Risk-Based Collision Avoidance in Autonomous Vehicles

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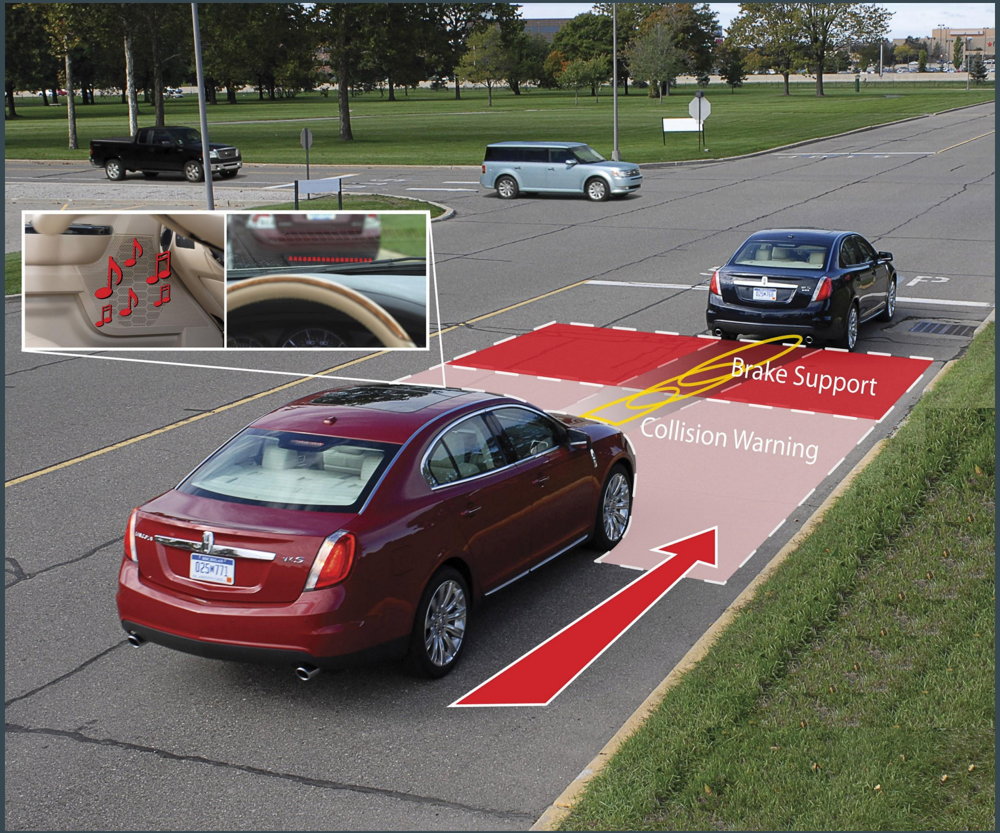
Motivation

- Motor Vehicle Fatalities
  - In the U.S., roughly 31,000 people die in road crashes every year [1]
  - 2.5 million are injured [1]
- Autonomous vehicles are on the rise, giving safety features greater potential
  - However, proprietary control systems in autonomous vehicles

Related Work

- Safety Mechanisms
  - ➢ **<u>Forward braking assist</u>**
  - Forward steering assist
- DeepDriving



Related Work

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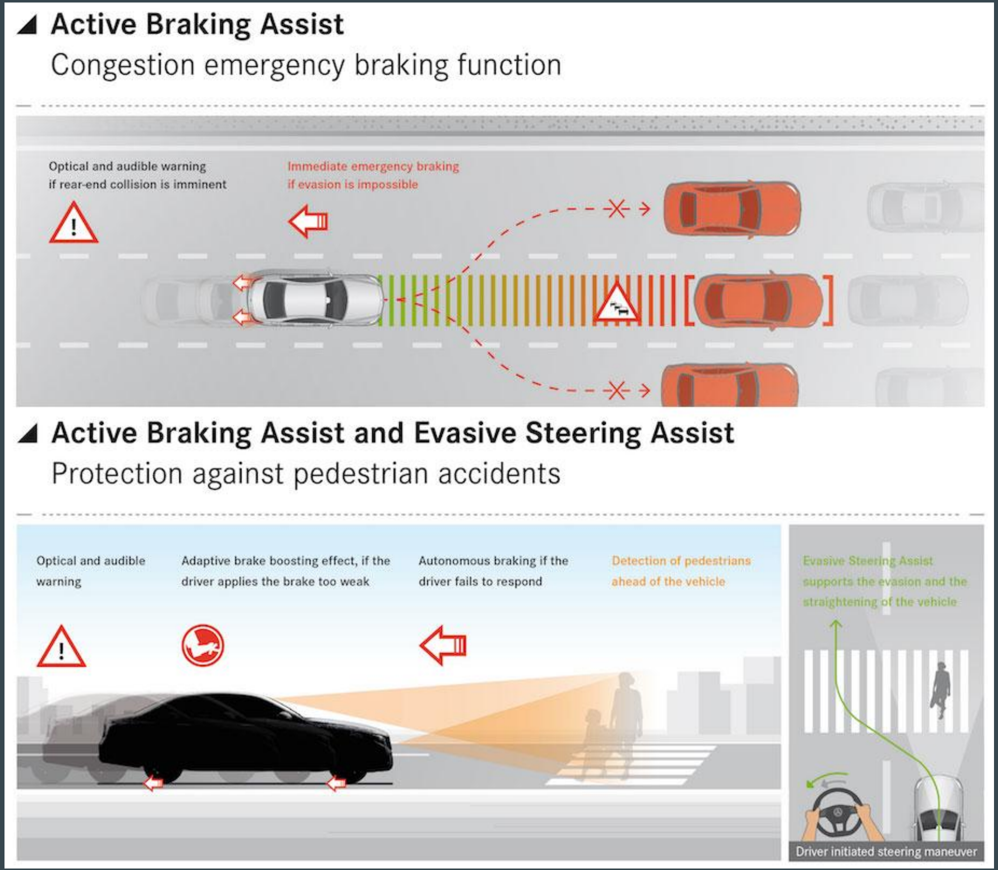
  - ➢ **<u>Forward steering assist</u>**
- DeepDriving



Related Work

- Safety Mechanisms
    - Forward braking assist
    - Forward steering assist
- **DeepDriving**

- Image-based
- Gives localization and distance to vehicles
- Has a controller, but it doesn't handle extreme situations well
- **Direct perception algorithm**

Related Work

- Safety Mechanisms
  - Forward braking assist
  - Forward steering assist
- **DeepDriving**

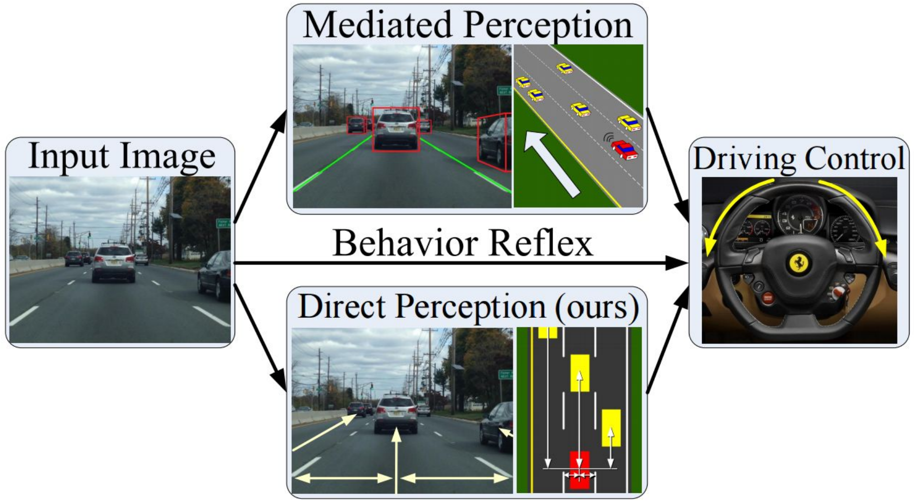


Figure 1: **Three paradigms for autonomous driving.**

Goal

- Create a collision avoidance controller for DeepDriving that prevents more accidents than its default controller as well as current forward assist systems.

Key Insight

- **Semi-Realistic Simulation + Direct Perception**
  - Direct perception algorithms allow simulation performance to more accurately reflect real world performance.
  - So, only need a roughly accurate physics engine

Approach

Implementation

- ➢ <u>**Generate Data**</u>
- Risk Estimation
- Minimize Risk

Implementation

- ➢ <u>**Generate Data**</u>
- Risk Estimation
- Minimize Risk

- Full knowledge of ground truths
  - True speed of both cars
  - true distance
- Predict crash
- Predict going offroad
- Features
  - Starting speed of our car
  - Starting distance between cars
  - Control behavior used

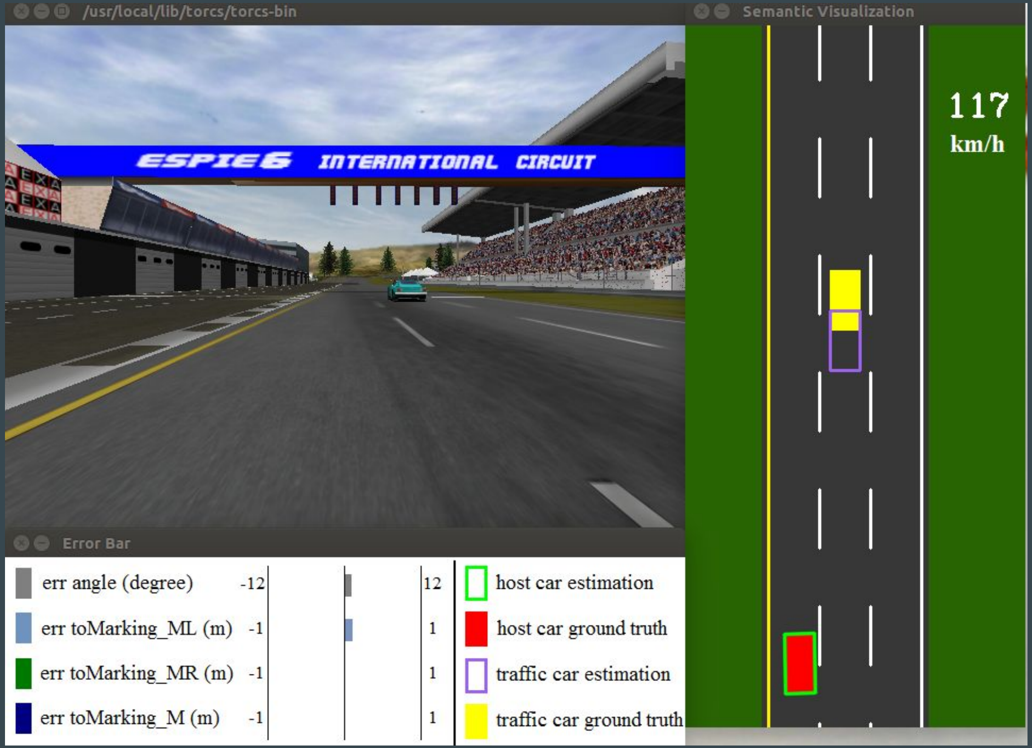
Implementation

- Generate Data
- **<u>Risk Estimation</u>**
- Minimize Risk

- NO knowledge of ground truths
  - Speed of our car
  - Distance to other cars
  - Estimated by DeepDriving algorithm
- Estimate risk for every possible action/control
  - Find the probability of collision or going offroad for every permutation of control:
    - Every permutation of steering, brakes, and desired lane: 144 behaviors

Implementation

- Generate Data
- ➢ **Risk Estimation**
- Minimize Risk



Implementation

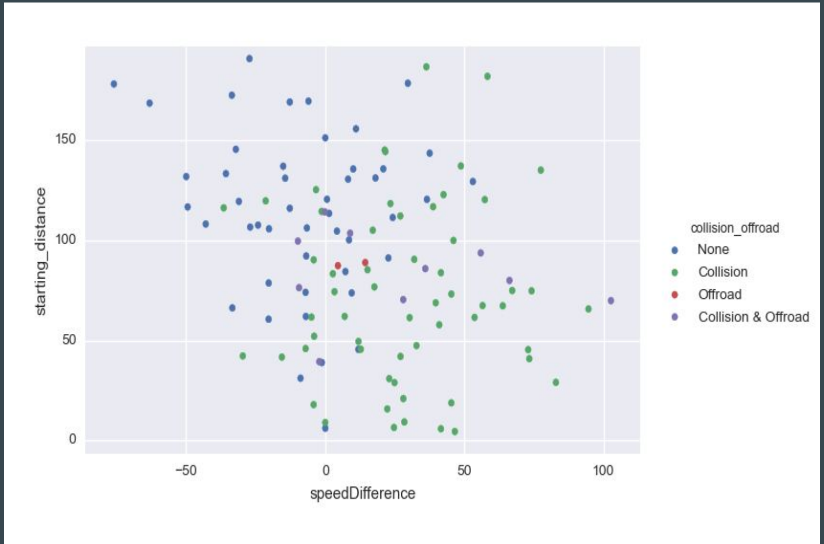
- Generate Data
- Risk Estimation
- <u>**Minimize Risk**</u>

- Choose the action with the lowest average probability of collision/offroad
  - Using :
    - Random Forest Classifier
    - AdaBoost Classifier
    - Logistic Regression

Training Results

- Brake assist and steering assist
  - Better than nothing
  - But no one-size-fits all solution
  - Always a trade-off between reducing collisions and going offroad

Training Results



No Brakes, No Steering

80% Brakes, 40% Steering

Training Results

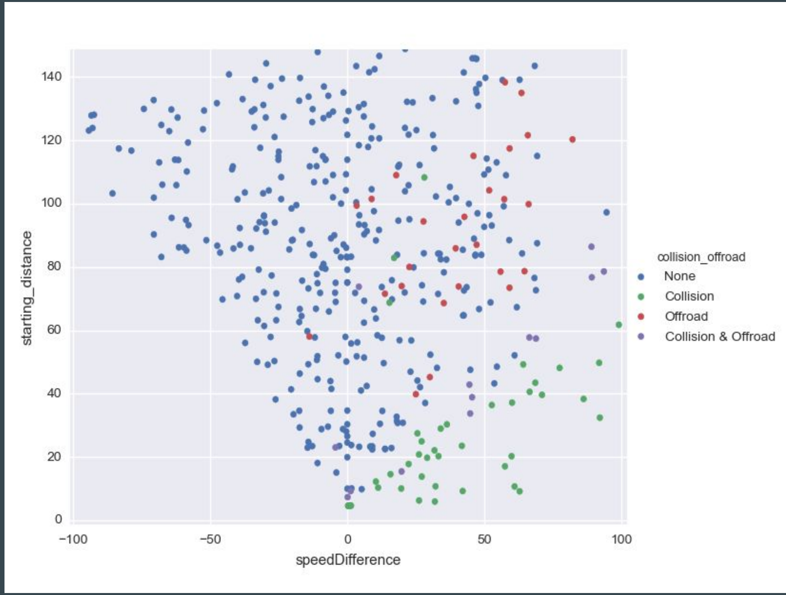
- Most accurate classification:
  - Random Forest Classifier
  - Neural Net
- Most accurate probability modeling:
  - Logistic Regression Classifier
- Single obstacle and three obstacle simulations have comparable results

Evaluation

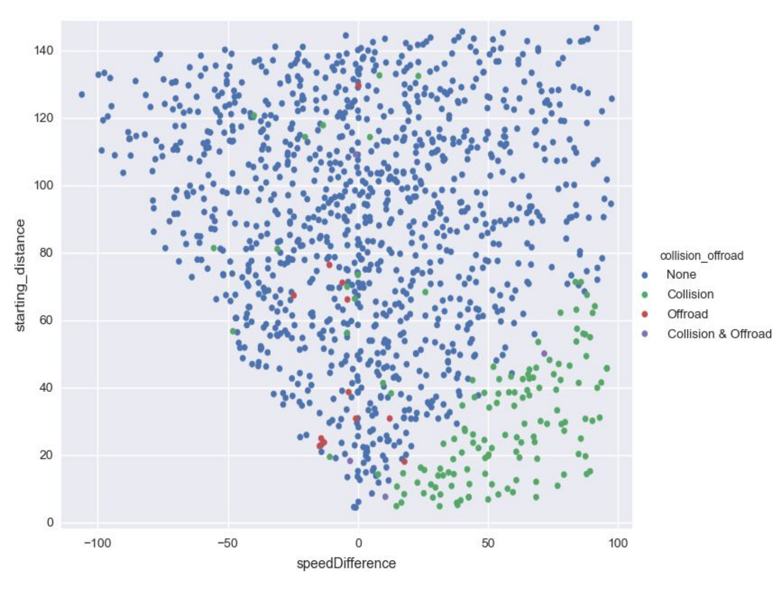
Method	% Collisions	% Offroad	% Collisions or Offroad
Forward Braking Assist	0.2269	0.0084	0.2269
Forward Steering Assist	0.1259	0.4251	0.4645
80% Brakes, 40% Steering	0.1231	0.0977	0.1868
DeepDriving Controller	0.2269	0.0084	0.2269
Proposed Controller	0.1178	0.013	0.1275

Table 3: **Comparison of Controller Performance**

Evaluation

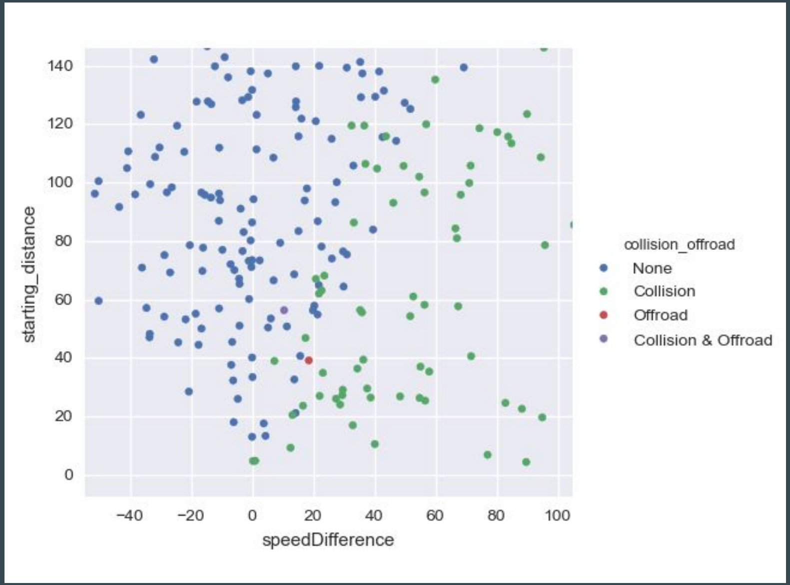


80% Brakes, 40% Steering

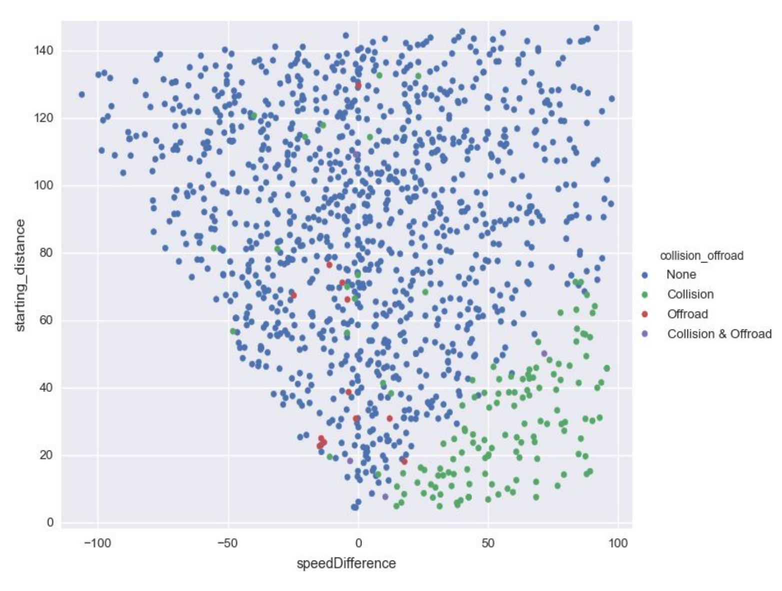


Proposed Controller

Evaluation



DeepDriving Controller



Proposed Controller

Conclusion

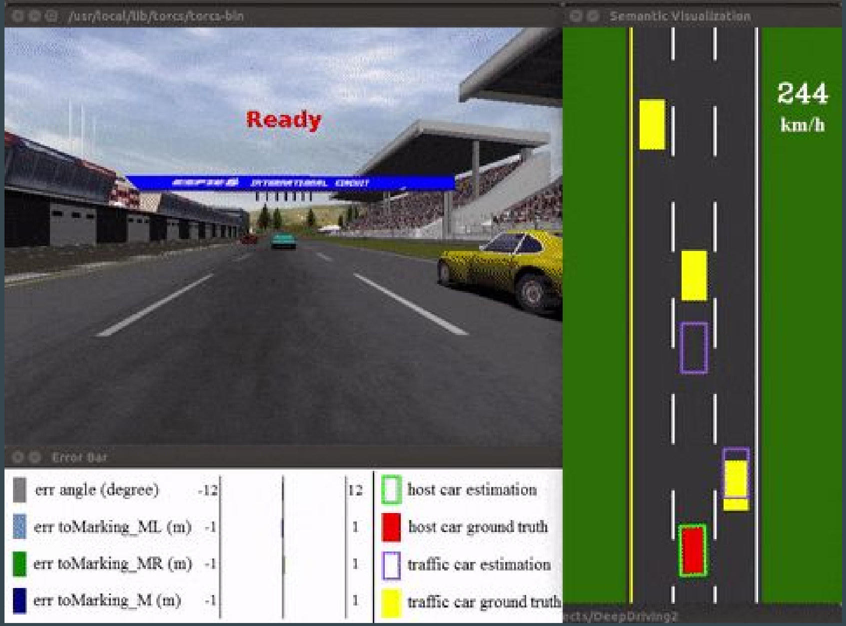
- Brake assist and steering assist
  - Do not perform well individually
  - A couple specific combinations do better than DeepDriving
- Direct perception + simulation + machine learning
  - Much better!

References

[1] Association for Safe International Road Travel. Road crash statistics.

Comparison

DeepDriving Controller



Proposed Controller

Results

- ➢ **Training Results**
- Evaluation

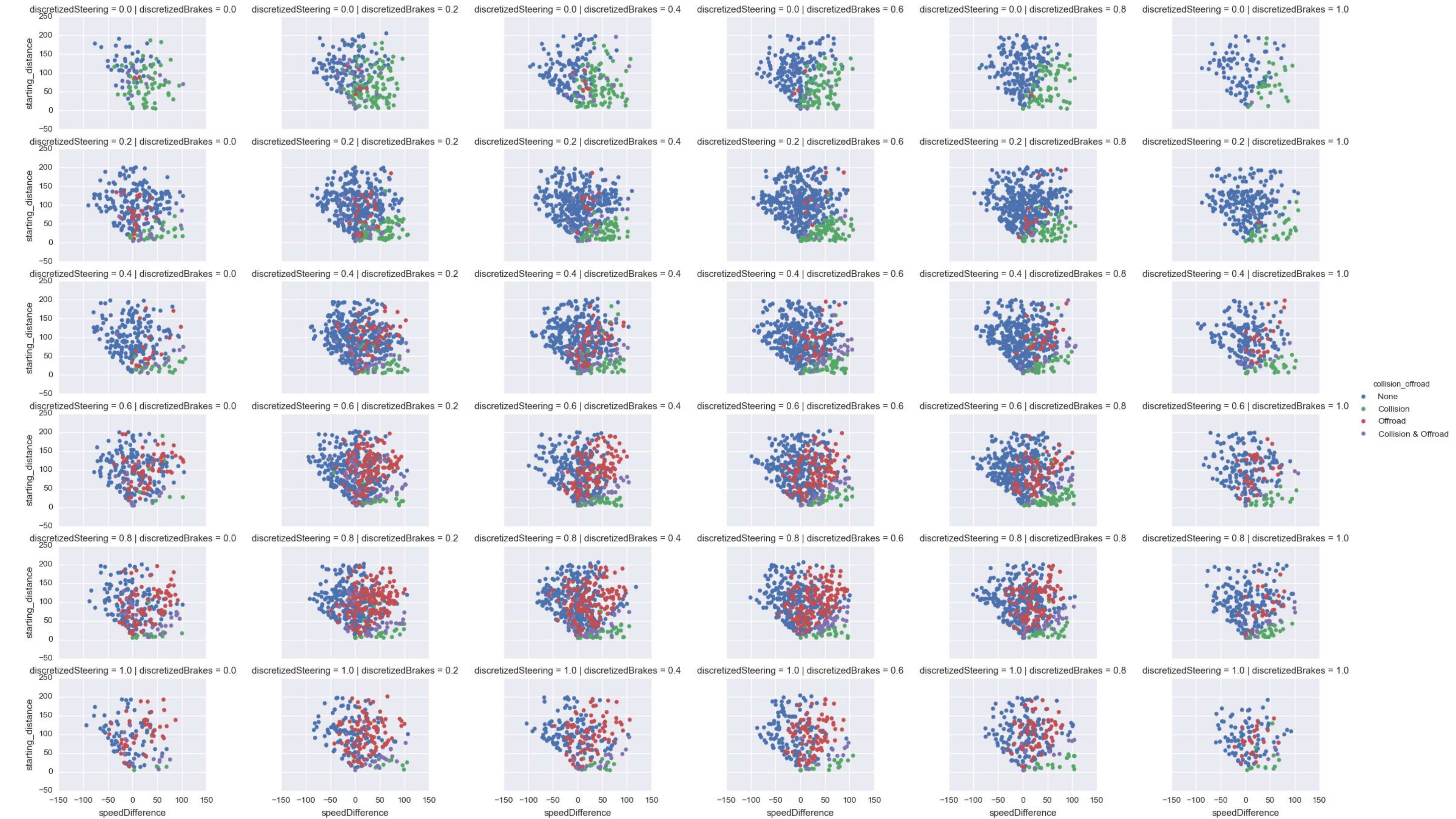
Only slight decrease in performance for most

Classifier	Precision F	Recall F	F1-score F	Precision T	Recall T	F1-score T
Random Forest Classifier	0.90	0.87	0.88	0.87	0.90	0.88
AdaBoost Classifier	0.86	0.87	0.87	0.87	0.86	0.87
Logistic Regression	0.87	0.83	0.85	0.83	0.87	0.85
Support Vector Machine	0.80	0.84	0.82	0.83	0.79	0.81
Bernoulli Naive Bayes	0.55	0.88	0.67	0.69	0.28	0.40
Neural Network	0.91	0.86	0.89	0.89	0.89	0.89

Table 1: **Training Accuracy for Single Obstacle w/Control Discretized to 6 Buckets**

Classifier	Precision F	Recall F	F1-score F	Precision T	Recall T	F1-score T
Random Forest Classifier	0.78	0.74	0.76	0.75	0.80	0.77
AdaBoost Classifier	0.76	0.71	0.73	0.76	0.71	0.73
Logistic Regression	0.74	0.73	0.73	0.73	0.74	0.74
Support Vector Machine	0.71	0.10	0.18	0.52	0.96	0.67
Bernoulli Naive Bayes	0.54	0.56	0.55	0.54	0.52	0.53
Neural Network	0.76	0.72	0.74	0.76	0.79	0.77

Table 2: **Training Accuracy for Three Obstacles w/Control Discretized to 6 Buckets**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discretizedSteering = 0.0 | discretizedBrakes = 0.2
discretizedSteering = 0.0 | discretizedBrakes = 0.4
discretizedSteering = 0.0 | discretizedBrakes = 0.6
discretizedSteering = 0.0 | discretizedBrakes = 0.8
discretizedSteering = 0.0 | discretizedBrakes = 1.0
discretizedSteering = 0.2 | discretizedBrakes = 0.0
discretizedSteering = 0.2 | discretizedBrakes = 0.2
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discretizedSteering = 1.0 | discretizedBrakes = 0.6
discretizedSteering = 1.0 | discretizedBrakes = 0.8
discretizedSteering = 1.0 | discretizedBrakes = 1.0
starting_distance
250
200
150
100
50
0
-50
-150 -100 -50 0 50 100 150
speedDifference
collision_offroad
None
Collision
Offroad
Collision & Offroad