Automated Drive West: What VSI Discovered on the 2,000+ Mile Drive

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In August 2019, VSI Labs embarked on a 2,000+ mile cross-country road trip with one of our research vehicles. VSI's vehicle drove from Minneapolis, Minnesota to Santa Clara, California by applying Automated Vehicle (AV) applications on highways.

The primary purpose of the Automated Drive West (ADW) was to better understand the limitations of over-the-road automation technologies. More specifically, this experiment relied on precision lane models (HD Maps) coupled with absolute localization using real-time kinematic (RTK) corrections.

VSI's research vehicle is a 2018 Ford Fusion equipped with Dataspeed's by-wire control system. The two primary components used in this project were HERE high definition (HD) Live Map and an OxTS inertial navigation system (INS). The OxTS INS is compatible with RTK corrections enabling precision localization. The vehicle was also equipped with a Delphi ESR radar, which was used for adaptive cruise control (ACC). For domain control VSI uses a custom-built Linux-based computer that runs the lane-keeping and ACC algorithms developed by VSI engineers. The vehicle also required LTE connectivity for dynamic map loading and correction services. In essence this was a Level 2+ vehicle because it used an HD map of the road network.

The ADW was the first experiment in which VSI attempted a cross-country highway drive in AV mode. This article walks through our observations and findings throughout the drive.

Key Findings

Overall, our HD-map based lane-keeping and ACC worked well throughout the drive. We observed that the HD-map based system performed adequately even when lane markings on the highways were not good for much of the drive, making a vision-based system inadequate for sustained lane keeping.

VSI practices strict discipline when testing automated driving functions and only operates when conditions are safe. We did not enable automated features under dangerous road conditions or conditions where the safety driver would not have adequate time to react. Such conditions include winding roads, low visibility, high roadways without guardrails, areas with pedestrian traffic, and late-night driving. Additionally, the system was disengaged in areas such as highway exits, construction zones, newly constructed roadways, areas with limited connectivity and RTK base stations.

While many of the observations along the drive were expected due to limitations of the system, key findings from this project are as follows:

The vehicle's automated features were engaged for 1,767 miles of the 2,000 miles. Most of this was on the Interstate Highway System, a network of controlled access multilane highways in the United States.

The quality of the HD Maps for the U.S. Interstate Highway System is quite good yielding very positive results with the VSI vehicle. On roads other than controlled access routes, the map data was not good enough to support highway automated lane keeping so we resorted to map-based ACC with a surprising side benefit – VSI discovered that applying maps to ACC improves the performance of radar-based ACC applications because you can filter out extraneous radar points (false positives) that yield inconsistent performance.

Maintaining connectivity over the western United States was a challenge. Wireless outages limited correction services at times. However, the OxTS device was able to maintain organic accuracy of 30cm, which was enough to bridge large gaps or a falloff in connectivity for periods of time.

When overtaking semi-trucks, human drivers naturally keep to the far side of the lane to give the truck more room and limit aerodynamic pull from the truck. Our AV was not programmed to do this, and our control stack did not take this disturbance into account. The ability of the control system to cope with large disruptions in airflow was very limited.

The best performance from the autonomous system took place on Interstate 90 in South Dakota and Interstate 80 in Utah and Nevada. This is where the map data was accurate for the longest periods of time, oftentimes allowing the system to stay enabled for over 50 miles at a time.

The radar in the front of the vehicle accumulated a lot of dust, bugs and debris along the drive. The output from the radar was unaffected, but other external sensors such as camera and LiDAR would see greater effects from this. As such, sensor cleaning will be necessary for autonomous vehicles driving long distances in the future.

Keeping AV computers cool when running in warm conditions was also a challenge on the drive west. To cope with this, VSI installed rack mounted server fans to cycle cool cabin air into the trunk where most of the AV gear is located. If we had not done this, the temperature would exceed 110°F and damage the computers. Cooling mechanisms are necessary to maintain proper operating temperatures for autonomous vehicles.

Lastly, throughout this drive, we reaffirmed the importance of safety driving when testing autonomous vehicle technologies on public roads. The safety driver must always be alert and understand how to use the system, where the system will perform well, and most importantly when the system might fail. Safety driving is more mentally taxing than regular driving, as the driver must constantly anticipate what might happen next. During the trip, it was important to take breaks from driving every few hours, even just to stop at a fuel station.

For our regular testing, we normally have two people in the car: one safety driver and one engineer. However, for this trip, there were three people in the car to ensure safe testing including the safety driver, the engineer, and the third monitor who sat in the passenger seat and managed the HMI controller to set and adjust desired speeds, adjust lane positions, and monitor the trunk's temperature.

A lot of communication was required between the safety driver and the engineer. The engineer was watching the lane model to make sure it aligned with what the driver was seeing on the roadway, monitoring the level of position accuracy from the INS device, watching the radar readings to see whether the radar was identifying the closest in-path vehicle for ACC, and finally making sure that the maps were downloading quickly enough. The driver communicated when things became uncomfortable and needed to judge when to ask for the status of certain systems so that the engineer could assist in determining whether to engage, stay engaged, or disengage.

Conclusion

After more than 2,000 miles of exploring the capabilities of lane-keeping and ACC with precision lane models and precision localization, VSI gained valuable insight and data to better understand the limitations of these systems. Testing these map-based solutions in isolation showed the strengths and weaknesses of the system, which is the vital first step in developing redundant systems. The Automated Drive West provided much-needed variety in the road conditions and situations experienced by the VSI research vehicle, giving insight that would not be possible to obtain when driving in a geofenced area with known conditions.

About VSI Labs

Established in 2014 by Phil Magney, VSI Labs is one of the industry's top advisors on AV technologies, supporting major automotive companies and suppliers worldwide. VSI's research and lab activities have fostered a comprehensive breakdown of the AV ecosystem through hands-on development of its own automated vehicle platform. VSI also conducts functional validation of critical enablers including sensors, domain controllers, and AV software development kits. Learn more about VSI Labs at https://vsi-labs.com/.

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