning models to recognise features from satellite imagery. This includes trees, windmills and buildings, with plans to expand to other features of interest. The aim of this project is to create a pipeline that can be used to take this feature location data and generate an interactive 3D model. This project will be designed to work with multiple feature types.

The purpose of the generated models will be for the support of urban planning and development in New Zealand cities. This will be supported by editing functionality in the application that will allow urban planners to plot out changes directly in the model. Other information concerning the location and intensity of UHIs will be displayed over the digital twin to help urban planners focus on problem areas.

III. Related Work

There exist a great number of tools integrating GIS functionality for use in urban planning [1]. Liu et al. [3] surveyed the use of GIS models by urban mobility planners in Europe and found that while these tools were considered useful, 60% of surveyed cities did not use them. A major factor in this seemed to be user friendliness of the tools, particularly for non-expert users [3]. Half of the cities using GIS-based models had been using them for 10 years or more.

There has been an interest in digital twins for the purposes of smart cities, where many aspects of the city are modelled, including street networks, urban mobility, wind flow, movement patterns and building information [6], [7]. Gholami et al. developed a digital twin of the city of Imola, Italy, to evaluate pedestrian comfort and temperatures [10]. Xia et al. studied the use of Building Information Modeling (BIM) and GIS in smart city technology. They found that BIM and GIS information focuses on different areas with different uses that when combined offer great advantages, especially in the development of smart cities [6].

While digital twins are being used in these studies and other new developments, there has not been any focus on the development of digital twins for New Zealand cities, which is the purpose of this project.

A tool called Participatory Planning has been developed by Esri as an example for the use of digital twins to support urban planning. It allows users to draw buildings and add other 3D models in a 3D representation of a suburb in Brooklyn, New York. It is limited by the fact that it only allows editing of a single location, and cannot model other cities. Participatory Planning is linked to in Appendix A.

Studies of the UHI effect have been made to investigate causes and ways to mitigate the effect. McCarthy, Best and Betts found that there is a disparity between hot nights in urban areas compared to urban areas because of UHIs that mean the heat does not disperse at night [8]. Helletsgruber et al. studied the effect of trees on UHIs, and found that different aspects of trees had a role in mitigating the UHI effect. They found that the most influential factors were tree species, height, height of crown base, and trunk circumference [11]. Chatterjee and Majumdar studied the rapid urbanization of Kolkata city from 2005 to 2019 and found that vegetation cover was declining while temperature was increasing, especially in the central areas of the city [12].

IV. Solution

A. Method and Project Management

The development of this project has been split into two stages. Stage 1 involves the development of an application that can build a 3D model of a city from observed data. Stage 2 involves extending the 3D city models to allow editing and display of UHI information. Stage 1 has been mostly completed, and development for Stage 2 will commence in July.

This work has been undertaken in collaboration with Edward Wong, the industry partner representing Eagle Technologies in this project. We meet once a week to discuss the work that has been done and the work to be done next week. We use a Trello board (Appendix A) to track the status of tasks, using Kanban methodology. At the start of each stage, tasks are added to the Trello board 'Backlog' section. Then, at each weekly meeting, tasks for that week are discussed and moved into 'Doing'. Completed tasks are moved to 'Code Review' or 'Done'. This helps make sure that I know what work I need to do, and that Edward can keep up to date with the progress of the project and whether it is being developed in the way that he expected.

We also use Slack (Appendix A) to keep in contact if there are issues or points that need to be discussed between weekly meetings.

Most of the work that has been done is development of an application and testing different methods of displaying 3D models using the Javascript ArcGIS API. The code developed for this is stored in a publicly accessible GitHub repository. This was decided to be the best way to store the code because Eagle Technologies hopes to use this project as an open source example application. Therefore, keeping the code in a public GitHub repository is consistent with other projects that Eagle has done in this area. Also, having the repository publicly available means that Edward and other people from Eagle can read and access the code easily while I am the only one able to make changes.

Some of the work involved researching different options and assessing whether they were possible, and if so, what the best option would be. The results of these investigations were documented in the wiki section of the GitHub repository.

As this project is being developed for Eagle Technologies, it is subject to their priorities and interests. This means that the focus of the project has shifted slightly since the beginning of development. Originally the project was pitched as a digital twin builder for use with windmill location data, based on some previous work that has been done with windmills. Since then, focus has shifted to urban areas and urban planning, as well as including the display of UHIs. The core functionality of the project is still similar to the original plan.

B. Design and Implementation

Stage 1 involved understanding the Javascript ArcGIS API and how it could be used to generate 3D models of New Zealand cities. Test applications were created to understand the features of ArcGIS and how it could be used. A simple HTML index file would be used to run different Javascript files. These test applications were hosted using the node module http-server, which allows for the simple HTML and Javascript application to be tested on localhost. However, the final application developed in Stage 2 is more likely to use a React framework that will allow easier development of the user interface.

The Javascript files would import features from the ArcGIS API and use them to create a 3D scene of a New Zealand city. A SceneView was created that showed a 3D map, where Esri data was used to generate ground elevation and a basemap that showed the streets and buildings in the area.

The ArcGIS system allows multiple layers to be created and displayed within a SceneView. A layer was used to display the 3D models that build up the digital twin. This was done using a FeatureLayer, which displays features based on the defined rendering settings and an array of feature locations. During testing, this was first done using points that were hard coded to appear within the camera view. Once available, this was then changed to use tree location data that had been generated by Eagle Technologies.

I investigated the best way to display 3D models of trees. I investigated the use of the program Blender (Appendix A) to create 3D models, and found that while it was very powerful and potentially useful, it would take so long to learn that it was not feasible to use for this project. I did create a sample flamingo model to demonstrate some of the capabilities, and used this model to test functionality like importing .glb and .gltf model types. This allowed me to discover an easy way to use 3D model files to represent features in a FeatureLayer. This would be useful if I had custom 3D models to use, but because creating custom models is too time consuming, I looked for other solutions. Another way to render features in a FeatureLayer is by the use of ArcGIS webstyles. Webstyles are 3D models or images that are hosted on ArcGIS Online and can be used in any ArcGIS application. These can be default webstyles or ones that have been uploaded by users. I will investigate the possibility of uploading custom webstyles and using those for this project, but I don't currently have access to ArcGIS Pro, which is used to upload webstyles. However, there are default webstyles that have worked for the purposes of this project so far.

A tree model webstyle has been used for displaying detected trees in an area of Wellington. The feature data available included the estimated height of the trees, so this data has been used to set the height of the 3D models used to represent each tree.

Now that there is a program developed that shows how to use feature data to create a 3D model, this can be applied to Esri's Participatory Planning sample application and begin to build a React application that displays a digital twin of Wellington with editing capabilities. These next steps are described in greater detail in Section V.

V. Plan

A. Risk assessment

The most likely risk in this project is that the work takes longer than expected, and therefore is not able to be completed in the time frame. This could be because of poor time management, or other factors such as loss of files, events that prevent work on the project, or tasks being more complicated and time consuming than expected. The effect of this on the project will be that less progress will be made than was planned.

This is mitigated in two ways.

First, by making a project plan, it is easier to see what has to be done, and judge whether development is on track. Development progress will be tracked using the online tool Trello.

Secondly, the project has been split into two stages. The first stage is the most essential stage, while the second stage is less critical. In the middle of the year, the progress on the first stage can be evaluated, and the plan for the second stage can be adjusted if the first stage has not been completed. Some milestones are less important and can be dropped in favour of more important features.

The risk of work being lost or deleted will be mitigated by using git as a version control system and keeping a repository on GitHub. The link to this repository is given in Appendix A.

There is a risk that the project is not completed, either because it takes too long or because something causes it to end early. In this case, it should be possible for someone else to pick up and continue with the project if required. The code should be clear and well documented to make it easier for someone else to work with.

B. Milestones

The first stage of development focused on making an HTML and Javascript application that can read in data files of feature locations and display those features with a 3D model. This development stage ran from the start of March until the end of May. The milestones during this stage are shown in Table I.

Most of these milestones were completed before the end of May, with the exception of Milestones 5 and 6. Milestone 5 was delayed because it requires access to location data of two different types of features in the same area, and this data is not yet available from the deep learning models used to generate data. Milestone 6 required feature information to be displayed. Currently, only the ability to display the heights of trees has been developed, and this functionality will need to be expanded when more feature data is available. These milestones will be worked on during the mid year break (23 June - 17 July), but completion will depend on when the required data is available.

Milestone 8 was planned to be completed before the 2nd of June, but was not able to be completed and has been pushed back to the 30th of June, to be completed during the mid year break after exams.

During the last week of Semester 1, the progress on Stage 1 of the project was evaluated and the plan for Stage 2 was finalised. This allowed flexibility in the plan so that if development had not progressed as expected, that could be accounted for. The resulting milestones for Stage 2 are shown in Table II.

TABLE I
STAGE 1: 3D MODEL GENERATION MILESTONES

#	Milestone	Date	Planned Outcome	Status
1	Place 3D objects on a map.	31 March	An HTML and Javascript application that uses the ArcGIS Javascript SDK to display a 3D scene of a location with elevation data. This application should display simple polygons in the scene. The purpose of this is to understand how to use the tools and start building the application.	COMPLETE
2	Investigate model file types	16 April	An assessment of different file types that can be used for 3D models, and a chosen file type to be used. Test models made using Blender A. Code written that can read in 3D models of the chosen file type. This milestone will be developed during the midterm break and so has a longer time to account for reduced availability.	COMPLETE
3	Display custom models	28 April	An application that can display custom models from model files.	COMPLETE
4	Read features from a file and display on map	10 May	An application that can read in a file of windmill locations and display windmill models at those locations in a 3D scene. This should use real data outputted by the deep learning model.	COMPLETE
5	Display multiple feature types	17 May	An application that can display multiple different types of features on a map. Each feature type should have a distinct 3D model. These features will likely be cars, trees, or buildings.	DELAYED
6	Display information about features	26 May	An application that allows users to see extra information about features. Users can view and hide this information when it is relevant to them.	PARTIALLY COMPLETE
7	Interim report	2 June	A report detailing the project objectives, progress, evaluation of progress, and detailed plan for the rest of the project.	COMPLETE

TABLE II
STAGE 2: EDITING AND USER TOOLS MILESTONES

#	Milestone	Date	Planned Outcome
8	User Stories	30 June	A list of user stories to guide the development of stage 2 of the development.
9	Create React Application	19 July	The application from Stage 1 integrated with the Participatory Planning application to create a React application that displays the Wellington model.
10	Users can mask area	26 July	The React application is extended to allow users to select an area of the digital twin for editing.
11	Users can add features	7 August	Once an area has been selected for editing, users are able to add new features in that area.
12	Users can edit features	14 August	Users are able to edit the shape, rotation and location of added features and preexisting features.
13	Display UHI	30 August	The Urban Heat Island effect can be displayed, where areas that trap more heat are highlighted. This display can be toggled on and off.
14	Measuring and Drawing (Optional)	8 September	Users are able to measure distances on the model and draw on the plan.
15	Showcase abstract	15 September	An abstract that describes the project to be used for the showcase programme.
16	Poster	2 October	A poster displaying the project.
17	Showcase Presentation	12 October	Presentation slides and script for presenting the process and results of the project at the showcase day.
18	Final Report	20 October	A final report writing up the entire project process and details.

C. Evaluation

The success of the project will be judged on how well it completes the objective. This will be assessed with the use of user stories that were developed during Stage 2. The evaluation will also involve working closely with the industry partner to make sure that the project accomplishes the goals they had going in. Measuring how well the project outcome implements the user stories and matches the industry partner's expectations will allow us to evaluate the success of the project.

VI. CONCLUSION

This report recorded the progress of a digital twin builder project being developed with Eagle Technologies, making use of Esri's ArcGIS API. The development of this application will help demonstrate what can be done with the ArcGIS API and help urban planners in New Zealand take advantage of GIS and modelling technologies. The inclusion of UHI data will help with finding ways to reduce heat trapped in urban areas.

Current development has been focused on creating a 3D model of Wellington city and using placing tree features in locations based on data generated by deep learning models. The next stage of the project will be to build an application that will allow users to edit this model and models of other cities where data is available.

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Appendix A
Tools used

1) Code repository stored at https://github.com/m-bastia/SENG402_DTB
2) Trello used for keeping track of tasks and progress. (https://trello.com)
3) ArcGIS Map SDK for Javascript used to access and display map data. (https://developers.arcgis.com/javascript/latest/)
4) Blender used to create custom models. (https://www.blender.org/)
5) Participatory Planning project used as a basis for editing functionality. (https://developers.arcgis.com/javascript/latest/showcase/participatory-planning/)
6) Slack used for keeping in contact with industry partner and supervisor. (https://slack.com/)