2020 UDOT RESEARCH PROBLEM STATEMENT

<u>Problem Statement deadline is March 16, 2020. Submit statements to UTRAC@utah.gov</u>

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Title: Leveraging the Existing LiDAR Data for Asset Management and HD Map Generation **No. (Office Use): 20.02.07**

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Select <u>ONE</u> Subject Group ☐ Materials/Pavements ☒ Maintenance ☐ Traffic Mgmt/Safety ☐ Structures/Geotech ☐ Planning ☐ Aeronautics ☐ Public Transportation ☐ Other

1. Write a brief research project objective:

The Utah Department of Transportation started employing LiDAR technology on a groundbreaking data collection project in 2012. The collected data have been used to improve asset management. This research project proposes to use machine-learning technology to fuse data collected from sources such as LiDAR, laser, camera, and GPS to expand the use of the collected data. The objectives of this research project are threefold: (1) line identification and paint stripe evaluation; (2) automatic assessment of a wide variety of roadway assets; (3) high-definition (HD) map generation for advanced driver assistance system (ADAS) and autonomous vehicles (AV).

2. Explain the problem and why this research is important: (*Importance reflects 50% of the statement score*)

As a general consensus and the growth of enthusiasm for self-driving cars, advanced driver assistance systems (ADAS) have successfully made their ways into the automobile industry. Many ADAS features are already available to luxury cars and quickly expanding to others lower cost selections. Autonomous driving is not far behind. Although fully autonomous (Levels 4 and 5) vehicles may still be many years away, preparation for the future should be in the planning. Researches have been conducted to identify challenges of adapting this exciting technology. As the AV technology advances, government officials will soon have to consider what they can and should do to prepare their citizens for the future [1]. Besides the technology developments, consumer confidence, policies, and legal and liability issues, roadway assets' suitability for AV usage is an important factor that affects the adaption of AV technology.

Vision sensors and LiDAR are arguably the most important sensing devices for AV. Vision sensors provide high-resolution color visual information for line detection for lane following, object and traffic signs detection and recognition, stoplight color reading, and vehicle localization. One of the primary advantages of LiDAR is accuracy and precision [2]. It provides extremely accurate 3D information that is not affected by shadows, bright sunlight, or the oncoming headlights of other cars, and it works in low-light or dark environment. LiDAR also records the strength of laser pulse (intensity), classification of objects, scan direction and angle, and GPS time, etc. Fusing these data with visual data helps the AV to make critical decisions and plan its path.

With the already collected LiDAR and visual data, this research proposes to automatically evaluate a variety of roadway assets for autonomous driving. Our first task is to detect and identify paint stripes and evaluate their quality and suitability for autonomous driving. Both LiDAR and visual data will be used for this study. We will then expand our research to evaluate other roadway assets such as traffic signs and street and highway signs. Our third task is to study the possibility of using the already collected data to generate HD maps for autonomous driving and document suggestions for future data collection.

The proposed research project will be able to streamline these evaluation processes and provide an accurate inventory of roadway assets automatically. The results of this research will provide important information for the preparation of Utah's roadways for the future.

1. https://www.weforum.org/agenda/2019/10/how-should-cities-prepare-for-self-driving-cars-heres-a-roadmap/
2. https://www.autopilotreview.com/lidar-vs-cameras-self-driving-cars/

3. Describe how the research results will be implemented and benefit Utah: (*Implementation reflects 50% of the statement score*)

This research will incorporate machine-learning based algorithms to evaluate the suitability of roadway assets for autonomous driving. One recent success conducted in the Robotic Vision Lab at BYU was to develop a machine-learning algorithm to evaluate pavement into 4 different conditions [3]. Expanding on our past success, it is proposed to use deep neural networks to analyze the collected LiDAR and visual data to automatically detect, locate, recognize, and evaluate the roadway assets and report their suitability for autonomous driving. Figure 1 shows a fully convolutional neural network proposed for this evaluation task [4]. This network will be trained to segment the input LiDAR intensity image into line and no-line regions. The LiDAR intensity is input to the left and the network will output an image on the right that marks the image pixels classified as line white and the pixels of the road black. The output image can then be compared with the recorded visual data to determine the LiDAR intensity's suitable for autonomous driving. This comparison can only be performed when visual data is available. For low-light or dark environment, image processing technique such as Hough Transform can be used for line and curve detection. Figure 2 shows a typical output image of Hough Transform with detected line highlighted in green.

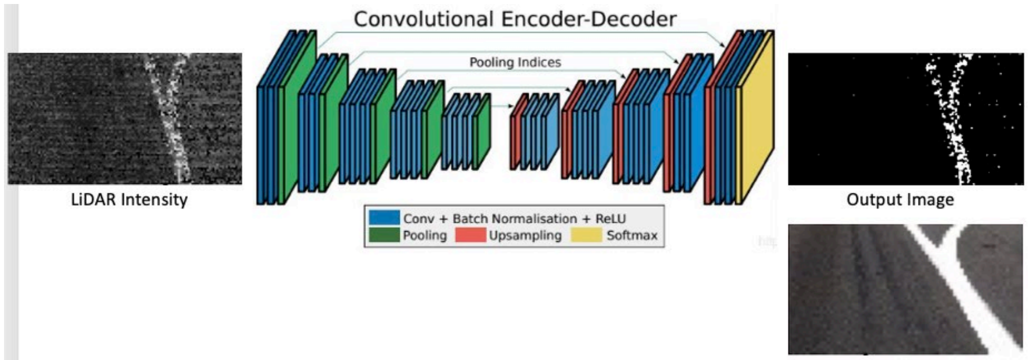

Figure 1. Fully Convolutional Network.

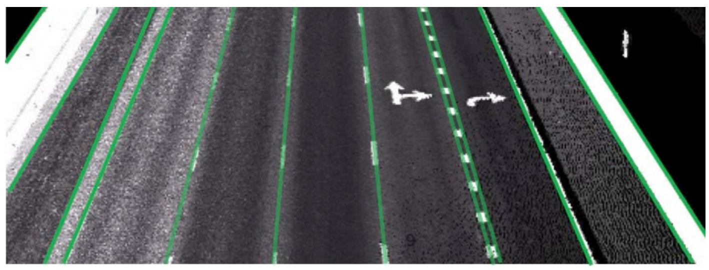

Figure 2. Typical Hough Transform Output.

For roadway asset quality evaluation, as shown in Figure 3, we have designed a convolutional neural network to extract visual feature from the visual data from the camera and fuse the features with LiDAR ranging data to locate a 3D bounding box in point cloud to analyze the asset structure and 2D bounding box for object location to evaluate asset quality. With this 2D and 3D information, we can also recognize the type of the object, the content of the sign, the condition of the road, etc. and add these data to the LiDAR date to generate and store the HD maps on cloud drives for self-driving cars to access.

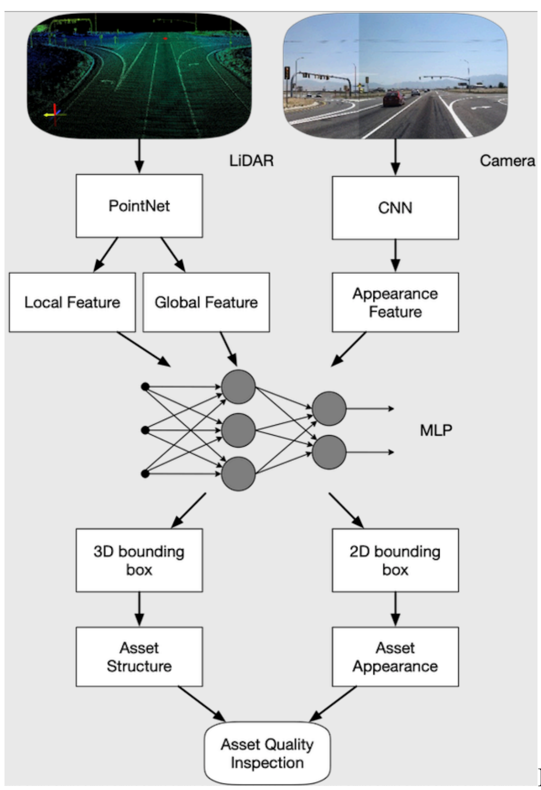

Figure 3. Asset recognition and evaluation.

3. ZH Guo, M, Zhang, and DJ Lee, Efficient Evolutionary Algorithm for Real-time Embedded Vision Applications. Electronics, 8(11), PP. 1367 18 pages. November 2019.
4. http://www.programmersought.com/article/1224188008/

4. List the major research tasks:

1. Kickoff meeting to finalize project scope of work and cost estimates.
2. Examine and evaluate the existing visual and LiDAR data.
3. Label the roadway assets for training.
4. Design and implement a fully convolutional network for line identification.
5. Design a 2D-3D network for asset structure and quality evaluation.
5. Develop the criteria for roadway asset evaluation.
6. Conduct experiments, compile statistics, and develop conclusions and recommendations.
7. Report results to UDOT in the form of a written report.

5. List the expected research deliverables (reports, manual, specification, design method, training, video, etc.):

1. Engineering report documenting the research results and technical publications.
2. A video demonstrating the functions of the software.

6. Requested from UDOT: $70,000 **Other/Matching Funds:** $ **Total Cost:** $70,000
Briefly explain funding sources:

7. Outline the proposed schedule, including start and major event dates:

It is recommended to start this project in the late summer or early fall of 2020 with completion of the first two tasks before October. Tasks 3, 4, and 5 can be carried out in parallel from November 2020 to May 2021. Task 6 will be completed in the summer of 2021 with the final review completed before December 2021. The total schedule will be approximately 16-18 months.