Prospectus

Remote-Sensing Enhanced Nondestructive Evaluation of Roadway Infrastructure
(Technical Topic)

Ethics of Autonomous Vehicles
(STS Topic)

By

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Introduction:

Currently, national regulations only enforce the inspection of roadways every 5 years and the inspection of bridges every 2 years (Gee, 2007). These inspections are done mainly by ground-based vehicles, which is a very inefficient method. The inefficiency of these inspections causes VDOT (the Virginia Department of Transportation) to focus on fixing only the roads in the worst condition, instead of maintaining worn roads. My team will work to develop a technical solution to this problem as part of Spacecraft Design 1 and 2 by designing a CubeSat (a small satellite that consists of one or more 10cm x 10cm x 10cm cubic modules) that will use remote sensing technologies to obtain data on roadway conditions from space. This data can be used by VDOT to dramatically improve the roadway inspection process.

My STS research focuses on another transportation related issue that is tangentially related to my technical topic. Autonomous vehicles (AVs) will soon be sufficiently advanced to be widely used, but although the technology will soon be a reality, there are still significant social and ethical questions that need to be resolved before this can happen. One of the central ethical issues with autonomous vehicles is how they will distribute harm in dilemma situations, an issue which is often studied using the trolley case (Himmelreich, 2018). It is also still unknown how liability will be determined in the inevitable case that autonomous vehicles crash. Currently, there are only rudimentary regulations and policies that address AVs, and much more will need to be decided on how to regulate the usage of AVs. My STS paper will address these and other ethical issues related to autonomous vehicles using Actor-Network Theory (ANT).

Technical Topic (Remote-Sensing Enhanced Nondestructive Evaluation of Roadway Infrastructure):

There are over 57,000 miles of roadways that need to be maintained by the state of Virginia and the Virginia Department of Transportation (VDOT). These roadways are crucial to transportation efficiency and the daily lives of the public. Current infrastructure evaluation methods such as Visual Inspection, Acoustical Techniques, and Infrared/Thermal Imaging are inefficient and accomplished only by using a variety of ground-based systems. These ground-based systems have many drawbacks, including traffic buildups, lane closures, and the fact that they are labor intensive (Vaghefi, 2012). Additionally, they each have limitations such as invalid assessment of interior infrastructure, inaccurate testing, and limited usage (McGuire, 2020, para. 1-3). To improve the inspection process, my team's solution will include remote-sensing enhanced nondestructive evaluation using data collected by a CubeSat. A satellite or possibly a constellation of satellites would be capable of continuously sending data on all roadways in Virginia to VDOT, allowing them to focus their ground-based methods on areas that are in poor condition, instead of periodically evaluating all roadways. This would create a more efficient system that would cost less, require less labor, and cause fewer delays.

Maintaining the condition of transportation infrastructure is vital for the wellbeing of the public. The collapse of bridges can be extremely dangerous; one such collapse of the I-35W in Minnesota caused the death of 13 people (Vezner, 2007). Although this particular collapse led to reform in how infrastructure is inspected, the methods used today are now dated and could be improved to be more efficient and less costly. Research has indicated that as road conditions deteriorate, there are more collisions and accidents tend to be more severe (Alhasan, 2018).

There are a wide range of remote sensing technologies that could be used to collect data on roadway conditions (Vaghefi et al., 2012). One of the most promising sensors is Interferometric Synthetic Aperture Radar (InSAR). Data collected with InSAR using TS (temporary scatterer) data points can be correlated with surface roughness of roadways (Hoppe et al., 2016). By collecting data on all transportation infrastructure continuously through the use of a satellite, it would be possible to identify which roads are deteriorating at faster rates and prioritize these problematic areas.

The goal of this technical project is to determine whether a spacecraft or constellation of spacecraft could use remote sensing data to help address the problem of remote sensing enhanced non-destructive evaluation of roadway infrastructure. This problem is one of three problems being researched by MAE 4690 Spacecraft Design 1. The project is completed in a group of 12 students, with assistance from technical advisor Chris Goyne. The team will present periodically to representatives from MITRE, with whom the class has a contract. The team will also produce an end of semester report detailing what work has been done. If the research done during the semester shows that a spacecraft solution to this problem is possible, then the team will work to create a conceptual design in the subsequent semester. This conceptual design can then be built upon by future classes of Spacecraft Design.

STS Topic (Ethics of Autonomous Vehicles):

Autonomous vehicles (AVs) will soon be advanced enough to be widely used, but there are numerous ethical questions that will need to be answered before this can happen. Even simple situations like approaching a crosswalk can raise ethical questions about how an AV should behave (Himmelreich, 2018). One of the cases that is often considered with respect to AV ethics is the so-called trolley case. The simplest trolley case is this; there are 5 people tied down to the tracks in front of an oncoming trolley. You can do nothing and let them die, or pull a lever to divert to trolley to another track that will only kill one person. Is the correct ethical decision to do nothing and let the 5 people die or to pull the lever to save 4 people but in doing so take responsibility for killing the single person on the other track (Fleetwood, 2017). This case is important for autonomous vehicles because in dilemma situations, AVs may be able to choose between, for example, continuing on course and running over a pedestrian or diverting course to crash off the road, potentially injuring the driver. In these situations, the Av must be able to make a choice that is both acceptable to the general public and acceptable to an individual driver. The public will not be comfortable with AVs unless they make ethical decisions, and drivers will not want to use AVs if they are too quick to sacrifice their driver (Fleetwood, 2017). Researchers at MIT have developed a program called the Moral Machine to collect data on how people would like AVs to react in different situations. The data from this study shows that people have a clear preference for sparing humans over animals, more people over fewer people, and young people over older people. However, the data on whether passengers should be spared over pedestrians or whether taking action is preferable to inaction is much more ambiguous (Awad et al., 2018). Research has shown that people would prefer AVs in general to use utilitarian algorithms (ones that do not preferentially protect their drivers and instead seek to minimize overall harm), but would be unlikely to consider purchasing an AV that uses a utilitarian algorithm. If regulations require utilitarian algorithms to be used, then this may delay the public's adoption of AVs. However, if both utilitarian and non-utilitarian vehicles are allowed, then the public would almost exclusively purchase the non-utilitarian models (Bonnefon et al., 2016). Both of these outcomes would have a negative public health effect.

Another ethical issue regarding AVs that has yet to be resolved is the issue of responsibility for crashes. Although some progress has been made on this issue by multiple countries, there is no definitive answer, and many different approaches have been used around the world (Taeihagh & Lim, 2019). Germany's ethics commission on AVs, for example, has stated that responsibility for AV related crashes should shift from the driver to the manufacturer (Germany's Federal Ministry of Transport and Digital Infrastructure, 2017). However, it is possible that holding manufacturers responsible like this may discourage innovation, and have a negative overall effect on public health. This is because AVs will likely be safer than human drivers, and any delay in the adoption of AVs would therefore be a negative outcome (Hevelke & Nida-Rümelin, 2015). Hevelke & Nida-Rümelin concluded in their research that there are 2 ethically acceptable solutions to this issue. The first is to hold the driver responsible if there was time enough to intervene and prevent a crash. This would only be applicable to AVs that are not fully autonomous. The second solution proposed is to hold AV owners collectively responsible for taking the risk of driving an AV. This would likely be accomplished through a mandatory insurance paid by all AV owners that would be used to resolve crash liability without holding a specific person responsible

My STS research paper will examine this problem through the lens of Actor-Network Theory (ANT). ANT treats relevant social groups and technologies as equally important actors that interact to form a network. ANT is appropriate for this application because there are many important factors at play in the ethics of AVs that are both human and non-human. The problem cannot be fully defined without considering all of these actors (AV users, AV manufacturers, the public, AV regulations, AV algorithms, etc.). Research methods will include examining available data from studies like those of Awad et al. and Bonnefon et al., as well as reviewing the literature on the topic. Sources will be examined to ensure they are peer-reviewed and reliable.

Conclusion:

My team's technical deliverable at the end of the second semester of Spacecraft Design will be a conceptual design of a CubeSat capable of obtaining data on roadway conditions. My team will produce a final report on the progress made and a deliver a final presentation to MITRE, the sponsor of the project. This conceptual design can then be used by a future class that can work on building and launching a satellite or constellation of satellites that will improve infrastructure inspection. My STS deliverable will be a better understanding of what ethical and social problems are raised by the coming introduction of AVs onto the road, and possible solutions to these problems. My research will accomplish this by using ANT to build on previous academic work done on the topic of AV ethics. This improved understanding can be used to help make more informed decisions on how to successfully integrate AVs into society.

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