# **CRASH FREE** AUTONOMOUS INTERSECTION SIMULATION

## The Simulation

### Features

Variable Scale

*Variable Intersection Layout*

*Adjustable Display/Debug Variables*

Variable Run Speed

*Keyboard Shortcuts*

*Realistic Vehicle Physics*

**Vehicle Turn Signals**

*Dynamic Simulation Drawing*

**Pedestrians (Jaywalkers)**

**Bold indicates new feature** *Italics indicates modified / improved feature*

### Vehicles' Acceleration Curve

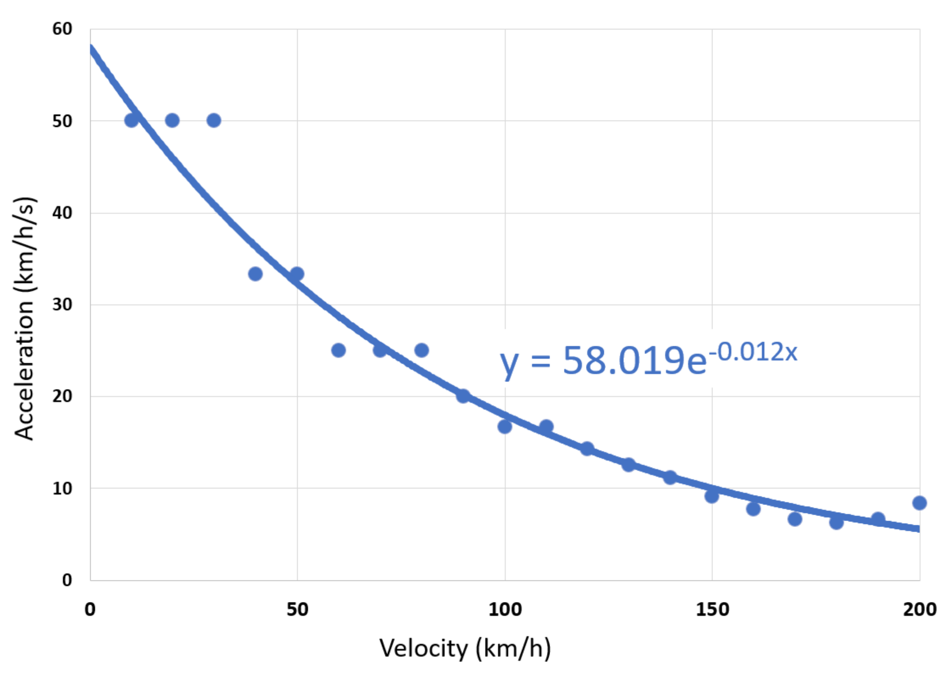


Chart 1 - Vehicle Acceleration vs Velocity

### Adjustable Variables

| | |
|---|---|
| Number of Lanes | Vehicle Processor Cycles per Second |
| Car Frequency | ETA Buffer |
| Max Number of Vehicles | Individual Turning Probability |
| Speed Limit | Road Drawing Specifications |

### Simulation Controls

**Space** - resume / pause car movement

**Up Arrow** - speed up time

**Down Arrow** - slow down time

**Left/Right Arrow** - reset speed of time

**H** - toggle between on screen text

**W** - spawn a car from the North

**A** - spawn a car from the West

**S** - spawn a car from the South

**D** - spawn a car from the East

**C** - clear all cars off of screen

**Click on car** - selects & views its variable values

**1,2,3...** - select lane number of next spawned car

**Numpad Left** - set destination of car to left

**Numpad Up** - set destination of car to straight

**Numpad Down** - set destination of car to right

**Delete** - deletes selected car

### Simulation Files

**Simulation.cs**
Main file that runs the simulation and draws the graphics. Runs 60 times a second
(600 lines)

**Vehicle.cs**
Responsible for all the artificial intelligence and the abilities of the cars to move and turn
(1300 lines)

**Vars.cs**
Contains all the simulation's core variables (public class), allows for adjustability
(75 lines)

**Protocol.cs**
Contains the universal protocol for encoding and decoding the cars' "states"
(75 lines)

**Methods.cs**
Contains functions not built into .NET (C#) , such as converting km/h to m/s
(100 lines)

**Maps.cs**
Mimics the basic functionality of downloaded map each car would have access to
(25 lines)

| Success Criteria (1-5) | Previous Year | This Year |
|---|---|---|
| **Vehicle Capabilities** | 3 | 4 |
| **Ergonomics** | 3 | 4 |
| **Adjustability** | 4 | 5 |
| **Physics Accuracy** | 4 | 5 |
| **As a Model To Real World** | 3 | 4 |
| **Debugging** | 3 | 4 |
| **Total** | **20** | **26** |
| **Overall Score** | **3** | **4** |

## Artificial Intelligence

### Features

*"State" Transmission and Reception*

**"State" Encoding & Decoding Protocols**

**LiDAR Object/Vehicle Detection**

**Following Distance Based on Vehicle Speed**

*Following Speed Limit*

**Relevant Vehicle Identification**

*Potential Collision Detection*

**Relative ETA Calculation Algorithm**

**ETA Calculation Throttle Logic**

**Expandability Across Different Intersections**

**Higher Efficiency Than Normal Intersection**

**Strong Intuition**

**Pedestrian Detection**

**Bold indicates new feature** *Italics indicates modified / improved feature*

### Intercommunication Protocol ("State")

| | |
|---|---|
| Current Intersection ID | Distance To Intersection |
| Road ID | Speed |
| Vehicle ID | Acceleration |
| Direction Number | Turning Radius |
| Destination Number | Front Car ? |
| Lane Number | In Intersection ? |

**Total Bit String Size**: 261 ("state") + 9 (error detection) = **270 bits**
(.0011% the size of typical JPEG)

### Artificial Intelligence Flow Chart

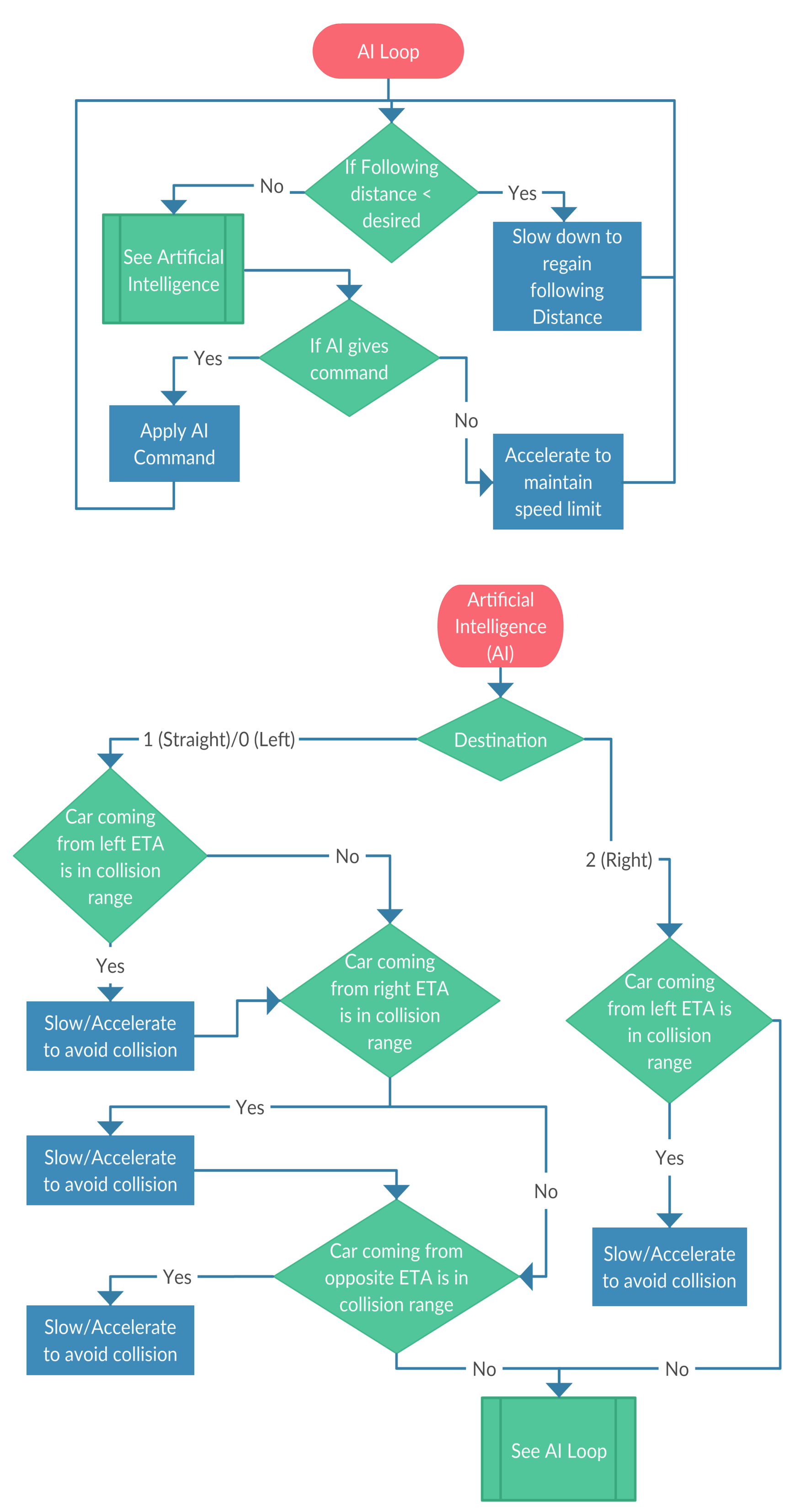


Figure 1 - Flowchart of Artificial Intelligence

| Success Criteria (1-5) | Previous Year | This Year |
|---|---|---|
| **Expandability** | 1 | 4 |
| **Crash Avoidance** | 2 | 4 |
| **Straight Line** | 3 | 5 |
| **Right Turn** | 0 | 5 |
| **Left Turn** | 0 | 4 |
| **Utilization of Swarm Intelligence / Decentralization** | 2 | 4 |
| **Vehicle Intuition** | 2 | 4 |
| **Applicability to Real World** | 0 | 4 |
| **Efficiency vs Real World Intersection** | N/A | 3 |
| **Feasibility of Intercommunication** | 3 | 5 |
| **Total** | **13** | **42** |
| **Overall Score** | **1.5** | **4** |

## Overview

### Previous Year Summary

The main focus of the previous year's work was creating the simulation, as without a reliable and accurate simulation, the results of the experiment would mean nothing. The physics and visuals of the intersection were made entirely from scratch. Making the cars realistically accelerate/decelerate was modelled after real-world Tesla Model S data. After some easy calculus, an acceleration equation based on instantaneous velocity, rather than time, was created. Therefore, the simulation can know exactly how fast a car should accelerate based on its current velocity. The physics of the simulation were tested for accuracy, and tweaked until realistic physics were achieved. Additionally, due to having all key aspects of the simulation be easily adjustable allowed for the intersection to be dynamically drawn each time it ran.

Overall, the simulation supported the hypothesis, although only accomplishing the basic goals of the project. The cars predicted potential collisions and adjusted their speed to avoid them, and needed no traffic signals nor an external controller to make these decisions. However, due to the amount of time necessary to make the computer simulation fully functional and realistic, less time was available to fine-tune the artificial intelligence of the self-driving cars. For example, the cars could only go straight through the intersection, and were unable to turn. Although the physics were accurate, they were not overly complex. Additionally, intuition and logic that humans naturally have, such as not accelerating when a car is stopped a few feet ahead, was not as easily programmed as initially expected, and was never fully reliable.

### Project Summary

#### Purpose

The arrival of fully self-driving cars is inevitable, and after spending countless hours stopped at stop signs and traffic lights with no vehicles with 100 meters of the intersection, we wondered if this new technology could be leveraged to eliminate this problem.

The purpose of this project is to improve the computer simulation of this intersection utilized last year and develop artificial intelligence capable of making decisions autonomously. This simulation uses a fully, highly improved decentralized system, which does add some complexities and redundancies, but is more reliable and resistant to hacking or failures if implemented in the real-world. This simulation will use a traditional four-way intersection, rather than a roundabout, as the project's goal is to be implementable into existing infrastructure, with no modifications. As opposed to last year, this four way intersection will be expandable, making its implementation much more feasible in a variety of intersections in the real world. Unlike the previous year, the cars' new AI is as simple, yet robust, as possible, keeping true to the soul of swarm intelligence.

#### Methods

This simulation was created in the Microsoft Visual Studio 2017 IDE using C# and leveraged the MonoGame framework, an improvement to Microsoft's XNA. The physics and mathematical details of the simulation were created by the experimenters, with improvements in acceleration control and logic being implemented this year along with notable additions to simulation expandability and practicality. The artificial intelligence was redesigned from the ground up, utilizing an ETA, estimated time of arrival, prediction algorithm that weighs the difference in arrival times to relative collision points, adjusting acceleration accordingly. Simulated LiDAR was also added to prevent rear end collisions outside of the intersection and augment braking within the intersection as collisions become more difficult to avoid.

#### Hypothesis

If the artificial intelligence is properly created using swarm intelligence, then the self driving cars in this computer simulation will regulate their speeds and make decisions autonomously, such that no traffic lights are needed

## Results

The results strongly support our hypothesis that if the artificial intelligence is properly created using swarm intelligence, then the self-driving cars in this computer simulation will regulate their speeds and make decisions autonomously, such that no traffic lights are needed. Vehicles utilize a more true form of swarm intelligence than the year prior, transmitting sets of their important data/information, in a compact encoded bit string, to other vehicles to aid in their decision making process. Vehicles regulate their speeds through both their LiDAR capabilities and using an ETA based artificial intelligence, clearly making decisions to avoid collisions while passing through the intersections at higher rates than traditional controlled intersections with stop signs and traffic lights.

**Traditional Controlled One Lane Four Way Intersection:**
0.427 Vehicles/Second

**Average Time Before Crash (Previous Year's AI)**
45 Seconds

**With Our Artificial Intelligence**:
>1 Vehicles/Second

**# Of Crashes After 3 hours (With new AI)**
*ZERO* Crashes

*Laptop Display Placeholder*
*:)*