Task 2: Development / Reflection Phase Report

Project: MetroMorph – A Generative Urban City Planner

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1. Abstract

As cities grow quickly, it has become harder for planners to design cities that are well setup and organised, sustainable and easy to live in a particular city. Traditional planning methods depend too much on human experience and old data, which often leads to traffic problems, poor layouts and fewer green spaces. This project introduces MetroMorph, an AI-based city planning system that uses Graph Neural Networks (GNNs) and Google Maps APIs to study city areas, terrain, and green zones. The system collects live location data, turns it into graph structures and uses AI to find the best places for future development. The backend is built with FastAPI for smooth processing and shows results with interactive visuals to help planners make good decisions. The prototype shows how AI and real time map data can work together. In the future, MetroMorph can be expanded to include featured like road planning, population and automated city layout generation.

2. Introduction

As cities continue to expand, designing well structured urban areas has become a major challenge and task. City planners often rely on traditional methods such as manual mapping, field surveys and experience based decisions. These methods take a lot of time and effort and sometimes fail to consider all important factors like terrain, population and available green spaces. Due to this many cities face common problems such as traffic congestion, poor layouts and less open areas. The main issue this project addresses is the absence of efficient and data orientated tools for urban planning tool that users real city data from google maps which then applies GNNs to study terrain and green zones. The system helps to identify suitable areas for development and management. It aims to support city planners by offering a faster and more reliable way to analyse different parts of a city. The project is built with a FastAPI backend that collects and processes data, while the GNN model examines the connections between land and terrains. The processed data is then displayed on the map, allowing users to explore terrain and green coverage in real time. This approach not only saves time but also provides a clear picture of how cities can grow in a more balanced and sustainable way. MetroMorph provides a practical and innovative solution for modern urban planning. It combines data analysis and visualisation to make the city more make design smarter, more sustainable.

3. Related work

The urban planning has gained attention in recent years, focusing on smart city development and sustainable design. Early research depended on geographic information systems (GIS) for visualization but lacked predictive modelling. Recent research shows the effectiveness of graph based learning for prediction tasks. “Li” (2022) presented that GNNs can learn topological dependency between urban features such as roads, green spaces and elevation. Similarly “Zhang” (2023) applied GNNs for urban heat island prediction, improving sustainability. “Rahman” (2023) applied GNNs for urban heat island prediction which improved sustainable planning accuracy. These works inspired the idea of MetroMorph with GNNs to build a prototype.

4. Technical background

- **Google Maps APIs**

  The google maps platform provides APIs for places, elevation and geocoding, which allow MetroMorph to fetch live terrain and environmental data. This ensures that the system works with real and up to date information.

- **Graph Neural Networks (GNN)**

  GNNs are a class of AI models designed to work on graph structures, where nodes represent geographical points and edges represent their relationships. In MetroMorph, GNNs are used to analyse how terrain and green zones interact, predicting suitable areas for future green sustainable development.

- **FastAPI**

  FastAPI is a modern Python framework used to build the backend of MetroMorph. It handles API requests, connects with Google Maps, manages data preprocessing, and runs GNN inference. Its asynchronous design ensures high performance even with multiple users or large datasets.

5. Methodology

- ## Data collection

  Terrain and green zone data were collected using-

  Google Maps API – to identify parks, forests, and recreational areas.

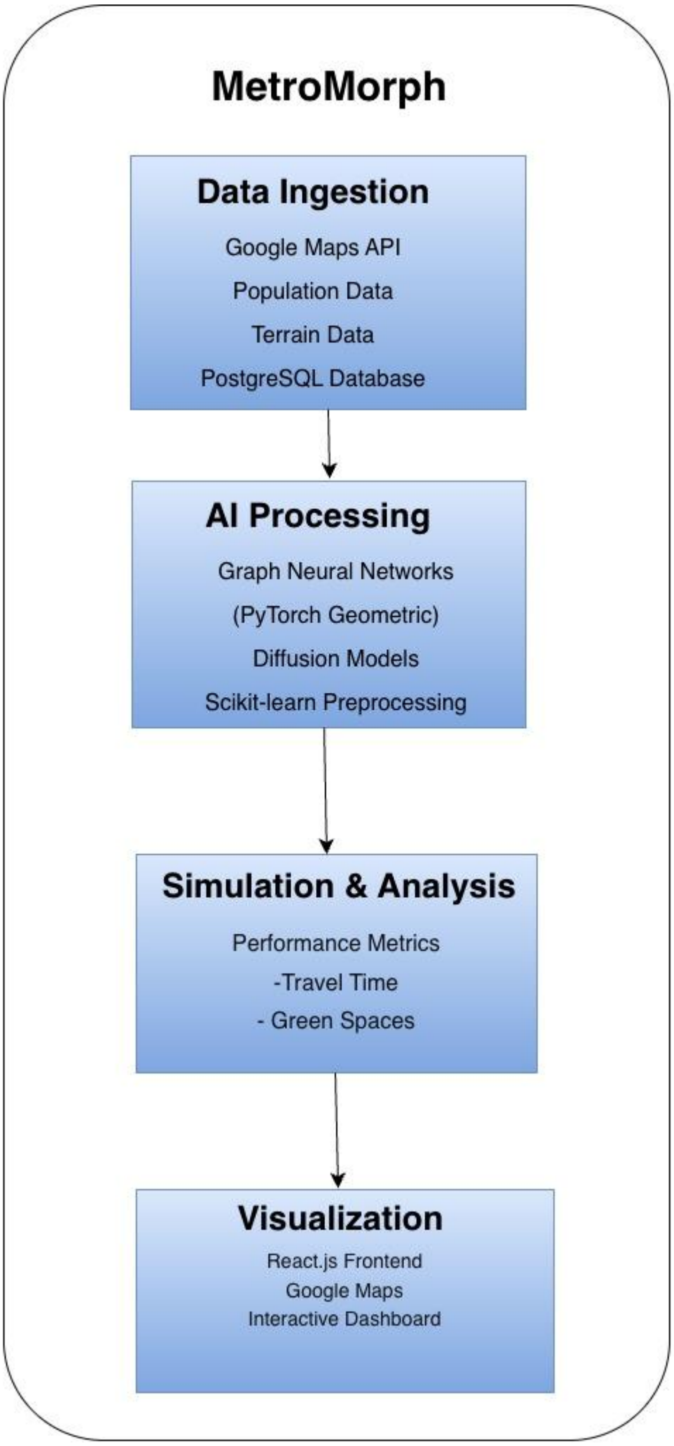
- ## Pre-trained GNN model

  MetroMorph analyses spatial and terrain data with a pre trained Graph Neural Network (GNN) model. Instead of creating a new model from scratch, a pre trained version was used to increase system efficiency and shorten development time. This model has already been trained on big open source geographic datasets, so it can recognize patterns like elevation, land, and vegetation coverage. During implementation, the pre trained GNN was fine tuned using selected local datasets to match the projects focal regions, such as Bayreuth green zones and terrain.

- **System integration**

  The trained model is deployed through FastAPI. Users can input a city name, and the backend fetches real-time terrain and green zone data, processes it through the model, and returns visual predictions in a map format.

- **Project architecture**



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6. Implementation

The backend was built in python which are having data fetching, terrain analysis and GNN prediction. The GNN model was implemented using PyTorch Geometric with two layers. Frontend was created using Angular which allows users to interact with live maps displaying terrain elevation and predicted green zones. The system was tested locally in VS code, with datasets stored in JSON formats for efficient access.

7. Testing

The GNN model was evaluated with sample city data to confirm that predictions align with real green zones. Further large-scale testing will be performed once additional features are integrated.

8. Conclusion

The MetroMorph project successfully developed a working prototype that integrates GNNs and Google Maps data to do urban planning. The system can analyse real terrain and green zone data and visualise it interactively.

The current version focuses on analysis rather than generation, it provides a strong foundation for future development. Future work will expand the system with road layout generation, traffic analysis, and pollution mapping to create a complete generative urban planning platform.

9. Bibliography and list of references

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