Summer Undergraduate Research Task: Geolocation/Navigation on the Moon Using Visual Place Recognition

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The Summer Undergraduate Research Fellowship program at the University of Houston seeks to provide funding for rising UH sophomores, juniors, and seniors to participate in a focused, full-time, 10-week research experience under the direction of UH faculty. Recipients will receive a $4,000 scholarship and three points toward the Honors in Co-Curricular Engagement transcript designation. Current freshmen who will be sophomores in fall 2024 are eligible to apply for the fellowship. However, students graduating in spring or summer 2024 are not eligible for this program.
No course credit will be offered for participation in this program, and students who have previously participated in the SURF program are ineligible to reapply. However, if you apply as a special problems topic then you can get course credit.
We recommend one student per research topic.

1 Logistics

If you're interested in any of the following topics, ***please contact us by Friday March 1, 2024*** at the latest.

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2 TOPIC 1: Supervised Visual Place Recognition

2.1 Input

Given a collection of unlabeled street view images and non-urban horizon images from different times and locations. The goal is to build a system that can identify whether two images depict the same place, even if they were taken from different angles under different lighting conditions. A recommended tool for the purpose is NetVLAD.

2.2 Deliverables

We create a system that can answer questions like "Is this image taken by a robot from the same area as this other picture taken by an astronaut?" without needing precise location labels. This is useful for tasks like geolocation, robot navigation, image retrieval, and understanding how places change over time.

2.3 Process

1. *Data*: Feed NetVLAD images of the same place captured at different times. This "weak supervi-

sion" means we know they're the same place, but not which specific parts match.

2. *Learning by ranking*: NetVLAD compares these features and ranks images based on how similar they are. Images of the same place should have similar features and rank higher than those from different locations.
3. *Incremental Improvement*: As NetVLAD processes more images, it learns to better identify and compare features, improving its place recognition accuracy.

3 TOPIC 2: Terrain Navigation

Given a digital elevation model (DEM) of a small area, create a contour plot and identify a navigable path with the least cost from a starting point to an ending point.

3.1 Input

1. Digital Elevation Model (DEM): A raster dataset representing the elevation of the terrain.
2. Starting point: Coordinates within the DEM representing the origin of the path.
3. Ending point: Coordinates within the DEM representing the destination of the path.

3.2 Deliverables

1. Contour plot: A visual representation of the terrain elevation with contour lines.
2. Navigable path: A sequence of coordinates representing the path with the least cost from the starting point to the ending point.
3. (Optional) Additional information about the path, such as total distance, elevation changes, and potential obstacles.

3.3 Constraints

1. The path must be traversable by a specified agent (e.g., human astronaut, moon rover with limited mobility).
2. The cost of traversing a segment of the path can be based on factors like elevation gain/loss, slope, terrain type (e.g., rock, crater), and distance.
3. Computational resources may limit the complexity of the analysis.

3.4 Process

The cost function for the path analysis can be customized based on the specific application and agent capabilities. Advanced pathfinding algorithms can consider additional factors like visibility, obstacles, and dynamic constraints. The DEM resolution and processing methods will influence the accuracy of the results. Also needed will be Geographical Information System (GIS) software for processing the DEM and generating the contour plot. Least cost path analysis algorithms (e.g., Dijkstra's algorithm, A*) to identify the optimal path.

4 TOPIC 3: Generate Synthetic Lunar Horizon Imagery

Develop a system that utilizes a StyleGAN model (or another Image Generation model of your choice) to generate realistic and diverse synthetic images of the lunar horizon surface, using the photographic data captured by the Apollo missions.

4.1 Inputs

1. High-resolution digital scans of the original Apollo lunar photographs (e.g., Hasselblad images).
2. Pre-trained StyleGAN model (e.g., StyleGAN2, StyleGAN3) capable of generating high-resolution images.

4.2 Deliverables

A set of synthetic lunar images that:

1. Visually resemble the original Apollo photographs in terms of texture, lighting, and overall lunar landscape characteristics.
2. Exhibit diverse variations in surface features, lighting conditions, and viewing angles not captured in the original photos.
3. Maintain a high level of photorealism and consistency with the visual style of the Apollo imagery.

4.3 Constraints

1. Computational resources may limit the number and resolution of generated images.
2. The StyleGAN model should be trained and fintetuned specifically on lunar imagery or adapted to generate lunar-like textures and features.
3. Generated images should not contain artifacts or inconsistencies that detract from their realism.

4.4 Process

We need to use image quality assessment metrics (e.g., Inception Score, Fréchet Inception Distance) and perform visual inspection and comparison with real lunar photographs. Consider incorporating additional data sources like lunar elevation maps and geological information to enhance realism and diversity. Explore techniques for generating specific types of lunar features (e.g., craters, mountains, lava flows).