AIMOTIVE

Introduction and Technical Overview

09.NOV.2016

Our mission

We at AImotive are committed to improving the lives of millions of drivers across the world.

We design AI software which powers self-driving vehicles, resulting in better safety, improved comfort, and increased productivity

Fast Facts

Company details	Founded in July 2015 as a spin-off of Kishonti Ltd. Headquarter: Budapest, Hungary Founder: László Kishonti
Investors	Funded by investors: Robert Bosch VC / Nvidia / Inventure / Draper Associates / Day One Capital / Samsung / Private investors
Team	100+ researchers/developers with in-depth experience in their field
Expertise	In-house developed AI algorithms and framework 10+ years in high performance embedded programming Complete navigation and mapping solution expertise 5+ years in Computer Vision
Membership	Khronos Group Embedded Vision Alliance

Our Partners

Our projects

L3 / L4-L5 projects

- Large European OEM
- Large global technology company
- Discussions ongoing with many other Automotive OEMs and Partners

L1 / L2 projects

- Delivering Parking Assist and rear-view camera solution for Tier1/Automotive OEM
- Delivered local positioning project for global map data provider

What We Offer

aiDrive

Artificial Intelligence-based full stack software suite for Level 5 self-driving cars

- RECOGNITION ENGINE (AI)
- LOCATION ENGINE
- MOTION ENGINE (AI)
- CONTROL ENGINE

OVER-THE-AIR UPDATES

DATA COLLECTION

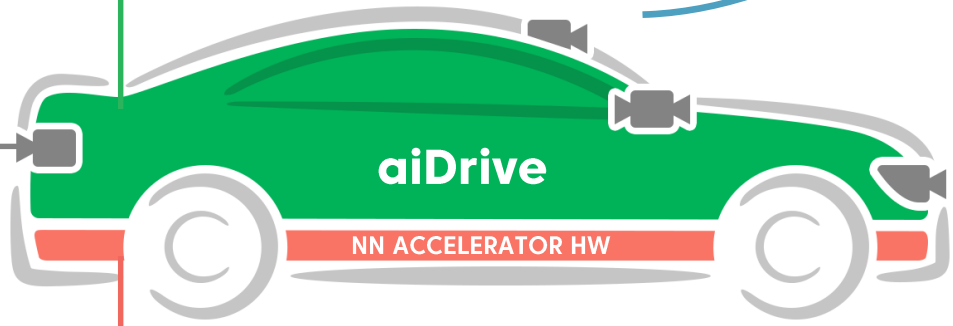
aiKit

A framework combining the training and testing tools essential to build the aiDrive suite

- CALIBRATION TOOL
- DATA COLLECTION
- ANNOTATION
- DATA GENERATION
- TRAINING
- REAL-TIME SIMULATOR
- VERIFICATION

SENSORS

- PRIMARY: CAMERAS
- OPTIONAL: RADAR / LIDAR
- OTHER OFF-THE-SHELF SENSORS



aiWare

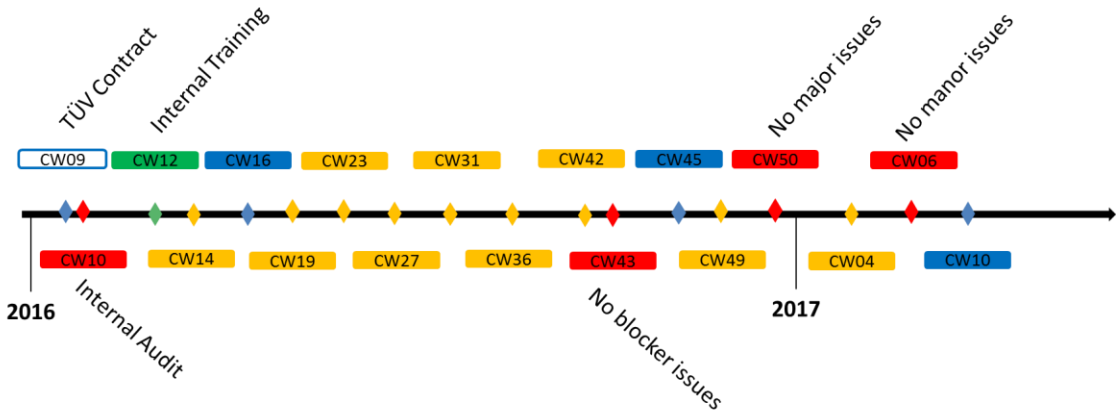
Neural network accelerator IP that helps chip companies build low power, high performance AI optimized hardware

We Work According to Automotive Standards

Cooperation with TÜV-Rheinland to establish the internal processes regarding to:

- ISO/IEC 33020:2015 Information technology -- Process assessment -- Process measurement framework for assessment of process capability
- ISO/TS 16949 – Quality Management Systems
- ISO/FDIS 26262 – Road Vehicles – Functional Safety

TÜVRheinland®
KTI
Precisely Right.



How is the Almotive Approach Unique?

	AIMOTIVE	Google	MOBILEYE
Technical approach and scalability?	L5 architecture (fully self-driving) Scalable (worldwide implementation possible)	L5 architecture (fully self-driving) Not scalable (optimized for local implementation)	Develops L1/ L2 solutions gradually towards L3/L4 functionality
How to identify relevant objects?	Primary sensor: Multiple cameras + optional sensors	Primary sensor: LIDAR + camera + High definition map data	Primary sensor: Single camera + mandatory radar sensors
How well does it see?	Similar to human eye Fine details visible (predicts behavior)	Very rough picture (LIDAR cannot see behavioral cues in humans)	Similar to human eye. Fine details visible
Does it work in various weather conditions?	Rain/Snow issues handled by AI Poor image quality in low light Other sensors as backup	Full day/night functionality but low resolution Rain/Snow issues	Poor image quality in low light Other sensors as backup
What is the annotation technique?	Fast & scalable annotation, 100k images/hour Semi automatic with some human intervention	No info, assumably semi-automatic	Time consuming human annotation only
Is a mandatory chip needed?	No, software runs on most chips Almotive supports automotive embedded chips	No, software runs on high-end chip	Runs only on Mobileye's own chip
Is the training technique scalable?	Yes, simulator tool can train various weather conditions and traffic situations	No, data collection for training purposes focuses on dry, temperate climate regions. Only 10 accidents in 1.5m miles	Not that we know of
OK, so what does this all mean?	Safe, more robust, highly scalable and can be used anywhere	Might work in predefined routes, e.g. for robotaxis	Incremental improvements to safety Multi-camera functionality expected in 2018, L3/L4 in 2021

We use cameras as primary sensors due to the higher performance they enable

	Advantages	Disadvantages	
Camera	Like the human eye, good for all use cases, best sensor for color and texture	High processing performance required	Primary
LIDAR	High precision detection unaffected by light/sound interference	Needs an HD map for localization to function, requires huge amount of data	Secondary
Radar	Cost effective, good as backup sensor	Poor resolution, 2D information only	Secondary

Most valuable use case

- Real-time localization, object recognition, classification, and tracking
- Real-time localization, identification of objects, static 3D geometry
- Backup to detect the location of objects if high resolution sensors fail

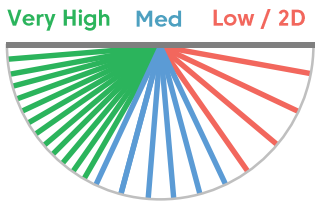
Range and distance accuracy

0 – 1000+ m	
3 – 150 m	
2 – 250 m	

Dark / bad weather usage

- Just like the human eye
- Limited in rain and snow
- Limited in rain and snow

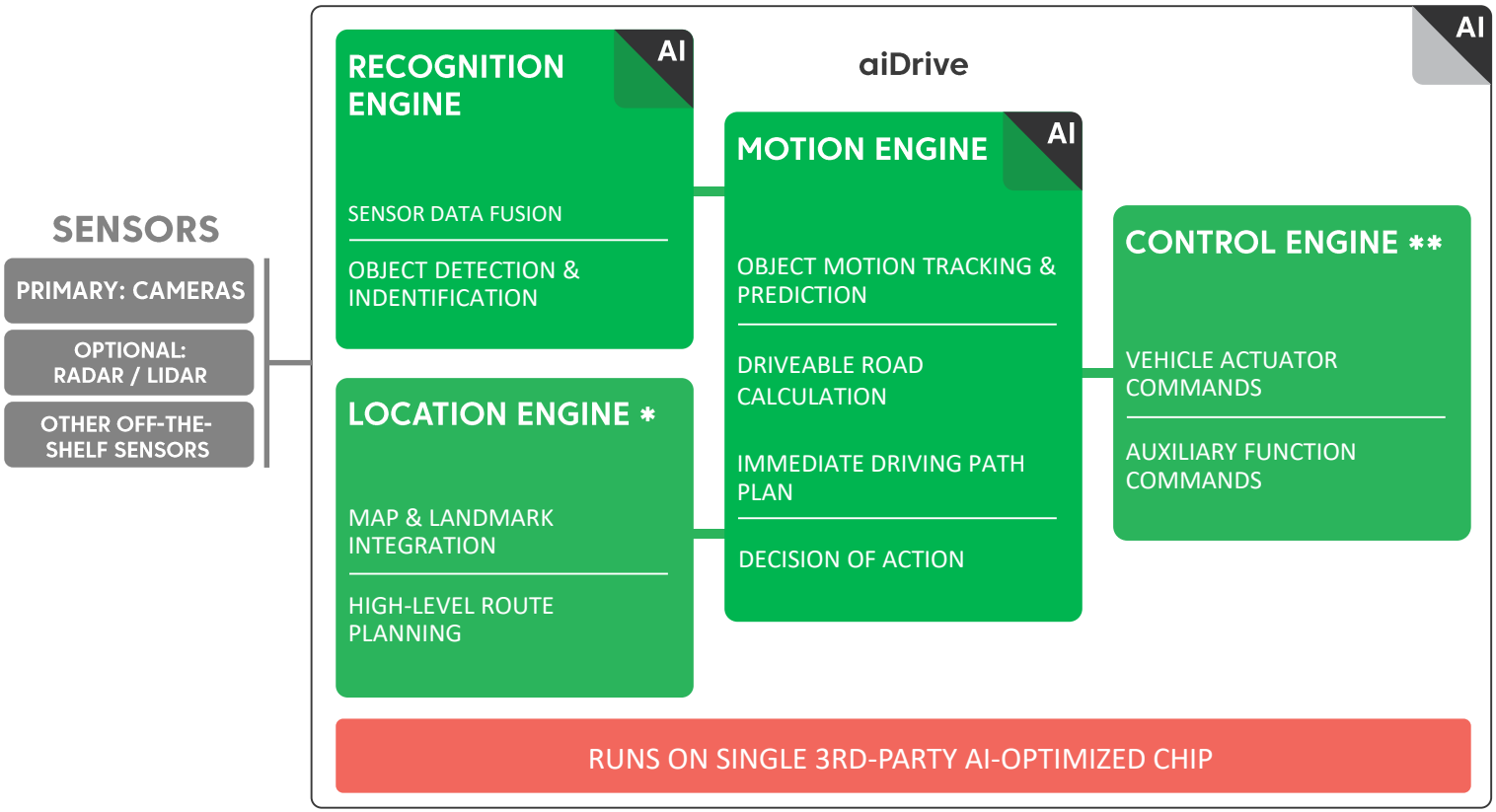
Angular Resolution



Sensors / car	Cost / piece
6–12 pieces	$20 - $70
1 Velodyne/4 Ibeo	$40,000 - $80,000
4–8 pieces	$500 - $1,500

aiDrive

aiDrive



* OPTIONAL: 3RD-PARTY NAVIGATION IS SUPPORTED

** OPTIONAL: VEHICLE'S OWN CONTROL SYSTEM IS SUPPORTED

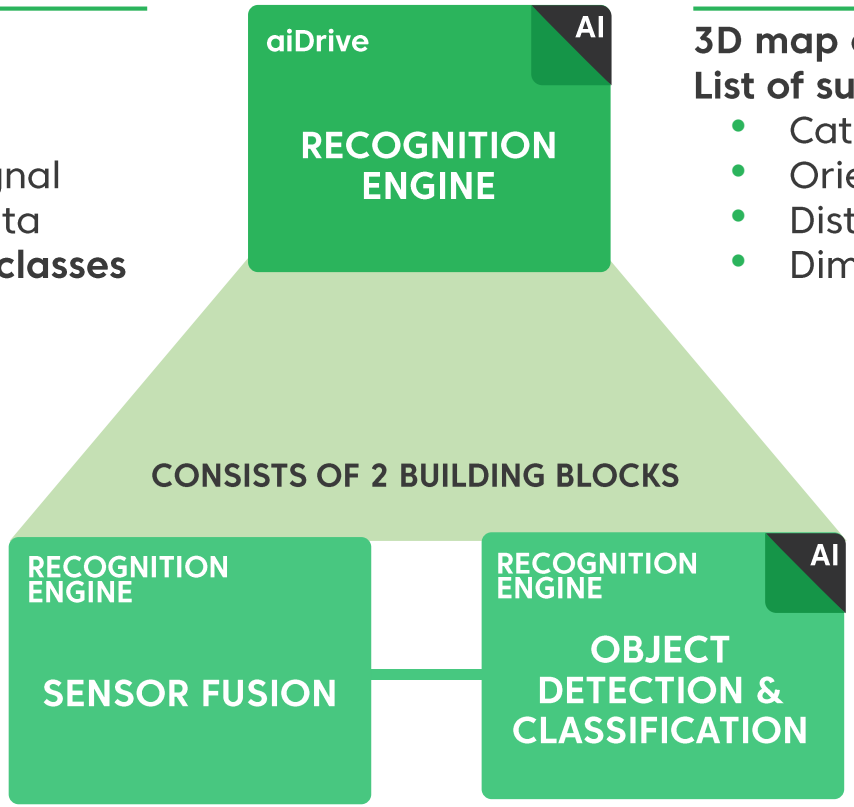
Recognition Engine

Recognition Engine identifies the objects and interprets the environment around the vehicle in real time.

INPUT

Perceived environment
- Camera vision
- CAN-bus
- Optional radar signal
- Optional LIDAR data

Region specific object classes

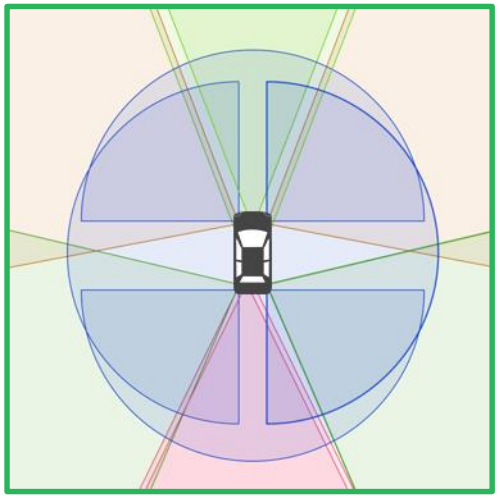


OUTPUT

3D map of vehicle environment
List of surrounding objects
- Category
- Orientation
- Distance
- Dimensions

Recognition Engine
Sensor Fusion

1. Preceiving real 3D environment via sensors
2. Camera is our preferred primary sensor
   - Synchronized multiple mono / stereo cameras
3. Optional sensors:
   - Radars, LIDAR, ultrasonic and IMU / GPS
4. Fuses all sensor inputs into an Artificial Intelligence interpretable format



INPUT

Perceived environment
- Camera vision
- CAN-bus
- Optional radar signal
- Optional LIDAR data

RECOGNITION ENGINE

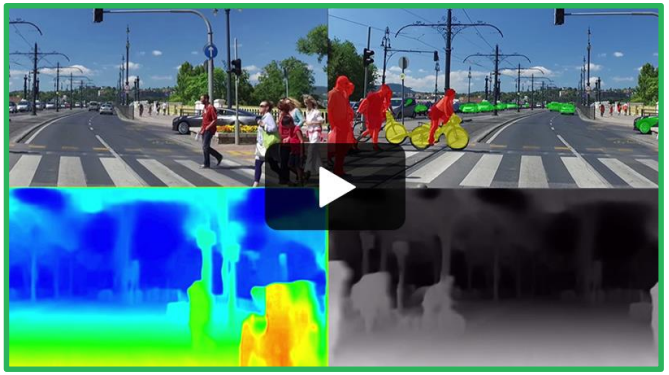
SENSOR FUSION

OUTPUT

Synchronized snapshots
- Fused and pre-processed sensor data in AI interpretable format

Recognition Engine
Object Detection and Classification

1. Same AI algorithm for object detection and classification
   - Bounding box
   - Pixel precise segmentation
   - Recognizes up to 100 different object classes
2. Determines distance / dimensions
3. Recognizes even partially occluded objects
4. Localization
   - Country specific object classes



INPUT

Synchronized snapshots
- Fused and pre-processed sensor data in AI interpretable format

Region specific object classes

RECOGNITION ENGINE
AI
OBJECT DETECTION & CLASSIFICATION

OUTPUT

3D map of vehicle environment
List of surrounding objects
- Category
- Orientation
- Distance
- Dimensions

Location Engine

1. In-house navigation engine which does not require HD maps for precise positioning
   - Regional localization
   - GPS position of vehicle
   - Next maneuver and distance
   - Lane indication
2. Special landmark information is added for accurate positioning of the vechicle even when the GPS signal is weak / lost
3. Can also rely on OEM installed navigation

INPUT

Almotive landmark database

OEM Navigation device incl. standard map (HERE, OSM, etc)

Destination

aiDrive

LOCATION ENGINE

OUTPUT

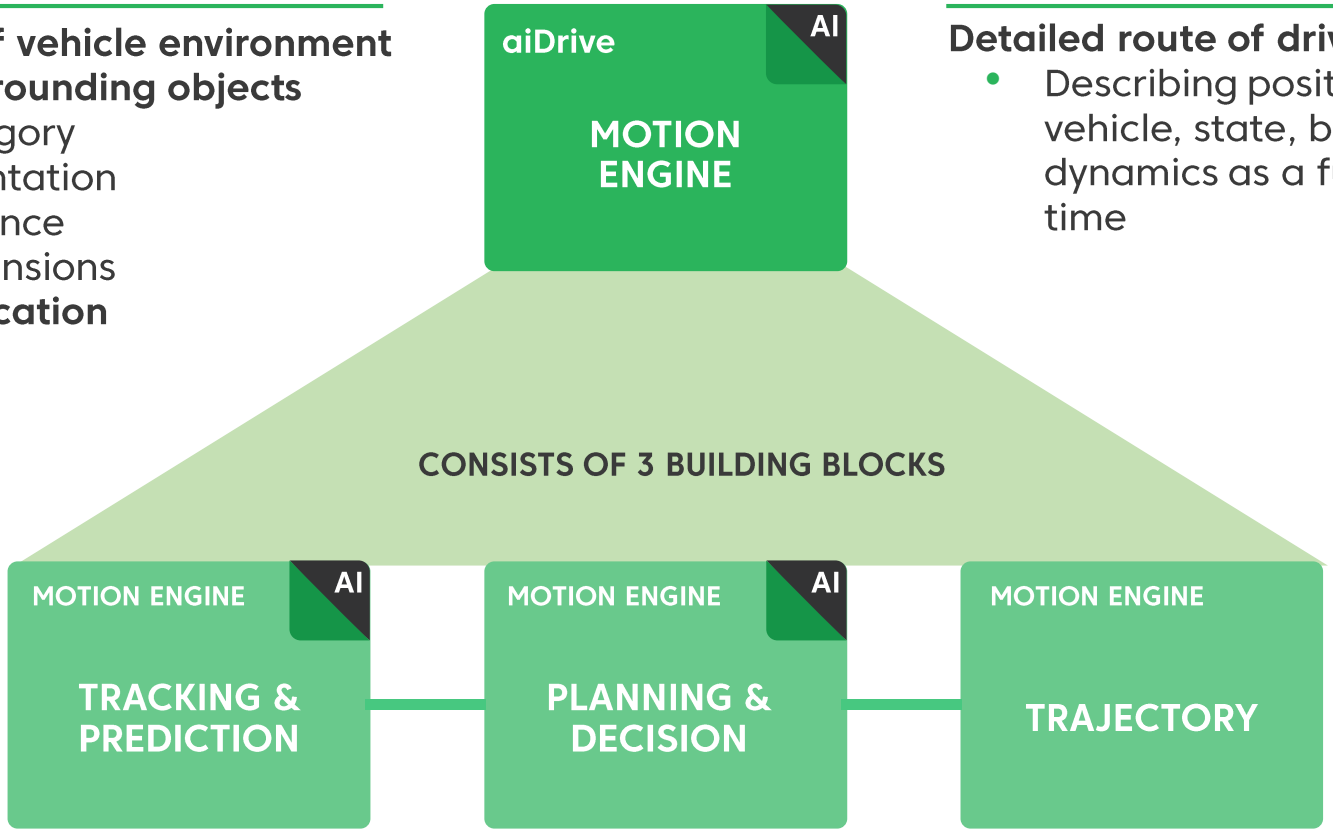
Precise vehicle location
Optimal route
- Next maneuver

Motion Engine

INPUT

3D map of vehicle environment
List of surrounding objects
- Category
- Orientation
- Distance
- Dimensions

Vehicle location

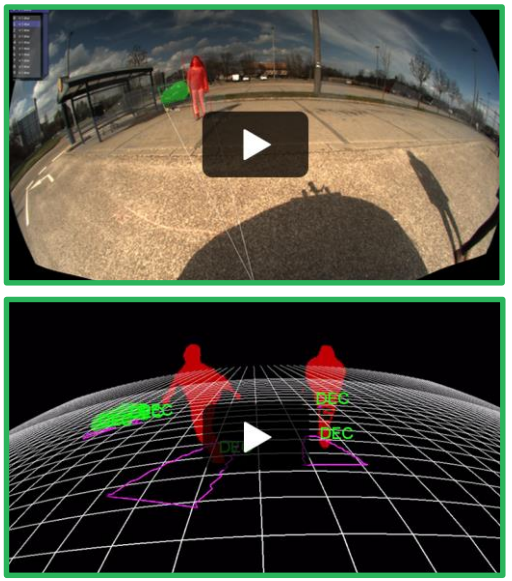


OUTPUT

Detailed route of driving path
- Describing position of vehicle, state, behaviour and dynamics as a function of time

Motion Engine
Tracking & Prediction

1. Develops a short term memory of objects by analyzing changes between snapshots
2. Movement characteristics of region specific object classes are taken into account
3. Individual deviation of behaviour is considered (Children, drunk people)
4. Probability distribution of future locations and speed is calculated



INPUT

3D map of vehicle environment
List of surrounding objects
- Category
- Orientation
- Distance
- Dimensions

Vehicle location

MOTION ENGINE AI

TRACKING & PREDICTION

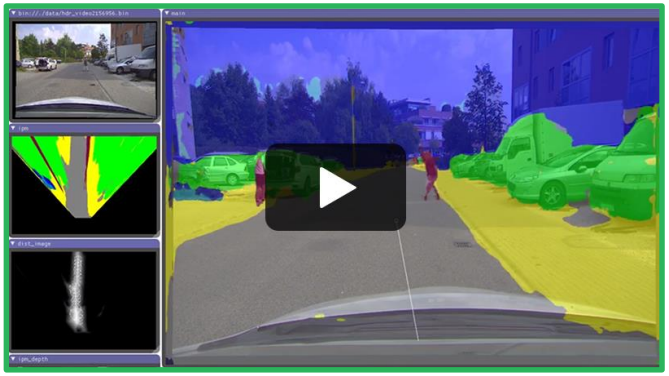
OUTPUT

Predicted state
- Future speed & location
- Behavior

Motion pattern of all relevant objects
- ID, Speed, Acceleration, Direction

Motion Engine
Planning & Decision

1. Identifies free space based on predicted enviroment
2. Determines driving style
3. Creates high level plans for both normal and emergency situations
4. Decides if normal or emergency situation applies



INPUT 1

Precise vehicle location
Optimal route
- Next maneuver

INPUT 2

Predicted state
- Future speed & location
- Behavior

MOTION ENGINE AI

DECISION & PLANNING

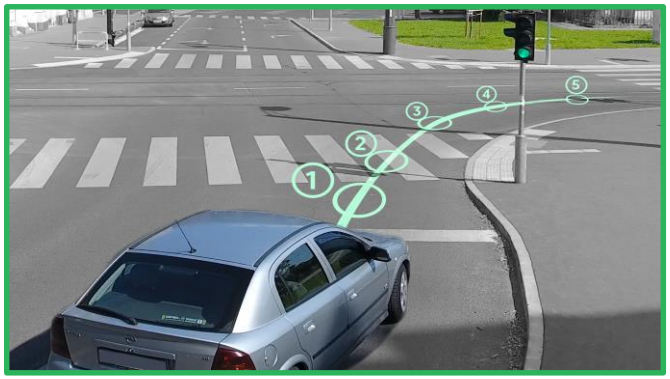
OUTPUT

Driving style of our vehicle

Decision about route
- Plan of normal or emergency situation

Motion Engine
Trajectory

1. Translates high level routing and free space information into low level controls
2. Calculates ego motion
3. Safely stops vehicle in case of emergency situation



INPUT

Driving style of ego vehicle

Decision about route

- Plan of normal or emergency situation

MOTION ENGINE AI

TRAJECTORY

OUTPUT

Detailed route of driving path

- Describing position of vehicle, state, behaviour and dynamics as a function of time

Control Engine

1. Executes chosen trajectory through the combination of (Control loop)
   - Vehicle actuators such as acceleration, braking, steering, gearshift
   - Auxiliary functions such as turn indicators, headlights, horn, etc
2. Control Engine is optional:
   - aiDrive can communicate with the vechicle's default control system

INPUT

Detailed route of driving path

- Describing position of vehicle, state, behaviour and dynamics as a function of time

aiDrive AI

CONTROL ENGINE

OUTPUT

Low level control

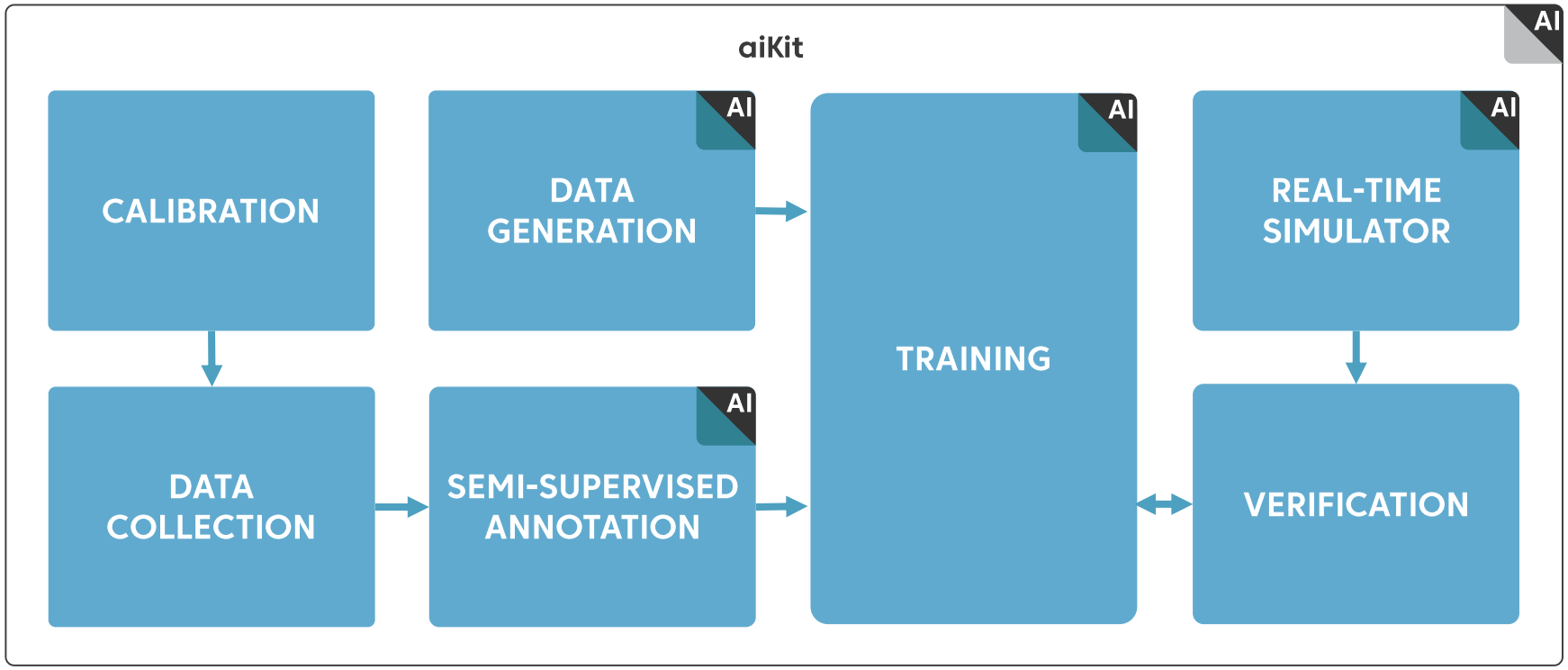
- Actuator control (acceleration, brake, steering, gearshift)
- Auxiliary control (indicators, lights, horn)

aiDrive is already being tested on the road

Video of our Toyota Prius test car in action

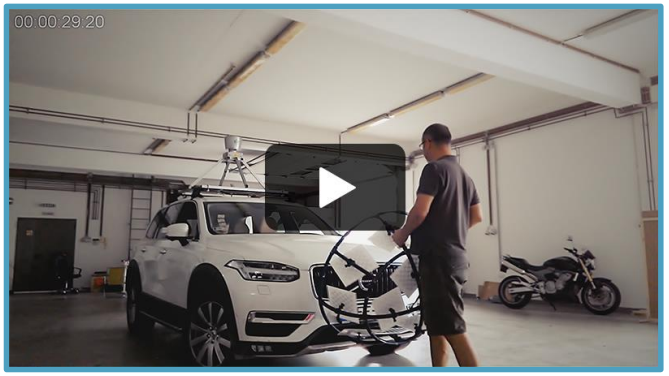
aiKit

aiKit


aiKit
AI
CALIBRATION
DATA COLLECTION
DATA GENERATION
AI
SEMI-SUPERVISED ANNOTATION
AI
TRAINING
AI
REAL-TIME SIMULATOR
AI
VERIFICATION

aiKit
Calibration Tool

1. Automated and fast process
2. Intrinsic/extrinsic calibration of cameras
3. Includes calibration of LIDAR to cameras
4. Radar solution is still under development, as radar currently penetrates our calibration kit (material issue)



INPUT

Physical calibration rig

aiKit

CALIBRATION

OUTPUT

Calibrated sensors:

- Multiple camera
- Radars, LIDARS, etc.

aiKit
Data Collection Tool

1. Real-time operation and simultaneous recording is used (logging of detection output)
   - Black-box functionality
   - Multisensor recording and playback
   - Modular sensor setup

2. HIL (hardware in the loop) testing

3. SIL (software in the loop) algorithm test

INPUT

Calibrated sensors:
- Multiple camera
- Radars, LIDARS, etc.

Vechicle data:
- CAN-bus

aiDrive detection output

aiKit

DATA COLLECTION

OUTPUT

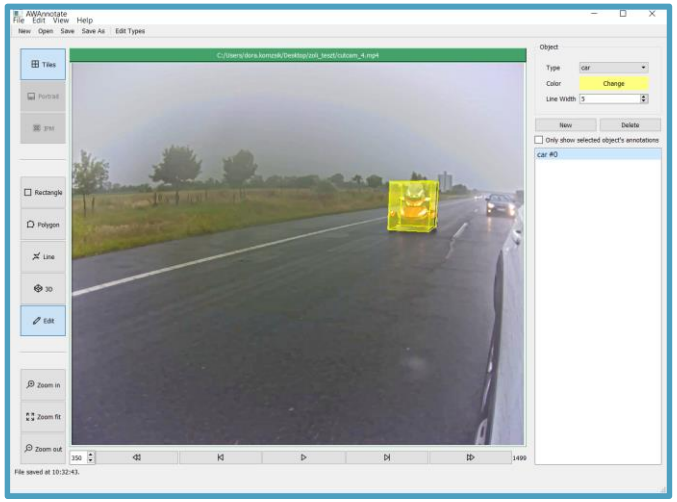
Synchronized data stream in user defined format

aiKit
Semi-supervised Annotation Tool

1. Semi-automated tool annotates reliably and fast (15 times faster than manual)

2. Capable of multisensory annotation based on camera image labelling

3. We have user definable object classes, attributes and output formats



INPUT

Synchronized data stream in user defined format

aiKit AI

SEMI-SUPERVISED ANNOTATION

OUTPUT

Labelled data according to the output format

- ID
- Object class
- Size, Distance, Orientation

Annotation of Non-camera Sensor Data

1. Capability to process sensor data from LIDAR and radar to verify the depth calculated by the cameras

2. Intelligent sensor fusion

    - Interconnected camera + LIDAR (depth) with camera based annotation
    - The annotated data is further extended with the radar's object list
    - The output is the complete set of necessary training inputs (object ID, class, distance, size and orientation)

3. Direct annotation of LIDAR point cloud data

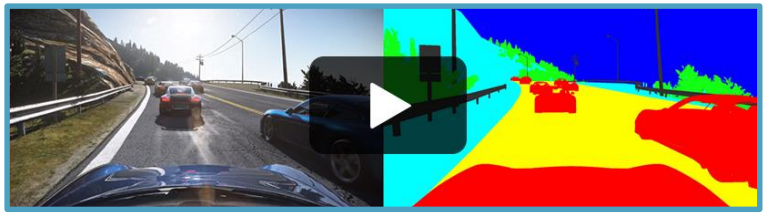
    - Not as relevant for AImotive since primary sensor is camera
    - Research is in progress on 3D point cloud annotation methods

aiKit
Data Generation Tool

1. Renders photorealistic camera images or sensor fused data in various
   - Weather & lighting conditions
   - Occlusion, orientation, distance

2. Pixel precise annotation and depth information improve detection accuracy

3. Optional sensor data generation (radar/LIDAR)
   - In fact much easier than generating visual data



INPUT

3D object models
- Vehicles, traffic signs, road paintings etc.

aiKit AI

DATA GENERATION

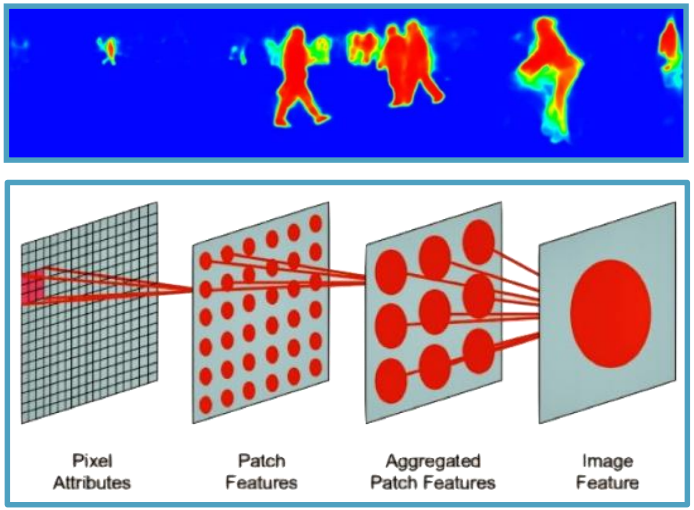
OUTPUT

Training data (image or fused data)

Ground-truth annotation

aiKit
Training Tool

1. In-house developed training tool for all type of neural networks (CNN, RNN, etc.)
2. Massively parallel GPUs used to train faster
3. Compatible with the major toolsets (Caffe, Torch, Tensor flow)



INPUT

Labelled or generated data

Feedback from testing tool

aiKit AI

TRAINING

OUTPUT

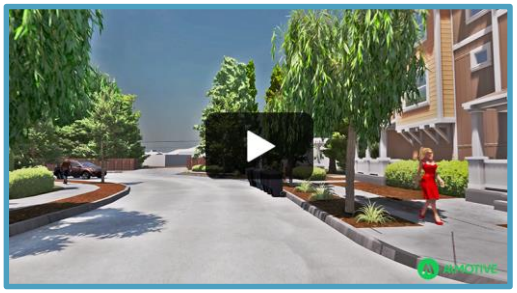
Trained network structure

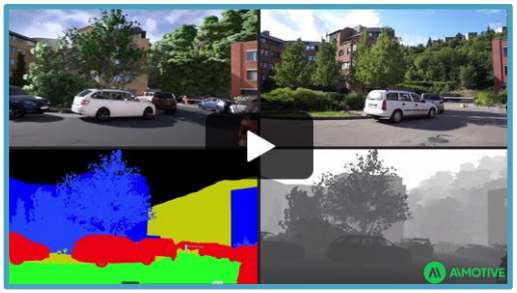
aiKit
Real-time Simulator

1. Generates complex and realistic traffic situations
   - Photorealistic camera images
   - Different weather conditions
   - Multiple sensor inputs
   - Vehicle dynamics

2. Train and test aiDrive in various scenarios

3. Will accelerate training time significantly





INPUT

Manually parametered scenes for testing

aiKit AI

REAL TIME SIMULATOR

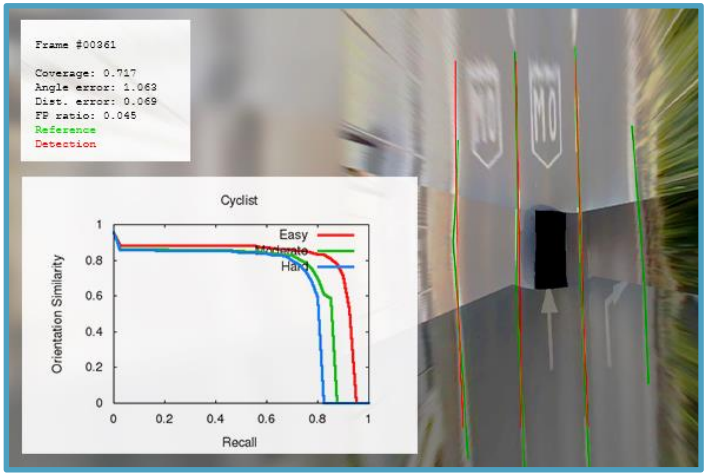
OUTPUT

- **Extreme traffic situations**
- **Various weather and lighting scenarios**
- **Simulated camera and sensor data**

aiKit
Verification Tool

1. Verification tests are based on specific customer requirements

2. Modular data verification
   - Various environmental conditions and object classes
   - Area of interest can be modified
   - Accuracy of evaluation criteria can be adjusted



INPUT

Trained neural networks

Test cases

aiKit

VERIFICATION

OUTPUT

Test and evaluation metrics

Feedback to the training process

Iterative Test Cycles Accelerated by Simulation

An example test program:

1. Test cases submitted into test tool
2. Testing vol. 1
    a. Road testing. Test tool recognizes automatically predefined test cases while driving and evaluates performance
    b. Simulator testing. Simulator can provide random or predefined driving scenarios. Test tool recognizes automatically predefined test cases while driving and evaluates performance
3. Test tool outputs the test results with opportunity for human check
4. Define additional test cases
5. Testing vol. 2
    a. Road testing efficiency will depend on encountered test situations (which can be organized)
    b. With simulator test tool can run a large test set without human intervention. Testing can focus on difficult corner cases instead of collecting millions of eventless miles

aiWare - Hardware IP Optimized for AI

aiWare
NN Accelerator IP

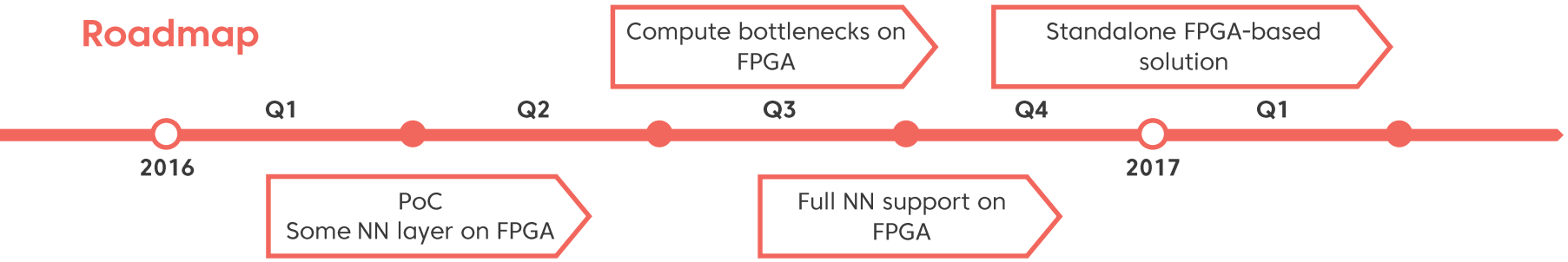
We offer performance efficient NN accelerated hardware for automotive embedded solutions

1. Benefits: low power consumption, high bandwidth, low latency NN computation
   - ASIC's power consumption is 3% of a GPU's

2. We provide the NN optimized RTL design for chip companies

3. AImotive also provides hardware agnostic solution to fit OEM / Tier 1 preferences

Roadmap



aiWare
NN Exchange Format Standard

KHRONOS GROUP

Almotive initiated the Khronos Working Group to create a new NN data format standard (NNEF) and actively contributes to the specifications

1. The NNEF standard encapsulates:
   - Neural network structure
   - Data formats
   - Common operations (convolution, pooling, normalization etc.)
   - Formal network semantics

2. Enables reliable import / export between network creating tools, inference engines and other toolkits

3. Reduces deployment friction and encourages a richer mix of cross-platform deep learning tools, engines and applications

Members of the Khronos Group

AIMOTIVE

Contact

Budapest Office

Szepvolgyi ut 39.
1037 Budapest, Hungary

Silicon Valley Office

1907 Colony St, Mountain View
CA, USA

www.aimotive.com