TRIBHUVAN UNIVERSITY

INSTITUTE OF ENGINEERING

PULCHOWK CAMPUS

A PROJECT PROPOSAL ON

Urban Labyrinth:

Navigating Pulchowk Campus with A* Algorithm

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Abstract

The project "*Urban Labyrinth"* focuses on the implementation and application of the A* algorithm for pathfinding in a 3D simulation environment of Pulchowk Campus. Utilizing the Godot Engine, we developed an accurate 3D representation of the campus and integrated various designated parking locations. Users can select a parking location, and the A* algorithm is employed to find the optimal path for the car to navigate to the chosen destination. This report provides a comprehensive overview of the project, including its objectives, methodology, implementation details, results, and conclusions.

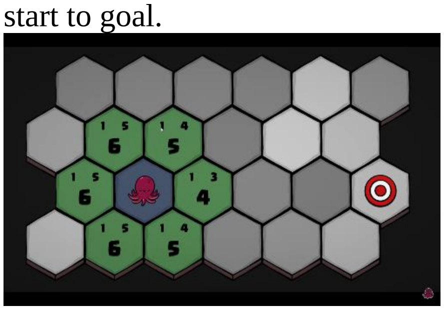
Background

Pathfinding algorithms play a vital role in various real-world applications, from optimizing routes for delivery vehicles to enabling autonomous robots to navigate complex environments. These algorithms efficiently determine the optimal path between a starting point and a goal, fostering efficient navigation and resource utilization. Our project, *"Urban Labyrinth: Navigating Pulchowk Campus with A* Algorithm"*, showcases the practical application of such algorithms within a 3D simulation environment of the campus.

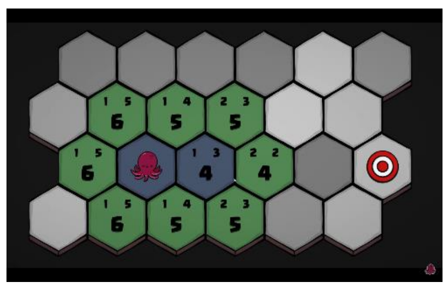
Among the numerous pathfinding algorithm, the A* algorithm has gained significant popularity due to its efficiency and optimality in finding optimal path between two points. A* was created as part of the Shakey project, which had the aim of building a mobile robot that could plan its own actions. The A* algorithm is an informed search algorithm that combines the advantages of greedy best-first search and Dijkstra's algorithm. A* operates by maintaining a tree of paths originating at the start node and extending those paths one edge at a time until the goal node is reached. At each iteration of its main loop, A* needs to determine which of its paths to extend. It does so based on the cost of the path and an estimate of the cost required to extend the path all the way to the goal. Specifically, A* selects the path that minimizes the function

$$f(n) = g(n) + h(n),$$

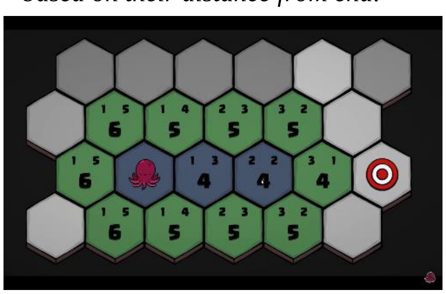
where n is the next node on the path, $g(n)$ is the cost of the path from the start node to n, and $h(n)$ is a heuristic function that estimates the cost of the cheapest path from n to the goal. The heuristic function is problem-specific, and if it is admissible – meaning that it never overestimates the actual cost to get to the goal – A* is guaranteed to return a least-cost path from start to goal.



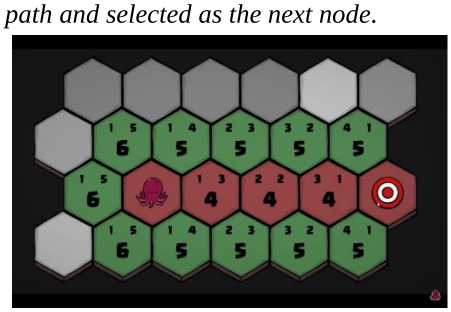
All the neighboring nodes to the start node are given g cost (top left) based on their distance from start and h cost (top right) based on their distance from end.



The node with the lowest f cost from the set of unprocessed nodes is considered the most promising candidate to be part of the optimal path and selected as the next node.



If the selected node is not the end node, the algorithm adds it to the list of processed nodes and removes it from the list of unprocessed nodes



This process is repeated until end node is reached

Ref: Pathfinding - Understanding A (A star) by Tarodev, site: youtube.com*

Project Overview

Our project, *"Urban Labyrinth: Navigating Pulchowk Campus with A* Algorithm"*, aimed to develop a 3D simulation of Pulchowk Campus and implement the A* pathfinding algorithm to navigate a virtual vehicle to designated parking locations within the simulated environment. The primary objectives were to create an accurate 3D representation of the campus, integrate multiple parking locations, and employ the A* algorithm to determine the optimal path for the vehicle to reach the user-selected destination.

The project sought to demonstrate the practical application of the A* algorithm in a real-world scenario, such as obstacle avoidance and route planning within a campus setting. By providing an interactive and visually engaging simulation, the project aimed to showcase the algorithm's efficiency and effectiveness in finding optimal paths within a complex environment, while also highlighting the potential applications of pathfinding algorithms in various domains.

Methodology

The development of the "Urban Labyrinth" project involved a combination of techniques and technologies to create the 3D simulation environment and implement the A* pathfinding algorithm. The methodology can be divided into two main components:

1. **3D Simulation of Pulchowk Campus using Godot Engine**

   The first step was to gather drone shots, campus map of buildings, roads, and other relevant structures within the campus to ensure a realistic representation. To construct the 3D simulation, we made use of **Godot Engine**, which is a free, open-source, cross-platform game engine to create 2D and 3D games. The Godot Engine provided a robust and versatile development environment for us to leverage its powerful tools and features for 3D modeling, texturing, lighting and environmental effects.

   During the 3D modeling process, we recreated each building, road, and structure within the campus boundaries. We employed various modeling techniques to ensure accurate proportions, and architectural details. We applied appropriate textures and materials to the buildings, roads and architectures, to replicate the signature look of Pulchowk Campus. And further, we added the environmental details, such as trees, benches, and other campus features, to make the representation more realistic.

   And then, we integrated multiple designated parking locations into the campus environment, for users to select their desired destination. We positioned these parking locations strategically based on the actual layout of the campus, to ensure a realistic and practical representation of parking areas in the campus.

2. **Integration of the A* Pathfinding Algorithm**

   After creating the detailed 3D simulation of Pulchowk Campus, we focused our efforts on implementing the A* pathfinding algorithm to navigate the virtual vehicle within the simulated environment. We carefully studied the A* algorithm's principles and designed an efficient implementation to drive our vehicle in the 3D simulation.

a. **Leveraging Mesh-based Representation:**

   Instead of using a traditional graph representation with nodes and edges, we made use of the mesh-based structure popular in 3D graphics. The campus simulation, consisting of buildings, roads, and other structures, is primarily constructed from *meshes*, which are collections of vertices (points in 3D space) connected by triangles. These triangles form the fundamental building blocks of 3D models in computer graphics, essentially defining the shapes and surfaces of virtual objects

b. **Navigation within the Mesh Data**

   We employed this mesh-based structure to represent the navigable areas and obstacles within the simulation. By analyzing the individual triangles and their spatial relationships, the A* algorithm could effectively determine feasible paths for the virtual vehicle. Navigable areas, such as roads and parking spaces, were represented by appropriately configured meshes, allowing the vehicle to traverse them smoothly. Conversely, building meshes and other impassable structures were identified as non-traversable, guiding the A* algorithm to navigate around them.

c. **Dynamic Pathfinding**

   The start and end points for the pathfinding process were dynamically determined based on the virtual vehicle's initial position and the user's selected parking location within the simulation. This dynamic approach allowed for a flexible and interactive experience, where users could witness the algorithm's capability to calculate optimal paths for various scenarios and starting positions.

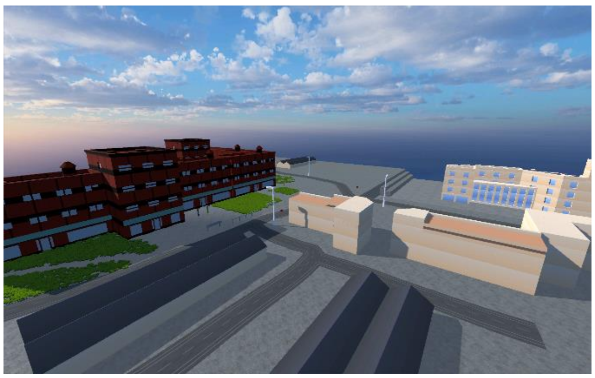
d. **Enhancing Vehicle Movement**

   To enhance the realism and smoothness of the virtual vehicle's navigation, we incorporated additional techniques alongside the A* algorithm. These techniques, such as interpolation, path smoothing, and obstacle avoidance, played a crucial role in refining the movement patterns of the vehicle. They helped ensure smooth transitions by eliminating sharp turns and unrealistic movements and reducing unnecessary deviations and creating a more natural flow for the vehicle's movement.

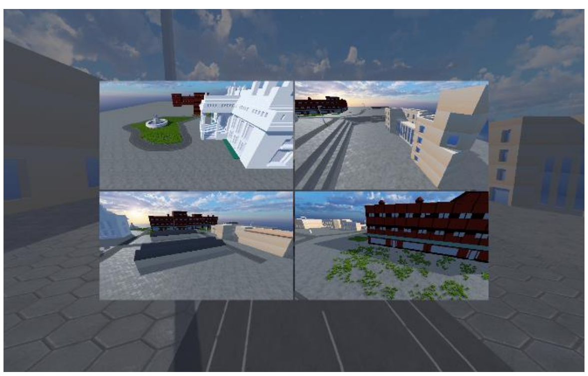
The methodology aimed to strike a balance between creating an engaging and visually appealing 3D simulation while maintaining the integrity and efficiency of the A* algorithm's implementation, ultimately providing a comprehensive demonstration of pathfinding in a real-world context.

Implementation & Result

The "Urban Labyrinth" project successfully translated the chosen methodology into a user-friendly and interactive experience. Users were able to:



Navigate through the visually appealing and detailed 3D simulation of Pulchowk Campus, providing a sense of immersion and familiarity.



Choose their desired parking location from designated spots strategically positioned within the environment, reflecting the actual campus layout.

Observe the A* algorithm in real-time as it calculated the optimal path for the virtual vehicle to reach the chosen parking location, demonstrating its efficiency and adaptability in various scenarios.

Challenges & Limitations

While the "Urban Labyrinth" project successfully demonstrated the application of the A* algorithm in a 3D simulation environment, it is essential to acknowledge the challenges and limitations encountered during the development process. Recognizing these limitations provides valuable insights for future iterations and highlights areas for potential improvement.

1. **Simplification of Real-World Environment**

   The project's 3D simulation, while aiming for accuracy, inevitably involved certain simplifications compared to the real-world Pulchowk Campus. Complexities like uneven terrain, dynamic obstacles (e.g., pedestrians, vehicles), and unpredictable environmental factors were not fully incorporated due to the scope and resource constraints of the project.

2. **Mesh Complexity and Processing Power**

   Leveraging the mesh-based structure for pathfinding offered advantages in representing the environment's features. However, it also presented a challenge. As the complexity of the 3D environment increases, with intricate buildings and numerous objects, the number of triangles forming the meshes can rise significantly. This can lead to increased processing power demands, especially when calculating paths involving complex maneuvers or in real-time scenarios. Exploring alternative pathfinding techniques optimized for detailed environments could be an area for further investigation.

By addressing these challenges and limitations in future iterations, the project can be further refined and real-world applicability can be further enhanced**.**

Conclusion

The "Urban Labyrinth" project successfully demonstrated the practical application of the A* pathfinding algorithm within a 3D simulation environment. By developing a visually appealing and interactive representation of Pulchowk Campus, the project showcased the algorithm's capability to find optimal paths in real-time. Users were able to interact with the simulation, select their desired parking location, and observe the A* algorithm in action, highlighting its potential for various real-world applications.

References

- **A* search algorithm – Wikipedia**
  https://en.wikipedia.org/wiki/A*_search_algorithm
- **Pathfinding - Understanding A* (A star) by Tarodev**
  https://youtu.be/i0x5fj4PqP4
- **Practical Search Techniques in Path Planning for Autonomous Driving**
  https://ai.stanford.edu/~ddolgov/papers/dolgov_gpp_stair08.pdf
- **A* Pathfinding in Unity by Sebastian Lague**
  https://youtube.com/playlist?list=PLFt_AvWsXl0cq5Umv3pMC9SPnKjfp9eGW
- **Godot Documentation**:
  https://docs.godotengine.org/en/stable/index.html