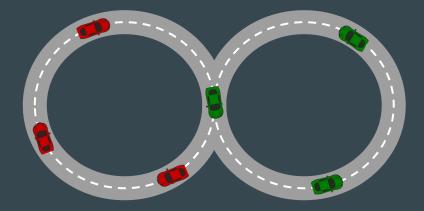
Cooperative vs Non-Cooperative Autonomous Driving

 $\bullet \bullet \bullet$

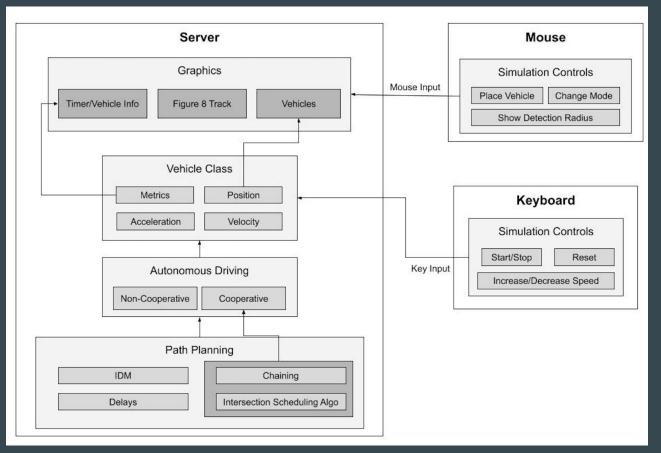
Team A1: Tito Anammah, Serris Lew, Kylee Santos

Problem

- Simulate non-cooperative vs cooperative autonomous driving
- Experiment with different scenarios of cars moving in circles on a figure-8 track
- Compare performance between approaches
- **Our solution:** Software-based simulation
 - Customizable setup mode
 - Testing mode
 - Average velocity
 - Average acceleration/deceleration
 - Waiting time
 - Total throughput



Solution Design



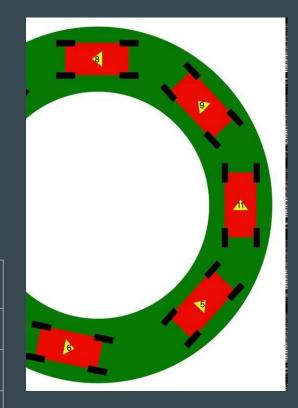
Intelligent Driver Model (IDM)

- Defines a vehicle's acceleration based on distance to nearest obstacle, difference in velocity, etc.
- Chose realistic numbers for parameters and converted to pixels using scale

$$s^{\star}(v,\Delta v) = s_0 + Tv + \frac{v\Delta v}{2\sqrt{lphaeta}}.$$

$$a_{\mathrm{IDM}} = lpha \left[1 - \left(rac{v}{v_0}
ight)^{\delta} - \left(rac{s^{\star}(v, \Delta v)}{s}
ight)^2
ight]$$

Parameter	Value					
Optimal Velocity	0.3 m/s					
Max. Accel.	0.3 m/s ²					
Max. Decel.	0.2 m/s ²					
Buffer Distance	7 m					



Cooperative Framework

- Car Chaining
 - Communication allows for closer following distance
 - Accelerate/decelerate at same rate as lead vehicle
- Intersection Scheduling Algorithm
 - Vehicles communicate length of queue
 - Priority is assigned to each lane based on a weighted combination of features
 - Aims to allow multiple cars from one lane to pass the intersection



Cooperative

Non-Cooperative

Design Trade-Offs

- Figure 8 Demo vs 2-Lane Track
 - Focus on optimizing, only using start/stop
- Central scheduler
 - Avoids the need for distributed consensus/decision making
 - \circ Requires Roadside Units (RSUs) when scaling to real world usage
- Multi-vehicle passage
 - Reduces delays from acceleration/deceleration
 - Tradeoff between fairness and throughput

Testing

- 50 test cases were randomly generated (9 13 vehicles per test, 40 seconds each)
- Internal simulation time was decoupled from system time
 - Simulation graphics were turned off
 - \circ Testing ran much faster and results outputted to a .csv file
- Metrics
 - Throughput was measured by checking every time vehicles passed the intersection line
 - Velocity was recorded at every iteration and averaged
 - Acceleration/deceleration were also recorded at every iteration and averaged
 - Acceleration/deceleration counts frequency of vehicle acceleration/deceleration
 - Waiting time was measured when a vehicle's velocity was 0 and averaged amongst vehicles

Results

• **30.33%** increase in throughput in cooperative vs non-cooperative case

	Non-Cooperative	Cooperative	% Change				
Avg Velocity	0.094 m/s	0.121 m/s	↑ 28.23%				
Avg Acceleration	0.0024 m/s ²	0.0032 m/s ²	↑ 31.25%				
Avg Deceleration	0.024 m/s ²	0.043 m/s ²	↑ 77.08%				
Avg Acceleration Counts	515.77	195.22	↓ 62.15%				
Avg Deceleration Counts	1497.5	1463.3	↓ 1.29%				
Avg Waiting Time	8.79 s	4.93 s	↓ 43.88%				
Total Loops	2305	3004	↑30.33%				

Requirements

- 30% increase in throughput
- 30% increase in average velocity
- 30% decrease in waiting time
- 15% decrease in acceleration
- 15% decrease in deceleration

(28.23% increase)
 (31.25% increase)
 (77.08% increase)

But we observed decreases in acceleration/deceleration counts

Takeaways

- More advantageous with denser tracks
 - Not much contention for the intersection with a sparse car population
- Higher acceleration/deceleration
 - Vehicles reach optimal velocity more often (higher change in velocity)
- Lower waiting time
 - Chaining removes intermediate delays between vehicles in a chain
 - Multiple vehicles allowed to pass intersection at a time
 - Lane with longer queue is prioritized

Project Management

Task breakdown

- Graphic simulation
- Intelligent Driver Model
- Cooperative Framework

Remaining tasks

- Create video
- Final Report

	A	В		С	D	E	F	G	н	L.	J	К	L	М	N	0	
		March		April				May									
	Tasks		8	15	22	29	5	12	19	26	2						
	Interim Demo (4/6-4/8)																
	Final Demo (4/20-4/22)										Key						
	Final Presentation (4/27-4/29)															Everyor	ne
	Final Report/Video (5/4)															Kylee	
												1				Tito	
																Serris	
â	Create graphics for vehicle and track classes																
)	Implement IDM																
	Implement cooperative scheduling																
2	Personalize vehicle location for more scenarios																
3	Make vehicle movement compatible with PP																
	Relate real world parameters to pixel values																
5	Test non-cooperative algos with vehicle movement																
6	Integrate cooperative scheduling with driver model																
, ,	Test cooperative algos with vehicle movement			1													
3	Integrate simulation with IDM and coop scheduling																
	collect measurements/statistics																
) '	Test cooperative scheduling with different scenarios																
li) a	Create test bench								-								
2	Optimizing cooperative case																
3	Optimizing cooperative case																
1 0	Compare coop vs non-coop performance																