How Simulation Accelerates Development of Self-Driving Technology

AIMOTIVE

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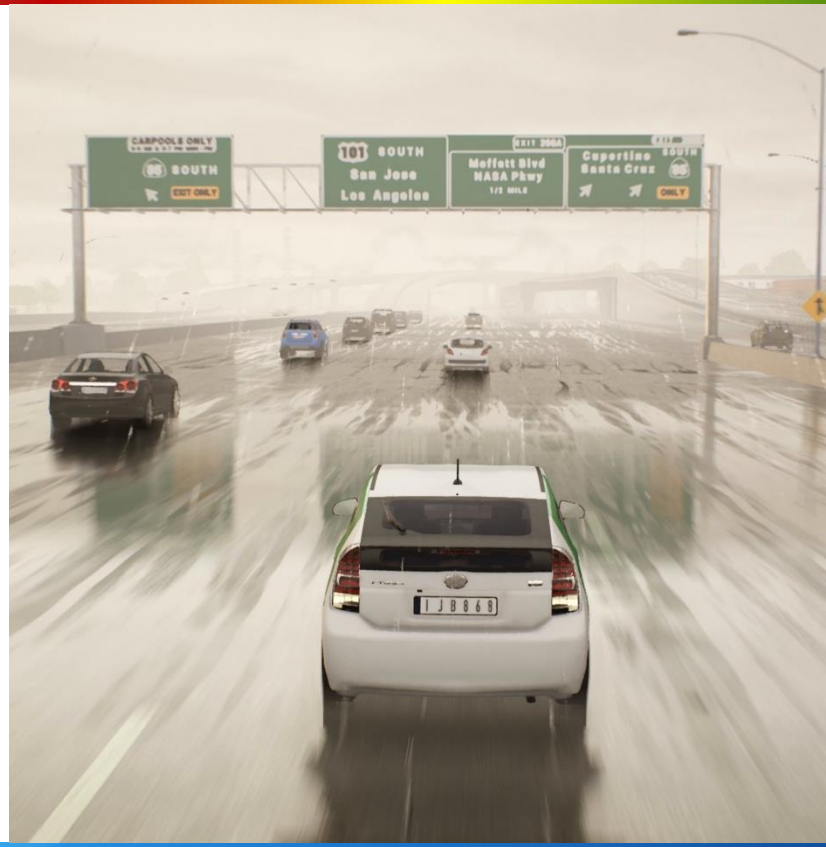
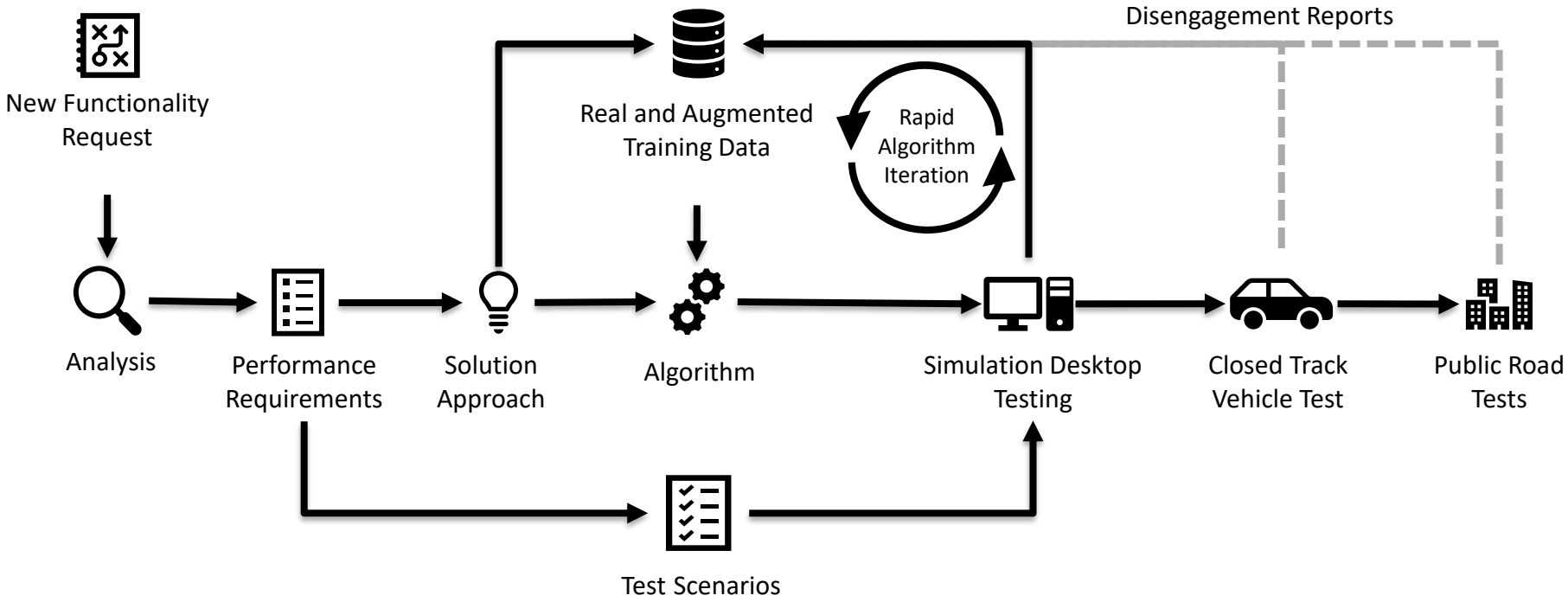
Overview

- **Simulation and Development**
  - Development Pipeline
  - Simulation Testing and Real-world Testing
  - Precommit Tests
  - Simulated Datasets
- **Simulation and Testing**
  - Types of Simulation
  - Development Tests and Nightly Tests
  - Mutual Benchmarking
- **Technical challenges and Human Limitations**
  - Technical Challenges
  - Metrics
  - The Human Touch



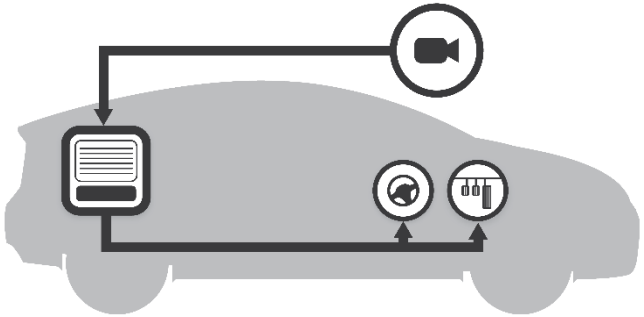
Simulation and Development

Development Pipeline

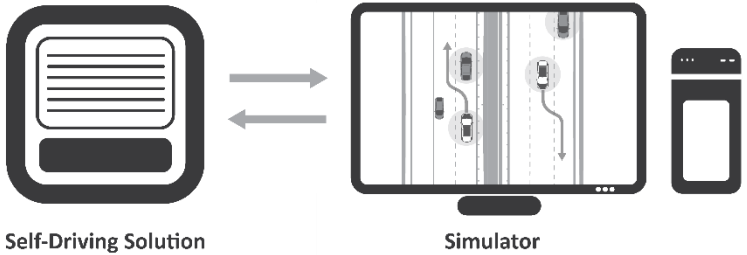


Real-world Solutions in Simulated Environments

- **Road tests**
  - Sensors
  - Software
  - Processing platform
  - Vehicle actuation
  - Run-time



- **Simulation testing**
  - Simulated image
  - Sensor simulation
    - cameras, radar, LiDAR
  - Software
  - Processing platform
  - Actuation of simulated vehicle



Precommit Tests

- All new commits must pass **pre-commit** test to reach code review
- Earlier software versions have always passed pre-commit scenarios
  - New versions must pass all scenarios
  - Tests serve as basic safety limit
  - Accelerate bug fixing by limiting area to be reviewed
- Supports regression free development

Simulated Datasets

- **Simulated datasets generated for neural network (NN) training**
  - NNs trained on simulated data used for prototype algorithm development
  - Data created overnight accelerates initial training data generation
  - Sensor setup can be changed easily
  - At a later stage real world data is needed
- **Real world data collection is slow**
  - Images have to be annotated and checked
  - If sensor setup is changed images become obsolete

Simulation and Testing

Real Time and Fixed Time Simulation

Real Time		Fixed Time Step
Same as real world environment	**RUNTIME**	Optimized to hardware capabilities
Not completely	**DETERMINISTIC**	Yes
Real time performance of algorithms on the same hardware as in AVs	**GOAL OF TESTS**	Evaluates logic of algorithms and accelerates development
Algorithm runtimes, visual information about vehicle behavior	**PROVIDES DATA ON**	Algorithm logic, numerical data on physical characteristics
High-end hardware	**PROCESSING REQUIREMENTS**	Wide range of compatible hardware
Variable	**HARDWARE UTILIZATION**	Maximized

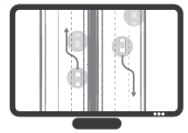
Daytime Tests and Nightly Tests

Daytime tests		Nightly tests
Test new features and the effects of changes to the code	**GOAL**	Guarantee quality of the self-driving solution; identify problems not seen in daytime tests
Development branches	**BRANCH**	Master
Defined and selected by developer	**NUMBER OF SCENARIOS**	Fixed set (2000+)
Test features under development or effects of changes to the code	**SCOPE**	Full range of self-driving tasks, situations and scenarios
Requested by developer from workstation	**REQUEST**	Run nightly on new software versions

Modular Testing

- Modules are solutions to certain algorithmic problems, e.g.:
  - Lane detection
  - Object detection
  - Free space detection
  - Sensor fusion
- Modular design allows testing of specific software components
  - Running one module (algorithm) in real time
  - Other components replaced by ground truth data
  - Accelerates identification of non-optimal algorithms

Mutual Benchmarking



Stable Simulator

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Stable Scenarios

Benchmarks

Development Version of Self-Driving-Solution

Stable Self-Driving Solution

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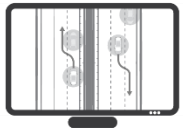
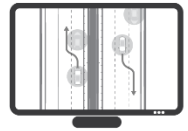
Stable Scenarios

Benchmarks



Development Version of Simulator



Stable Simulator

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Stable Self-Driving Solution

Benchmarks

New Scenarios

Technical Challenges and Human Limitations

Technical Challenges 1

- Correlating vehicle physics in simulator with real-world
  - Actuation commands must be within limits to ensure safe control
  - Limits must be the same in simulator and real-world
  - Vehicle physics and world physics have to be recreated precisely
- Getting the timing right
  - Real-world: sensor delays and latency
  - Simulation: images created instantly
  - Delays and latencies created artificially based on real world data

Technical Challenges 2

- Original idea: build in game engine
  - Requirements for self-driving testing are significantly different
  - Game engines are limited by:
    - GPU usage
    - Lack of multiple points of view
    - Physical realism
    - Precision rendering
- Testing for autonomous vehicle technology requires purpose-built engine
- Simulation is a growing industry trend: NVIDIA, AirSim (Microsoft), Carla

Metrics

- Fixed time step simulation provides huge amounts of numeric data
  - Used to create detailed graphs and metrics
    - Scenario pass/fail rates
    - Deviations from planned trajectory
- Deterministic tests
  - Results are always the same
  - Exact numerical data based on algorithm logic
  - Physical characteristics (speed, brake distance etc.) can be measured precisely

The Human Touch

- Videos from real time simulation tests are processed by humans
  - Large amount of data is needed
  - Processing is a problem

- Possible solutions:
  1. Concentrate efforts on one functionality or development branch
  2. Tag known bugs and errors to reduce number of repeated reviews
  3. Automate preliminary review and flag data for human review
     - Is a system in which a computer is responsible for both testing and review desired?

Summary

- Simulation technology is a safe, economical and quick development tool
  - Implementation in development process must be thought-out and safety conscious
  - Real-time and fixed time step simulation serve different purposes
  - Developers should have direct access to simulator
- Physics model correlation and latency recreation are challenges
  - Realism is often limited by engine choice
- Processing extreme amount of data is difficult

Almotive at a Glance

COMPANY	• Founded in 2015 by CEO Laszlo Kishonti • Incorporated in Germany, headquartered in Budapest
GLOBAL GROWTH	• 4 Offices across 3 continents: Budapest (HU), Helsinki (FIN), Mountain View (USA) and Tokyo (JP) • 4 Licensed testing locations: Hungary, Finland, California, Nevada • 3 self-driving test car models: Toyota, Volvo, Citroen
TEAM & EXPERTISE	• 180+ passionate team, including 120+ highly skilled engineers • In-house developed AI algorithms and framework • 10+ years in High Performance Embedded Programming
SELF-DRIVING ECOSYSTEM	• Developing full self-driving ecosystem • aiDrive: Vision-first self-driving artificial intelligence • Advanced development tools to accelerate development • aiWare: efficient, scalable host offload for NN processing

Resources

- More about simulation:
  - Vanessa Bates Ramirez, This Self-Driving AI is Learning to Drive Almost Entirely in a Virtual World
  - William Wong, Will Automotive Simulation Catch Up with Self-Driving Cars?
  - Devindra Hardawar, NVIDIA aims to make self-driving safer with virtual simulations
  - Sean O'Kane, How Tesla And Waymo Are Tackling A Major Problem For Self-driving Cars: Data
- Further videos:
  - aiDrive in Simulator
  - Microsoft AirSim