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Optimized Auto-Navigation on a Google Map Image

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Abstract:*This research describes fundamental ways to navigate an optimal driving path within a road map image from Google. Without any usage of developed driving software and well-made test curves for a road, we seek for a path on an interesting Google Map image using basic MATLAB functions. Considering the natural driving factors of visibility and the speed limit, a proper step size is selected and a driving algorithm is established by utilizing mathematical modulus theory and Image Processing technique of color identification. The optimized driving path with the minimum angle turns at each step is sought and refined for the better smooth path. The research concludes that consideration of visibility factor is very important in the design of smooth pathways. With a corresponding USGS elevation data three dimensional terrain map is created and the virtual 3D trajectory is simulated parallel to the 2D plotting.*

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I. Introduction

As an extensive teaching and learning methodology, the undergraduate research experience has been advocated to have a higher impact on students' academic achievement. Many academic surveys on these undergraduate research state that through a series of research practice under professional mentors, students gain two types of research benefits: professional growth and personal growth. Professional growth includes research skills such as the method of inquiry and analysis, critical thinking in professional mode, and communication skills. In the personal growth, students have benefits of independence of intrinsic motivation for learning, the increase of self-confidence, and more advantages in any career path in ([1], [2]). Many educators, particularly in the science-technology-engineering-mathematics (STEM) fields have believed that a research experience also compels the student's interest in a science career [3]. Such a sequential effects produce the positive long-standing effects of heightened performance, such as achieving academic excellence in graduate degrees ([4], [5] [6]).

This article is written based on an undergraduate research, which is conducted by a sophomore undergraduate student who is pursuing double majors in Mathematics and Computer Science. The article introduces sequential processes of how the undergraduate researcher approaches the topic, resolves the problems and brings out good results.

The technology of autonomous vehicles has been drastically developed in the last decade and becomes a great interesting area in modern engineering fields. As of 2019, twenty-nine U.S. states have passed laws permitting autonomous vehicles ([7]) as the technology for them continues to develop. An autonomous or self-driving system is briefly a synthetic product of modern science and technology, including operating machinery, electronics, artificial intelligence techniques, etc. See [8]. As a part of development of full automation vehicle of level 5 ([9]), the technology of autonomous navigation is also vividly being developed to overcome various real-time situations.

On the other hand, the modern navigation systems direct only the direction of driving and road traffic levels and the direction maps from Google or Mapquest literally indicate the direction from the starting point to the destination point with blue lines without addressing the details of how to drive. Our research starts with one directional image from Google map. Since any program, including the MATLAB driving Toolbox, does not allow to mount an arbitrary road image for testing drive but requires a numerical functioned road with numeric center points, our concerns in this research is to search the most optimized driving way on an imaged road, without calculating the road boundaries as mathematical functions.

II. Methodologies

1)Image acquisition: A map of interesting area is sought by surfing the Google map and maps in both the street view and the satellite view formats are extracted and saved in Tiff format by using the 'extend' function of QGIS program [10]. In the similar way, a DEM map for corresponding street area is acquired from USGS web-site [11]. In order to proceed to finding a pathway, we work with a google map [12] representing a part of Mt. Lemmon Rd, Mt Lemmon, AZ 85619, USA (Latitude: $32° \, 28' 36''$ N,, Longitude: $110° 42' 54'' W$) which corresponds about 1 mile driving distance or 5 minute driving time as shown in blue line in the Figure 1. Since this road is located on a mountain, the narrow and winding road leads to the top of the mountain. So that it makes driving difficult. We mainly work with the street viewed map.

Figure 1. Street view map from Google

2)Pre-processing: The road map image has its size (resolution) 1218 x 1567 x 3 pixels. That is, we can consider the image as a 1218 x 1567 x 3 dimensional matrix. The street names on the road form the obtained RGB colored image (street view) is erased by identifying the black color from other colors (black (0) and white (255)). For convenient usage of numerical color identification, the image may be converted to a grayscale image. And then median or Gaussian filtering techniques may be applied to the image to remove present noises. We set (or plot) the starting point and the ending point of driving on the road. In addition, not to step on the road curve itself, the virtual boundary curves are set up to 2 pixel inside of the real road boundaries as shown in Figure 2.

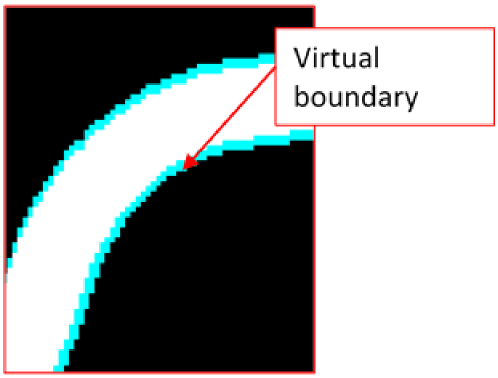

Figure 2. Virtual shoulder of road

3) Determination of step-size: A normal step size is determined as: The speed limit for driving on this area is restricted to 25 mile/hour, which is 11.176 m/sec. Since the 1 pixel in the image equals 0.5m, 6 pixels is 3 m. If we set the magnitude of step size at 6 pixels, it has 0.25 second driving interval. It looks feasible.

4) Determination of driving direction: Once you positioned at a certain cell, you have a 32 possible forward ways as shown in Figure 3 a). Considering the previous position and maximum handling (90 °) of the car, you have only 17 choices for the future position as shown in Figure 3 b).

5) Design of driving path with optimizing constraints: In the design of the driving path, the code in MATLAB is written considering the priority of the following:

a. Run inside of safe region of the road
b. Keep going straight, if possible
c. If you can’t go straight, make the minimum turn (left turn first, or make a right turn of the same angle)

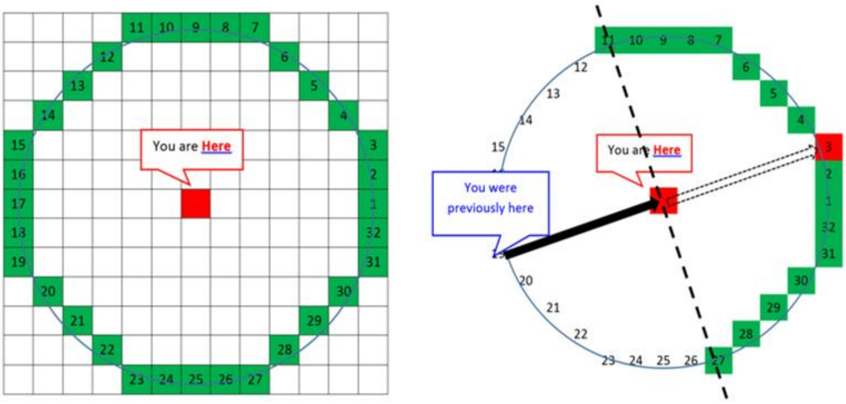

Figure 3. a) Possible 32 directions   b) Possible 17 driving directions

The mathematical modulus theory is mainly utilized to implement the overflow circular iteration in code.

III. Experimental Algorithms

1) Test Driving 1: Basic six pixel forwarding

In order to determine the first direction, the first two initial points are set at (884. 2) pixel and (883, 8) pixel. Then it is successful to drive from the starting point to the ending point. It has the total number of 643 steps and the total sum of curvature 10.5352. However, the path has the zigzag patterns here and there as shown in Figure 4 a) because of the maximum straight forward condition.

Figure 4. a) Zigzag driving sample   b) Imaginary straight guideline in red

Idea to improve: In order to design the better path, we consider the possible straight path interval. Since we work with an imaged road, we can find out the section of road where straight driving is more efficient. We put this imaginary straight guideline into the map in red as shown in the Figure 4 b) and push the car to pass through them.

2) Test Driving 2: Basic six pixel forwarding with straight guideline

The second test driving is also successful to drive to reach the ending point. It has the total number of 633 steps and the total sum of curvature 11.5936. That is, it has a successful reduction of steps implying the shortened driving time, but increases the sum of curvature implying the increase of unnecessary handlings. Thus, it still shows the crooked paths before or after the straight driving sections as shown in Figure 5 a). We figure the reason that each path point only concentrates on the next point without considering the further future points. To get the improved path, we need to secure the further distant sight.

Idea to improve: While driving, the drivers see naturally more than 100m front scenes in the daytime and 30 m – 40 m scenes (normal visibility by headlight) in the night time [13] as long as there is somewhat visibility reduction factors,

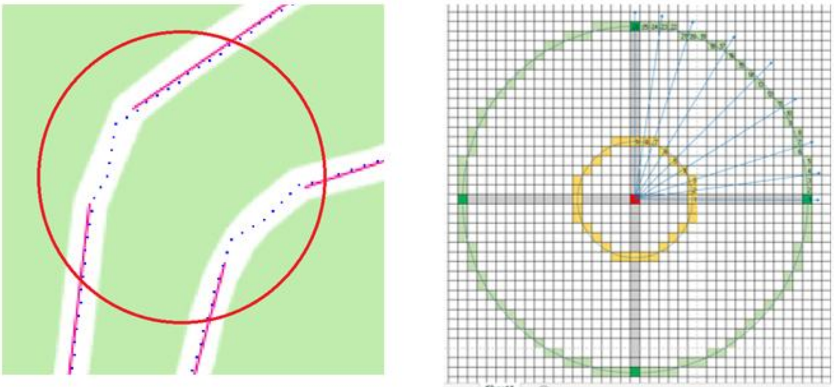

Figure 5. a) Another Zigzag driving **b) Consideration of the 18 pixel distant visibility**

such as air pollution, fog, smoke, and so on. In a heavy air pollution or rainstorm, the drivers may not be able to see more than 100 feet (30.4 m) ahead of their vehicles. Moreover, their headlights only let them see about 350 feet (106.68 m) ahead [14] and the pedestrian visibility distance is just 150 - 250 feet (45.7 – 76.2 m) at night in [15]. (Daytime pedestrian visibility distance is around 1000 feet (304.8 m).) Furthermore, minimum acceptable visibility (MAV) on highways due to smoke is 108 feet (32.9 m) in [16]. To examine this visibility effect to our driving pathway, we set the visible point at 12 m (18 pixels) ahead (instead of natural 60 pixel (30 m) ahead) for a calculation convenience. See Figure 5 b). Once the 18 pixel direction is determined, we choose the 6 pixel step again which is closest to the 18 pixel direction.

3) Test Driving 3: Six pixel forwarding with straight guideline and 18 pixel visibility

Then as shown in Figure 6, the third test driving is very successful to reach the ending point without zigzag handling. In addition, it has only the total number of 619 steps and the total sum of curvature 10.0607 as an effect of driving time reduction and improvement of smoothness of the path. As addition work, the implemented path is plotted on the satellite map in Figure 7 and a 3 dimensional terrain map in Figure 8.

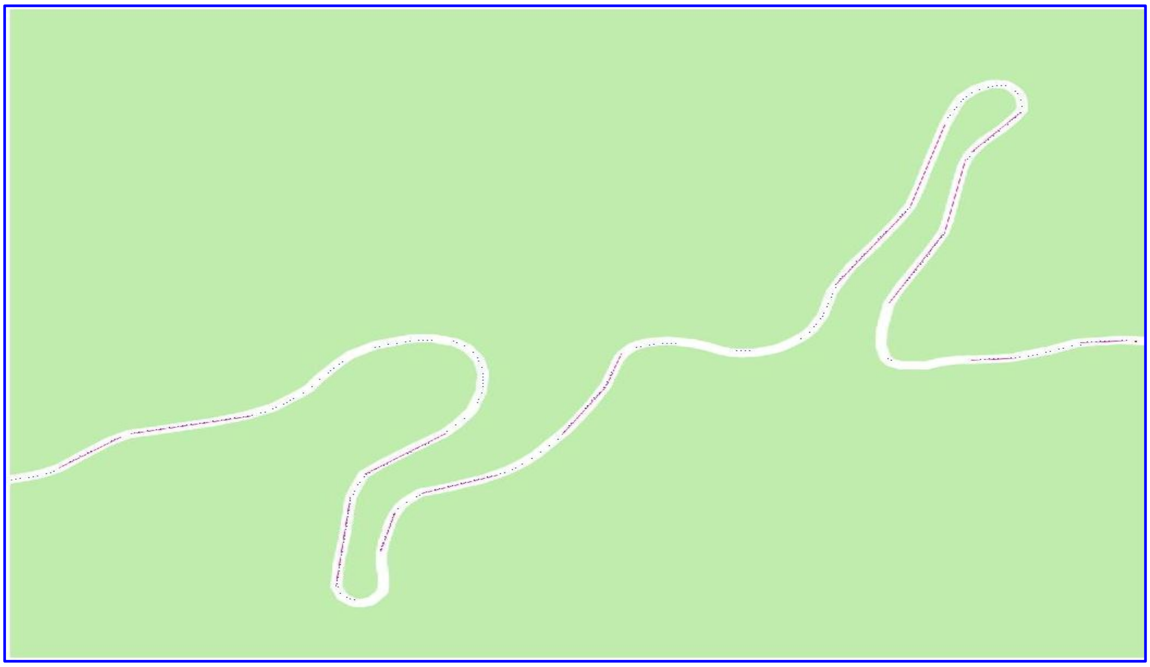

Figure 6. Driving path of 6 pixel forwarding with straight guidelines and the 18 pixel visibility

Figure 7. Driving path of 6pixel forwarding with straight guidelines and the 18 pixel visibility on the satellite map

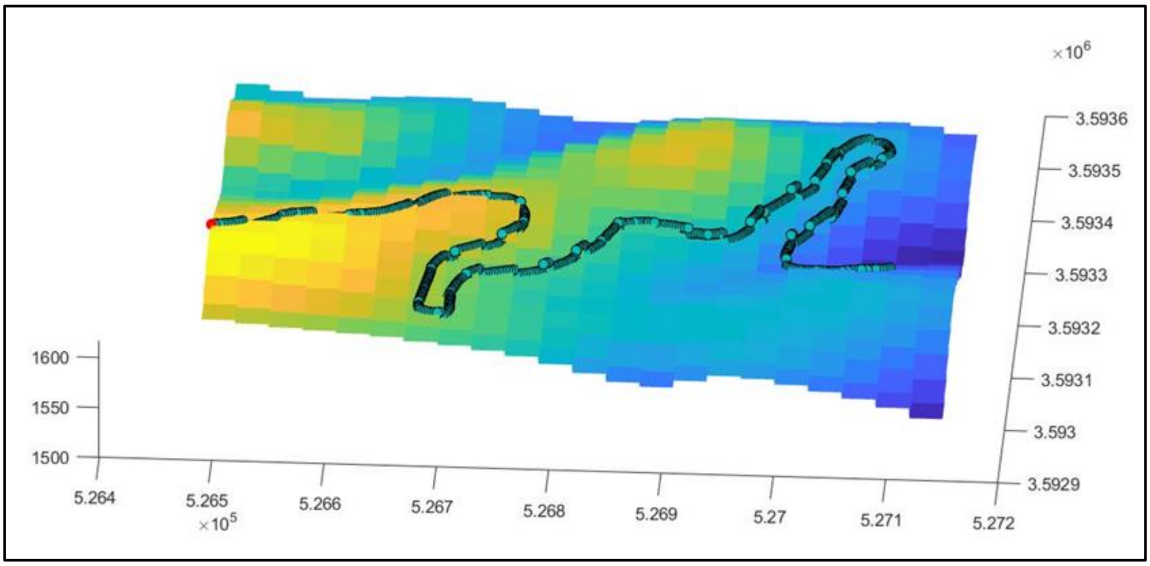

Figure 8. Driving path of 6 pixel forwarding with straight lines and the 18 pixel visibility on a 3D terrain map

Remarks:

In Figure 10 the 3D terrain map is created from the 1 arc-second (approximately 30 m- 1:24,000 scale) resolution digital elevation map (DEM) data (Entity ID: ASTGDEMV2_ 0N32W110) from USGS in [17] with the Universal Transverse Mercator (UTM) coordinate system. As shown in the figure, however, the 1 arc-second elevation data looks so tough to create the terrain map for this small area.

IV. Conclusion and further discussion

We explored optimized navigating algorithms following an interesting road on a Google street image. Each pathway obtained from each algorithm is basically sought using the color identification technique in image processing. Pathways are developed one by one by improving issues found in the previous trial. Table 1 compares the results from these three trials. It states that consideration of the visibility factor is very important in the design of smooth pathways.

Table 1. Comparison of three driving pathways

Test Trials	Total steps (Driving time)	Total Curvature	Handling
Basic with 6 pixels	643 (2min 41sec)	10.5352	Worse
Guideline with 6 pixel visibility	633 (2min 38sec)	11.5936	Bad
Guideline with 18 pixel visibility	**619 (2min 35sec)**	**10.0607**	**Good**

The research can be extensively applied to the development of real-time navigation while accepting the broadcasted information and thus contributes to the development of autonomous vehicles.

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