BigRoad

Scaling Road Data Acquisition for Dependable Self-Driving

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Self-Driving Cars

Opportunities

Challenges
Pedestrian crossing highway

Heavy snow on the road

Deer crossing street

Tree failing down on the road
HUMAN DRIVER

100 million miles / fatality

SELF-DRIVING CARs

Billions of miles / fatality
Existing Approaches

\[
\begin{align*}
\text{Mileage Goal} & \quad 1,000,000,000 \\
\text{Mileage / Year} & \quad 100,000 \\
\text{Vehicle Num} & \quad \times \
\end{align*}
\]

\[
= \quad \text{Year} \\
100
\]

Highly instrumented vehicles

Reverse Engineering vehicle CAN Bus
BigRoad

Mileage Goal
1,000,000,000

Mileage / Year × Vehicle Num = Year
100,000 × 100,000 = 100
BigRoad Contributions

**Internal Driver Inputs**
- Steering Wheel Angle
- Driving Speed
- Vehicle Acceleration

**External Perceptions**
- Road Condition
- Front-view Video

- Training Self-Driving System
- Unusual Situations Detection
Challenges

• How can we accurately determine proprietary driver inputs such as the steering operations with such light-weight instrumentations?

• How can we make the setup widely deployable across vehicle models?
Steering Wheel Angle Estimation

Remove error caused by vehicle motion

Track steering wheel angle
Steering Wheel Angle Estimation

Steering Wheel Coordinate System

\[ \theta \]

\[ X' \]

\[ Z' \]

\[ Y \]

\[ Z \]

\[ g \]
Steering Wheel Angle Estimation
Steering Wheel Angle Estimation

Accelerometer based approach

\[ \theta_{\text{accel}} = \text{atan2}(\text{accel}_x, \text{accel}_z) \]

Gyroscope based approach

\[ \theta_{\text{gyro}} = \int \text{gyro}_y \, dt \]

Complementary Filter

\[ CC \cdot \left( \theta^{t-1} + \Delta \theta_{\text{gyro}}^{t|t-1} \right) \]

Low-pass filter

High-pass filter
Steering Wheel Angle Estimation

Accelerometer based approach

\[ \theta_{\text{accel}} = \arctan2(\text{accel}_x, \text{accel}_z) \]

\[ \theta_{\text{error}} = \arctan2(\text{accel}_{x_v}, \text{accel}_{z_v}) \]

Steering wheel angle estimation
Challenges

• How can we accurately determine proprietary driver inputs such as the steering operations with such light-weight instrumentations?

• How can we make the setup widely deployable across vehicle models?
Device Calibration

Vehicle System

Steering Wheel System

$\mathbf{Y}$

$\mathbf{s}$

$\mathbf{Z}$

$\mathbf{X}$

$\mathbf{Y}_S$

$\mathbf{Z}_S$
Device Calibration

Steering Wheel Coordinate System

Vehicle Coordinate System
Device Calibration

Vehicle Coordinate System

Steering Wheel Coordinate System

\[ \mathbf{X}_v \]
\[ \mathbf{Y}_v \]
\[ \mathbf{Z}_v \]

\[ \mathbf{Y}_s \]
\[ \mathbf{Z}_s \]

\[ \phi_{\text{pitch}} \]
Other Outputs

• Vehicle Speed
  • Fuse the GPS and accelerometer readings to derive high frequency vehicle speed on smartphone.

  \[ V_{t|t-1} = (1 - cc) \cdot V_{gps}^t + cc \cdot (V_{t-1}^t + \Delta V_{accel}^t) \]

• Vehicle Acceleration

• Road Condition Estimation
  • Detect binary road condition using the crowd sourced data from smartphone.
Experimental Setup

- 6 vehicle models.
- 7 drivers.
- 143 daily commute drives.
- 3 –month period.
- Various types of road in NJ and NY, USA.
Evaluation: Steering Wheel Angle

Mean error: 0.96 degrees
90-percentile error: 1.99 degrees

(a) Error distribution with respect to vehicle speed.

(b) Error distribution with respect to steering angle.
Evaluation: Driving Speed & Road Condition

Mean error 0.65 km/h. 90-percentile error: 2.11 km/h

Determine road conditions with 95%

(a) CDF of speed estimation absolute error.  
(b) Error distribution with respect to acceleration.
Evaluation: Usefulness of BigRoad

Self Steering Algorithm

3 Convolutional Layers

2 Fully Connected Layers
Evaluation: Usefulness of BigRoad

Model 1: Trained with In-vehicle data

Model 2: Trained with BigRoad data
Deep Neural Network-Based Self-Steering Algorithm

Trained with BigRoad Data

-3.9°

Trained with In-Vehicle Data

-3.1°
Conclusion and Future Work

• We present BigRoad that can scale road data acquisition for self-driving.
• We show that driving and road data can be estimated accurately using very few off-the-shelf sensing devices.
• BigRoad can calibrate itself to different vehicle types, steering wheel positions and sensor placements.

• Build an easy-to-install and sustainable setup for BigRoad.
• Design an interesting and unusual events detection method on smartphone.
• Deploy the BigRoad system.
Thank you!

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