Autonomous Vehicle Scenario Modeling System Requirements Specification

Version 1.4

2/4/2025

Document Control

Distribution List

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Change Summary

The following table details changes made between versions of this document:

Version	Date	Modifier	Description
0.1	Oct-22-24	All team members	Initialization of the document and addition of rudimentary information.
0.2	Oct-24-24	All team members	Continuation of documentation
0.3	Oct-28-24	Davian, Isabella, and William	Continuing to work on document, divide sections and assign work between team
0.4	Oct-28-24	Hannah	Update TOC, updating grammar in section 1, updating references, comments, updating bibliography.
0.5	Oct-29-24	Isabella	Work on remaining parts of Section 2.
0.6	Oct-29-24	All team members	Worked on Sections 4-7.
1.0	Nov-24-24	All team members	Made small changes and updates based on Clay's comments from Version 0.1.
1.1	Jan-28-25	All team members	Worked on the version that is due on February 4th which involves the addition of
1.2	Feb-2-2025	All team members	Continued working on new section of SRS
1.3	Feb-3-2025	William Reimer	Worked on Social section of new part of SRS

1.4	Feb-4-2025	All team members	Continued working on new section of SRS document

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1. Introduction

Purpose and Scope

PolyVerif is a simulation tool that is used to test the verification and validation of autonomous vehicles by performing multiple tests in different traffic scenarios. It is currently being used by researchers, developers, and engineers and it was developed by a team of individuals that saw the need for a testing platform for autonomous vehicles. PolyVerif provides itself as a noteworthy option in autonomous vehicle testing. However, seeing as preliminary documentation and software dates back as early as 2021, it is still a relatively new tool on the market. A lack of sufficient testing scenarios within PolyVerif's database leaves room for improvement, which is within the scope of this project's goals. To expand the testing within PolyVerif, Embry—Riddle Aeronautical University will be utilized as a testing ground. The campus provides a set of unique scenarios with varying traffic laws, object interactions, and traffic patterns. This should provide the necessary dynamic and customizable plane to bolster PolyVerif's capabilities.

Intended Audience and Reading Suggestions

This SRS includes all vital information required to properly understand the Autonomous Vehicle Project. For those unfamiliar with PolyVerif or simulation software, it is suggested to read through the entire document, focusing on background information first and then once a basic understanding is reached, continue reading through the document and focus on the more specific and technical sections. Below are some reading suggestions to fully understand the concepts gone over in this document:

Reading Suggestions:

For Those Unfamiliar with PolyVerif and Simulation Software:

- Public Transport System–Test and Validation framework for Autonomous Vehicles [1]
- Autonomous Vehicle Verification Consortium [2]

For those Familiar with PolyVerif and Simulation Software:

- PolyVerif Validation Report [3]

Document Conventions

The fonts throughout this document are consistent for each section and there is no highlighting of sections, each section is separated by its header in bold.

Project References

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Definitions, Acronyms, and Abbreviations

i.Definitions

This section lists terms used in this document and their associated definitions.

Table 1: <Definitions>

Term	Definition
PolyVerif	An open-source validation and verification framework for autonomous vehicles.
Autonomous Vehicle Testing	An autonomous vehicle utilizes a fully automated driving system to allow the vehicle to respond to external conditions that a human driver would manage.
Verification	The process of checking that software achieves its goal without any bugs
Validation	The process of checking whether the software product is up to the mark or in other words product has high-level requirements
Scenic	A language for scenario specification and data generation

ii.Acronyms

This section lists the acronyms used in this document and their associated definitions.

Table 2: <Acronyms>

Term	Definition
AVVC	Autonomous Vehicle Verification Consortium
SUMO	Simulation of Urban Mobility
OSSDC	Open-Source Self Driving Car Initiative
LGSVL	LG Silicon Valley Lab

iii.Abbreviations

This section lists the abbreviations used in this document and their associated definitions.

This does not apply to our project right now; we do not currently have any abbreviations.

Table 3: <Caption>

Term	Definition
AV	Autonomous Vehicle

2. General Description

Product Perspective

This product is intended to expand upon pre-existing test simulations found in the PolyVerif GitHub. Currently, 4 distinct maps exist, with several different traffic scenarios involving each map. The product adds another map to these test simulations, the ERAU campus, and a new test scenario (the number of scenarios is subject to change depending on time). The structure and function of pre-existing code or products will not be altered with this product's introduction, rather, this project will utilize the software currently available, and add plugins, APIs, and supporting code, if necessary, but only to support the functionality of the ERAU map and scenario(s). The existing code allows us to build on the verification and validation of our initial scenario that we will be testing, as well as any other scenarios that we may create in the future.

These additional scenarios will be valuable to the overall PolyVerif system because the amount of raw data to pull from is lacking. The overall goal of PolyVerif is to assist in the creation of autonomous vehicles, and to have a successful autonomous vehicle, it needs to access data created from simulations to address as many different scenarios as possible. PolyVerif does have a library of scenarios to choose from, however, more scenarios to draw from means an objectively safer autonomous vehicle. The addition of the map and scenarios our product provides will contribute to the overall performance of PolyVerif when applied to real-world autonomous vehicles.

Product Features

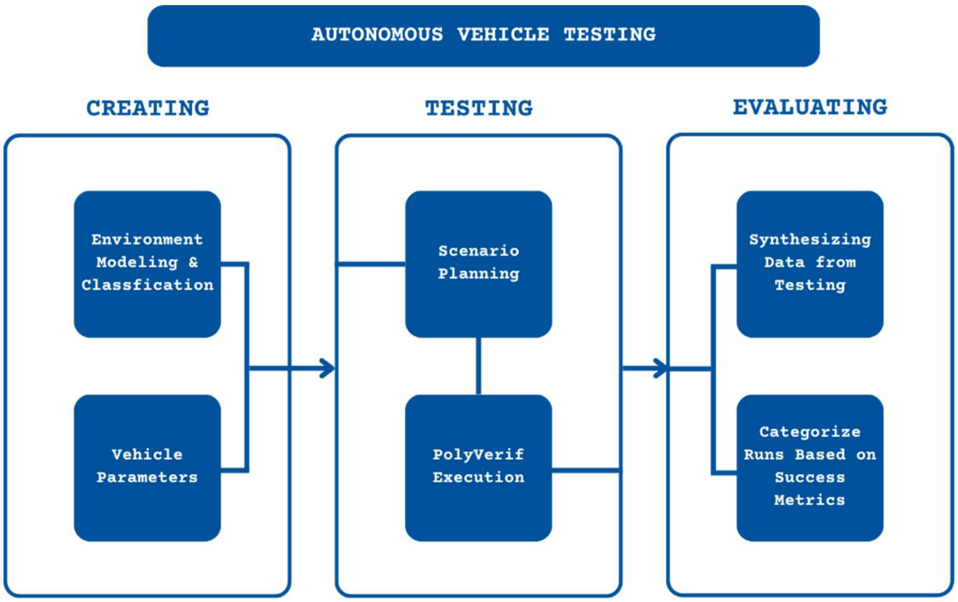

Figure 1: Polyverif Framework and Functionality

Both Environment Modeling and Classification and Vehicle Parameters are responsible for creating the landscape and environment for the digital twin vehicle to operate. Vehicle Parameters gives the vehicle instructions on how to operate (e.g, how to move forward, turn, stop, etc.)

Scenario planning is responsible for creating the problem needing to be tested by the simulation user. If the user wants to test an autonomous vehicle stopping at a red light, the user will select that scenario. Additionally, this scenario planning gives instruction to the vehicle parameters on how to operate, to move in accordance with the selected scenario.

PolyVerif execution is responsible for running the simulation according to the selected scenario.

Synthesizing Data from Testing and Categorize Runs Based on Success Metrics are both generated when the simulation successfully runs, and a report is generated that contains simulation data in an organized and efficient manner.

User Classes and Characteristics

This diagram is coming soon (use case diagram of the system).

i.Actors

This section presents the actors in the system.

- Simulation User
  - A user that runs the simulation and collects the data when the simulation ends
  - Can also use this data for external products, such as implementing the gathered data into an autonomous vehicle.
- GitHub Contributor
  - A person that contributes updates to the PolyVerif product as a whole.
  - A simulation user can make changes to PolyVerif locally, as PolyVerif is open source, however, these changes will not be reflected in the PolyVerif GitHub unless a GitHub Contributor approves these changes

ii.Use Cases

This section presents the Use Cases, developed for the system.

- Running a simulation
  - A simulation user uses the system to collect data on various traffic scenarios. If the user needs to collect data on an autonomous vehicle response when at a red light and a car passing through th intersection, the user will run that corresponding scenario and collect the data from that simulation.
- Generating a report
  - When the simulation successfully runs, the user can generate a report of the simulation's results and corresponding data

iii.2.3.3. Scenarios

<u>Scenario 1: Running Simulation</u>

Description: The user runs a simulation using the PolyVerif framework

Actors: Simulation User

Preconditions:

- PolyVerif has successfully been installed onto a machine with Linux Ubuntu OS

Trigger Condition: The user chooses to create an account.

Steps:

1. PolyVerif successfully loads, and the user is prompted to select a map for the simulation to run in. (ALT 1)
2. The user is prompted to select a type of scenario to run.
3. The user is prompted to run the simulation.
4. The simulation runs to completion. (ALT 2)

(ALT 1)

1.1. PolyVerif fails to load correctly.

(ALT 2)

4.1. The simulation fails to fully run to completion.

<u>Scenario 2: Generating a report</u>

Description: The user generates a report from a simulation

Actors: Simulation User

Preconditions:

- PolyVerif has successfully been installed onto a machine with Linux Ubuntu OS
- A simulation has successfully run to completion

Trigger Condition: The simulation is successfully run to completion

Steps:

1. The user is prompted to generate a report of the simulation results. (ALT 1)
2. The report loads, and the user has access to the report generated from the simulation.

(ALT 1)

1.1. The user is not prompted to generate a report
Note: This prompt should occur immediately after the simulation runs, if not, simulation must be re

(ALT 2)

2.1. Report fails to generate successfully due to errors in simulation.
2.2. Report generates successfully, but has faulty data present.

General Constraints

The CPU that is running PolyVerif must have a minimum 8-minimum core. The machine must be running on the Operating System of Ubuntu V.18.04 or V.20.04, it cannot run otherwise. The simulation must be run in the terminal, it will not run otherwise. Currently, the only computer usable is in the Micaplex MP 224(WiDe Lab), we are working on getting PolyVerif installed on Serena's computer. The reason that it can only run on this computer is because it needs a GPU to run and none of our team members have one on their computers, except for Serena. The computer that is running the simulation must have a NVIDIA GTX 1080 (8GB or higher). It also must have Python 3.8 running on the machine. To download it on another Linux machine, the machine must be connected to Wi-Fi to download it and run the simulations as well as meeting all the requirements stated above.

Operating Environment

Micaplex MP 224 WiDe Lab Computer

OS: Ubuntu Linux

Version: 18.04 or later

User Documentation

Research Papers:

- PolyVerif: An Open-Source Environment for Autonomous Vehicle Validation and Verification Research Acceleration [1]
- PolyFlows: Modular Test Framework Design for Autonomous Vehicles [4]
- An Integrated Scenario-Based Testing and Explanation Framework for Autonomous Vehicles [5]
- Testing and Validation Framework for Autonomous Aerial Vehicles [6]
- Scenic: a language for scenario specification and data generation [7]

Websites:

- SUMO Download - https://eclipse.dev/sumo/ [8]

Git Hub Repositories:

- PolyVerif GitHub - https://github.com/PolyVerifFramework/PolyVerif [9]

Assumptions and Dependencies

Assumptions:

The assumptions that can be made are:

- Docker shall be properly installed, and set to automatically turn on upon starting the computer
- The computer shall meet the minimum qualifications to run PolyVerif, including
    - 8+ Core CPU
    - NVIDIA GTX 1080 or higher GPU
    - Ubuntu Linux with at least version 18.04
    - Python version 3.8 installed
- The computer shall be connected to Wi-Fi, ensuring successful download, initial installation, and update installations.
- The user shall have a list of test cases that are pre–determined and will have the ability to add new test cases.

Dependencies:

Dependencies within this project include:

- 3D maps within PolyVerif must be approved by Acclivis for use
- Docker must be running properly before any simulation can be ran using PolyVerif
- Docker must be upgraded to NVIDIA Docker 2 version before use.
- OSSDC simulator and LGSVL must be running before a simulation can be started

3. External Interface Requirements

User Interfaces

Hardware Interfaces

This is not applicable to our project.

Software Interfaces

[REQ-BEHAV.1] PolyVerif
[REQ-BEHAV.1.1] The system shall define simulation scenarios as two components. [REQ-BEHAV.1.2] The system shall have the first simulation interface be visual with OSSDC-SIM. [REQ-BEHAV.1.3] The system shall have a second simulation interface for Lidar calculation interface.

[REQ-BEHAV.2] Blender 3.5
[REQ-BEHAV.3] MapsModelImporter Plugin 0.6.2
[REQ-BEHAV.4] RenderDoc 1.26
[REQ-BEHAV.5] LGSVL 2020.06

Communications Interfaces

This is not applicable to our project.

4. Behavioral Requirements

Same Class of User

This is not applicable to our project, as all users will have the same permissions throughout the system.

4.2. Related Real-world Objects

[REQ-BEHAV.1] The ERAU DB Campus shall be modeled using the Open Street Map (OSM) program.

[REQ-BEHAV.2] This model will include traffic intersections, vehicles, and environmental factors that are relevant to each scenario for our simulation(s).

[REQ-BEHAV.3] All intersections throughout the ERAU Campus will be modeled.

[REQ-BEHAV.4] The intersection that will be focused on is the intersection between Aerospace Blvd and Clyde Morris.

[REQ-BEHAV.5] This model will then be implemented into PolyVerif.

[REQ-BEHAV.6] This shall allow for customization of data, such as speed and position throughout the simulation.

[REQ-BEHAV.7] Within PolyVerif, the simulation will begin with the vehicle at a pre-determined starting point

[REQ-BEHAV.8] The user will be able to begin the simulation, pause it, and stop it.

4.3. Stimulus

The PolyVerif simulation will not have any dynamic stimuli, with two main scenarios being simulated: (0) the autonomous vehicle will stop on time when approaching a red light, or (1) the autonomous vehicle will not stop on time and run a red light. As such there are no stimuli requirements.

4.4. Related Features

[REQ-FUNCT.1] To be expanded on once system has been utilized more.

4.5. Functional

[REQ-FUNCT.1] To be expanded on once system has been utilized more.

5. Non-behavioral Requirements

Performance Requirements

[REQ-PER.1] The system shall not accept more simulations than can be accurately simulated.

[REQ-PER.2] The system shall only run one scenario at any moment.

[REQ-PER.3] The system shall not terminate a simulation to begin a new simulation.

[REQ-PER.4] The system shall accept file inputs of any size.

Safety Requirements

[REQ-SAFE.1] The system shall only be read in python scripts for validation test cases.

[REQ-SAFE.2] The system shall accept python scripts exclusively for simulation test cases.

[REQ-SAFE.3] The system shall print result reports in separate text files.

[REQ-SAFE.4] The system shall validate location data for each simulation.

[REQ-SAFE.5] The system shall validate decision data for each simulation.

[REQ-SAFE.6] The system shall validate control data for each simulation.

Qualitative Requirements

[REQ-AVAIL.1] To be expanded on once system has been utilized more.

i. Security

[REQ-SEC.1] To be expanded on once system has been utilized more.

ii. Maintainability

[REQ-MAINT.1] To be expanded on once system has been utilized more.

iii. Portability

[REQ-PORT.1] To be expanded on once system has been utilized more.

Design and Implementation Constraints

[REQ-CONST.1] The system shall operate using PolyVerif.

[REQ-CONST.2] The system shall run on Ubuntu V.18.04 or V.20.04.

6. Other Requirements

Database Requirements

This is not applicable to this project.

Operations

[REQ-OPS.1] The system shall save all map render information locally.

[REQ-OPS.2] The system shall save all scenario information locally.

7. Analysis Models

Data Flow Model

i.Data Sources

This diagram will be coming soon.

ii.Data Sinks

This diagram will be coming soon.

iii.Data Dictionary

Name	*Description*	*Structure*	*Range*
	To be filled in.		

This diagram will be coming soon.

iv.Context Diagram (Level 0 Data Flow Diagram)

This diagram will be coming soon.

v.Level 1 Data Flow Diagram

This diagram will be coming soon.

vi.Level 2 Data Flow Diagram

This diagram will be coming soon.

Class Model

This diagram will be coming soon.

State Model

This diagram will be coming soon.

8. Real-World Impacts

Purpose:

This assignment aligns with ABET accreditation criteria emphasizing the importance of engineering solutions in societal contexts. It helps students develop a holistic perspective, preparing them to consider the ethical and professional responsibilities of their work and its long-term impact on society. By completing this analysis, students will not only refine their understanding of their project's purpose but also learn to communicate its significance effectively to stakeholders, ranging from industry professionals to the general public. As part of this analysis, you need to identify who are the stakeholders of your project and then assess any positive and/or negative effects of the project in these areas. It is also important to recognize, there are some commonalities in some of these areas, for example, global effect may also look at the environment in which the system is going to be used, therefore there are some commonalities between the global and environmental aspects. However, there are more to global affect than just environment, and there are more in the environmental effect than there is just in global effect.

In another word, each area needs to be assessed separately.

Description:

As part of the senior design experience, each team is required to analyze the broader societal impact of their capstone project, specifically focusing on:

• Public Health –

The use of PolyVerif within autonomous vehicles verifies the safety and fast reaction times of computational algorithms for decision making. Instead of human reaction time and decision making, which is significantly slower, using the decision-making framework within autonomous vehicles is much safer. With this added safety, autonomous vehicles overall positively impact public health - crashes are reduced, and safer driving practices are implemented, taking human emotion and reaction out of driving. Using PolyVerif to validate decisions, including routing, reaction times, and localization within autonomous vehicles, driving incidents are reduced significantly. A study in the Annual Review of Public Health [10] explains how in 2017, 94% of all crashes in the United States involved impaired driving, distracted driving, illegal maneuvers, and speeding. Autonomous vehicles, equipped with PolyVerif's validation and verification software, can reduce these rates by always abiding by local traffic laws, and reduce the risk taken in decision-making when driving.

With this, simulations can be done to test how autonomous vehicles can avoid dangerous situations in PolyVerif itself, reinforcing the safety regulations and requirements necessary. These simulations are customizable to each situation, so testing with public health concerns in mind is possible – either through detecting and reacting to pedestrians, taking the safest route through a city, or navigating a busy intersection. Each of these scenarios provide detailed reports on braking, reaction times, and route planning choices, allowing researchers and engineers to fine tune the autonomous vehicle to be as safe as possible for the public in any situation.

• Safety –

The use of Polyverif promotes more secure practices within the autonomous vehicle scope. The simulation allows for verification and validation of multiple scenarios across extensive environments with very customizable parameters. This flexibility allows for testing to be more reliable and accurate within the simulation. This simulation plays a vital role in real-world applications and resembles accurate depictions of the surroundings. This accuracy in the surroundings allows for more accurate predictions of vehicles, pedestrians, and safety protocols. By simulating real- world situations, PolyVerif can be more reliable within certain communities and the trust levels for autonomous vehicles can rise.

As people gain more experience with and knowledge about AVs based on accurate and balanced information, they would develop “strong” mental models, which could also help ease AV-related concerns and, subsequently, potentially lead to higher trust and comfort in the technologies [11]. It is imperative that testing for autonomous vehicles continues to ensure public trust and confidence for these types of vehicles. It not only allows for more transportation measures and accessibility opportunities but also will ensure efficiency globally.

• Welfare –

PolyVerif contributes to the welfare of society by improving transportation accessibility, reducing transportation costs, strengthening businesses, and supporting a lifestyle centered around people instead of vehicles.

Autonomous vehicles have the potential to significantly improve mobility for individuals who are unable to drive due to age, disability, or other factors. By providing on-demand autonomous transportation services, AVs can offer greater independence and access to essential services 24 hours a day. If public transport is inaccessible, PolyVerif can be used in personal autonomous vehicles, providing the same level of independence to those living in rural communities. Transitioning to a transportation system that prioritizes people over vehicles can lead to more inclusive and sustainable communities. AVs can provide mobility and independence to people who are unable to drive or use public transport due to age, disability, or other factors, thereby promoting a more people-centered lifestyle.

The integration of AVs into logistics and supply chain operations can lead to more efficient routing and load balancing, minimizing transportation costs, and enhancing overall productivity. This efficiency not only reduces operational costs for businesses but also results in faster delivery times and improved customer satisfaction. Additionally, autonomous vehicles utilizing PolyVerif incorporated into shipping operations can optimize supply chains and transportation routes, enabling businesses to operate more efficiently, leading to increased profit margins. The reduction in transportation costs allows companies to allocate resources to other critical areas, fostering innovation and growth.

These could encompass access to resources, quality of life improvements, economic impacts, or equitable technology distribution. The above three criterions are graded for the entire team. Each team will provide a half-page description analyzing how their project influences public health, safety, and welfare. This analysis should be specific to the project's context and real-world application. This exercise encourages students to think critically about the ethical, social, and practical implications of their engineering solutions and how these solutions interact with society at large. Teams should provide specific examples or scenarios illustrating your project's societal impact. Avoid generic statements—tie the analysis to tangible outcomes, potential risks, or opportunities created by your project. Use clear, professional language for an academic or industry audience. In addition to the above, each team shall assign a member of the team to conduct individual analysis for one of the following:

• Global effect (Isabella Acosta) -

The use of Polyverif and its performance have had several global effects that have significantly impacted the scope of autonomous vehicles. Polyverif's settings allow for the user to customize the parameters of the scenario based on their environment/region, ensuring that they are reaching maximum accuracy and reliability. By allowing the scenario to adapt to the regional factors surrounding it, Polyverif's performance remains optimal and provides precise results. With its flexibility and modern technology, PolyVerif is able to bridge and connect multiple countries and continuously improve their autonomous systems.

Along with this, PolyVerif also allows for the development of mapping and access for underdeveloped countries. Having these mapping resources allows these countries to be able to improve their infrastructure, able to manage resources in a more efficient manner, and make sure that they have access to essential resources. PolyVerif's simulator includes a decision-making process that can help governments and organizations to make more effective decisions and implement more effective strategies to give these underdeveloped nations what they need to thrive.

Global effect also encompasses the sections included in real – world impact: social, economic, environmental, and cultural. Socially, by introducing PolyVerif into communities with consecutive testing, the trust rate for autonomous vehicles can rise and more opportunities for transportation open. Economically, PolyVerif could create new jobs in multiple different fields like engineering and maintenance and increasing revenue within the community as well as infrastructure development. Environmentally, the use of PolyVerif optimal systems could lower emission rates and overall reduce carbon footprint. Culturally, PolyVerif's behavior can be tailored to different geographical regions and ensure that road laws are being properly followed. PolyVerif has various global effects and has an overall positive impact within the autonomous vehicle verification and validation system.

• Cultural (Davian Rosario-Ortiz)

The implementation of autonomous vehicle (AV) scenario modeling through PolyVerif has significant cultural implications, particularly in how AVs interact with human drivers, pedestrians, and road infrastructure. By validating AV behavior under diverse traffic scenarios, PolyVerif helps refine decision-making processes in these AVs to align with local customs, legalities, and ethical standards. For example, in highly regulated driving environments such as Germany, where strict adherence to traffic laws is expected, PolyVerif can test AVs to ensure they follow precise stoplight timings and lane discipline. On the opposite side in countries such as India, where traffic conditions involve a mix of formal and informal driving practices, PolyVerif can model scenarios where AVs must safely navigate through dense, unpredictable road conditions, adjusting to real-time human driver behaviors.

Legal and societal expectations also play a crucial role in AV deployment, as traffic behavior varies widely across regions. Some cultures prioritize strict adherence to traffic laws, while others exhibit informal driving habits like rolling stops or jaywalking. In cities like Tokyo, where pedestrian crossings are highly respected, PolyVerif can test AVs for compliance with pedestrian-first principles [12]. In contrast, in places like Mexico City, where jaywalking is common, the system can evaluate AV responses to unpredictable pedestrian movement. Additionally, PolyVerif supports testing in multi-modal transportation environments, addressing accessibility concerns in areas where public transport dominates, such as the Netherlands, where AVs must integrate seamlessly with bicycles and trams. As AV technology advances, PolyVerif's ability to model cultural nuances will be essential in promoting broader acceptance and seamless integration of AVs worldwide.

Beyond just driving behaviors, the public perception of AVs varies based on cultural attitudes toward automation and technological trust. In the United States, where personal control over driving is deeply ingrained, a 2024 survey by the American Automobile Association (AAA) found that 66% of drivers expressed fear about fully autonomous vehicles due to concerns over reliability and decision-making in critical situations [13]. Meanwhile, in technology-driven societies such as Japan and China, where government-backed initiatives and a tech-friendly public opinion fosters higher acceptance, AVs are more readily embraced. Through the use of PolyVerif's simulation environment, AV developers can fine tune any safety measures and demonstrate greater reliability which in turn would improve the public's perception and confidence in AV technology.

• Social (William Reimer) –

A significant social impact of PolyVerif is its role in fostering public trust in autonomous vehicles. PolyVerif can help alleviate concerns about safety and reliability, leading to greater acceptance of autonomous vehicles in everyday life. This increased trust paves the way for smoother integration of autonomous into communities, reducing resistance to technological advancements. Increased use of PolyVerif can lead to the creation of private and public programs providing greater transportation access for individuals who are elderly, disabled, or unable to drive, especially so for these individuals in rural communities without access to buses, taxis, or other forms of public transport. Additionally, with a reduction in traffic congestion and accidents that PolyVerif can provide, cities and neighborhoods will be safer for pedestrians, encouraging greater social engagement and community interaction. Public spaces may even be redesigned to accommodate a shift in mobility patterns, fostering more walkable and livable environments.

After long-term usage of PolyVerif and autonomous vehicles by cities and communities, a widespread adoption of PolyVerif-validated autonomous vehicles could lead to a fundamental redesign of city and town infrastructure. Traffic signals and intersections could be optimized for autonomous coordination, reducing congestion and improving overall traffic efficiency. Dedicated lanes for autonomous vehicles may emerge, ensuring safer and more predictable movement within urban environments. Parking structures could shift to more space-efficient designs, with autonomous vehicles dropping off passengers and then relocating themselves to designated remote lots, freeing up prime real estate for commercial or residential development. These are just a few possibilities that could occur because of successful widespread implementation of autonomous vehicles with PolyVerif as a main component.

Environmental (Serena Conticello)

Autonomous vehicles (AVs) will have a large impact on the environment, whether it be positive or negative. Currently there is large discussion over the usage of artificial intelligence energy consumption. Popular Large Language Models (LLMs) like Open AI's ChatGPT model have been cited to have 10 time more electric consumption than a simple Google search [14]. This seems small on an individual level, but understanding the amount of people utilizing this tool and the millions of queries daily, results in a substantial environmental impact. This is something that should be considered but thankfully is not too encompassing to the current state of the product. The same level of tasks will not be completed by this PolyVerif or the neuroevolution algorithm during this project in terms of generation and computation. This should be reevaluated in the future if this were to be implemented on a larger scale.

To assess the energy footprint of the current set up required to run the software, only a PC tower and some peripherals are required. This project utilizes a Dell Precision 5820 Tower with two Dell monitors, a keyboard, and a mouse. The Tower has a short-idle energy consumption of 79.1 W [15], which is equivalent to roughly 0.068 lbs of CO2 emissions [16]. Assuming the perhiperals are negligible in their energy consumption, this is not a great deal of power required to run this computer. Even increasing the power usage to 100W which is equivalent to roughly 0.086 lbs of CO2 [16]. While these numbers provide a baseline, the actual energy consumption from PolyVerif and the algorithm will likely vary depending on how complex the processes are and how long they are run. Ideally, the algorithm will help provide a solution to reduce the required run time needed for the PolyVerif software in order to find ideal scenarios.

While controlled testing offers an initial estimate of AI energy consumption, real-world scenarios present greater challenges which we are unable to assess at this given moment. The energy demand in operational environments will likely exceed controlled conditions. Further research into this area would be required, which is out of scope for the current project.

• Economic (Hannah Ramsden) –

With the implementation of PolyVerif in autonomous vehicles, there are many impacts to consider within the economy, including employment, resource use and allocation, income impacts, and government spending. The proven testing and implementation of this software could lead to autonomous vehicle fleets being implemented by cities. [17]

When considering employment, Autonomous vehicles would negatively impact the taxi industry, creating direct competition to applications like Uber, Lyft, etc. [18] On the other hand, autonomous vehicle usage would create jobs as well. Autonomous vehicles would need engineers (both software and hardware) to update the testing platform, check data and report logs, and ensure that the cars are operating properly. Mechanics are also necessary, as they would focus on the physical car. The usage of autonomous vehicles as well promotes increased hiring in the economy, as people who previously couldn't access reliable transportation. PolyVerif helps to promote trust in autonomous vehicles, as it is proof that the vehicles are safe and would respond properly to any situation. With this trust and advancement, more jobs are created, and it impacts the economy positively.

When considering the economic resources, PolyVerif's test results can demonstrate overall safety and traffic pattern improvements. With this, people can decide to not buy a car in a major city, and use autonomous vehicles for transportation instead, lowering import costs. Implementing fleets of autonomous vehicles also provides improved public infrastructure, expanding the resources available to the public for safe transportation.

Taking income under consideration, PolyVerif's test case results are proof that autonomous vehicles are a growing industry, addressing the need for safety on the road. With these results, public use of autonomous vehicles can help save money for households due to not having the need to buy a car in a city. This reduction in price helps with saving money. Other income benefits include the government as well, where tickets or car passes (similar to bussing systems) can bring income for the government to spend on repairs and advancement of the autonomous vehicle system. With this maintenance, more jobs will be created, including mechanics, software engineers, maintenance, etc.

Overall, PolyVerif's safety and decision-making reports help to prove that it has significant economic impact, with overall improvements to the economy.

9. To Be Determined List

- PolyVerif may change to a different, unknown simulator.

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