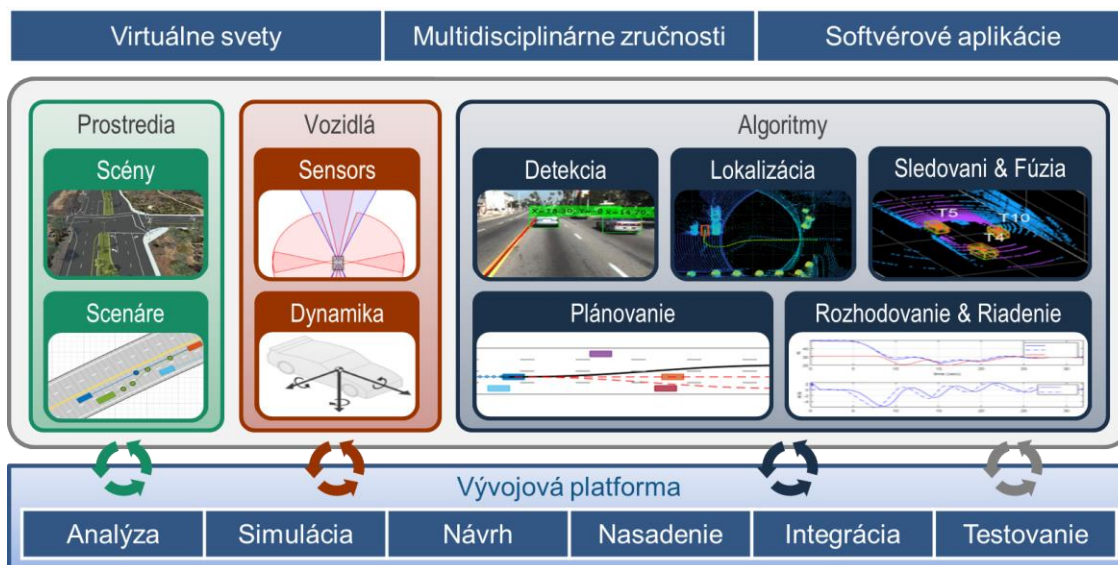


12.05.2022 Technical Computing Prague

Algoritmy autonómnych systémov



Michal Blaho

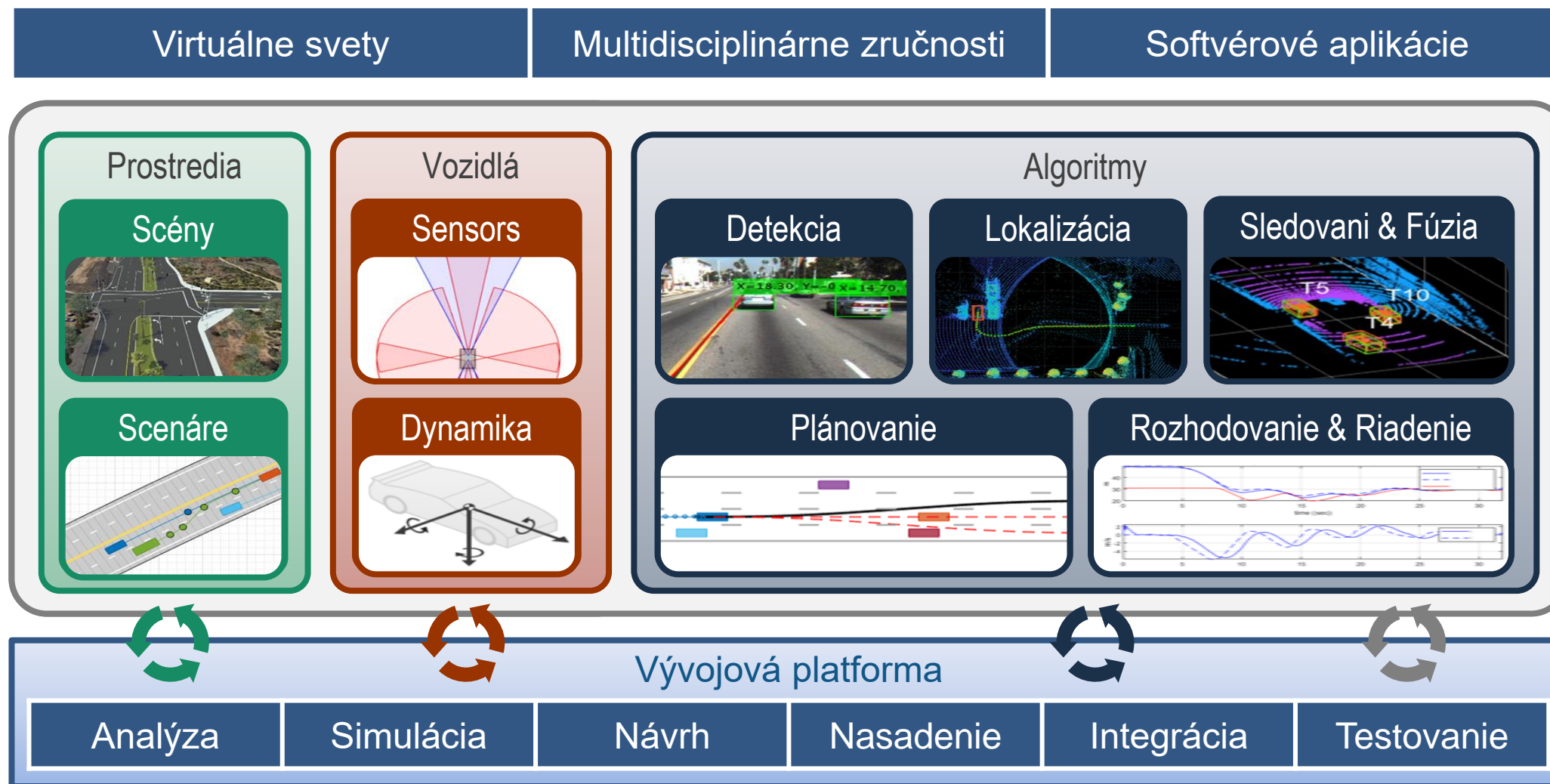
blaho@humusoft.cz

www.humusoft.cz

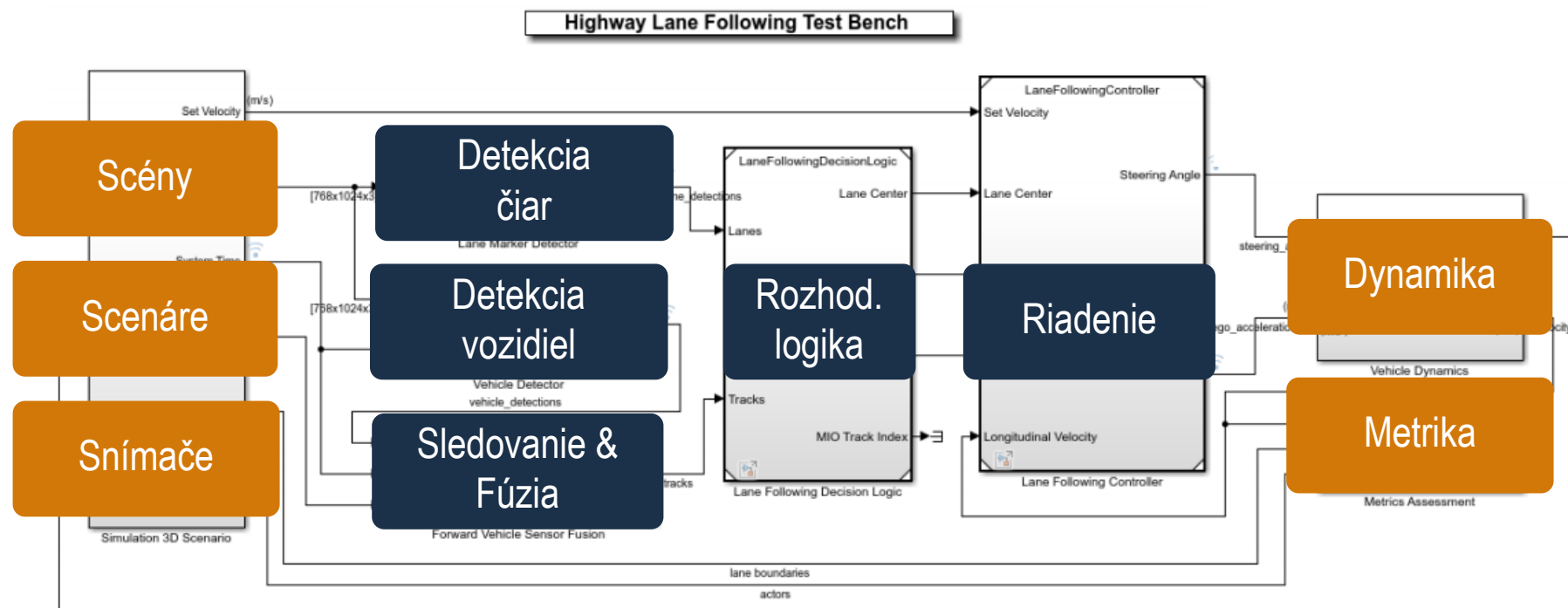
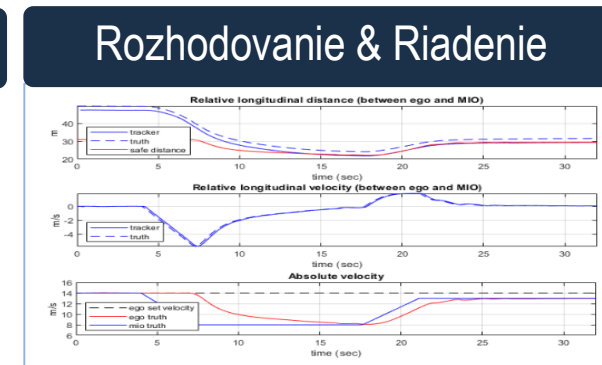
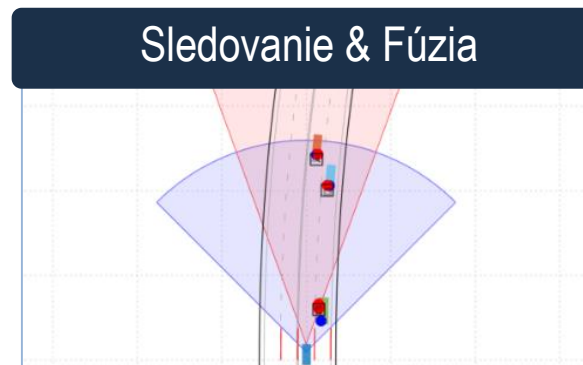
info@humusoft.cz

www.mathworks.com

Vývoj systémov autonómneho riadenia

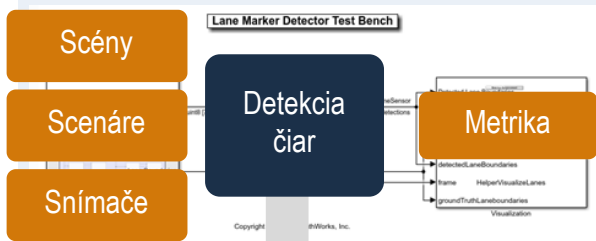
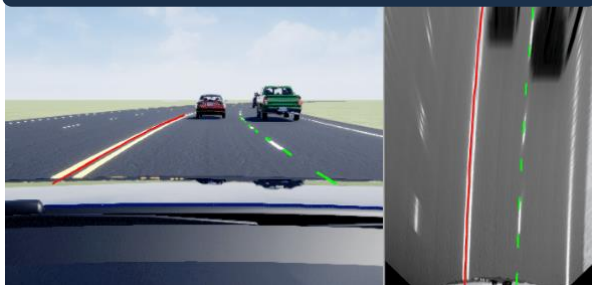


Simulácia autonómneho riadenia vo virtuálnom svete



Vývoj algoritmov pre viaceré disciplíny

Detekcia čiar



Kód

Lane Detector

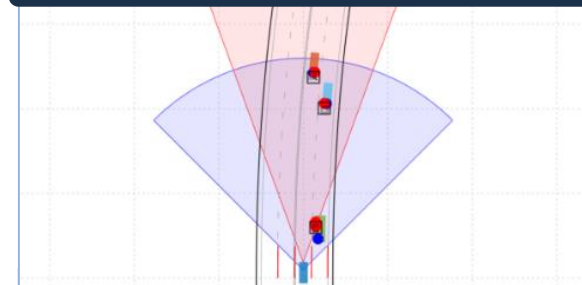
Detekcia vozidiel



Kód

Vehicle Detector

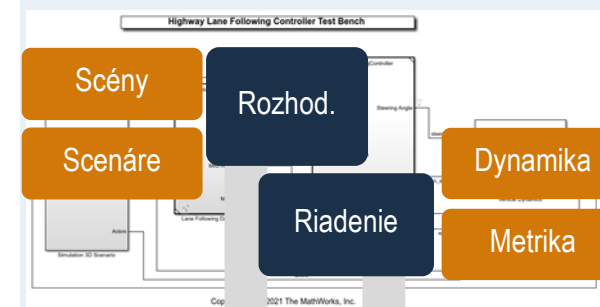
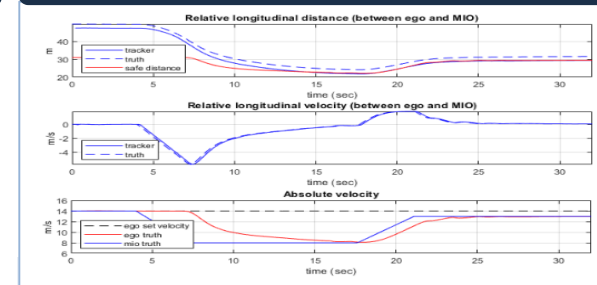
Sledovanie & Fúzia



Kód

Vehicle Sensor Fusion

Rozhodovanie & Riadenie



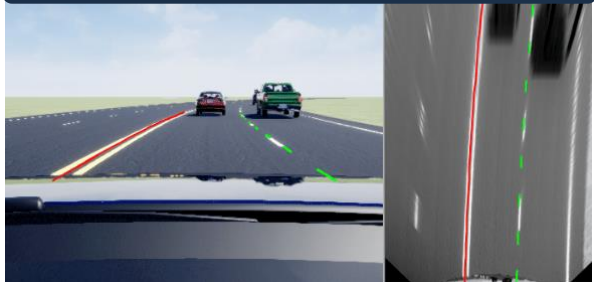
Kód

Kód

Decision and Controls

Vývoj softvéru pre autonómne riadenie

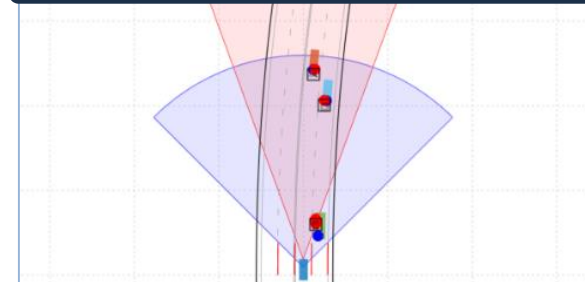
Detekcia čiar



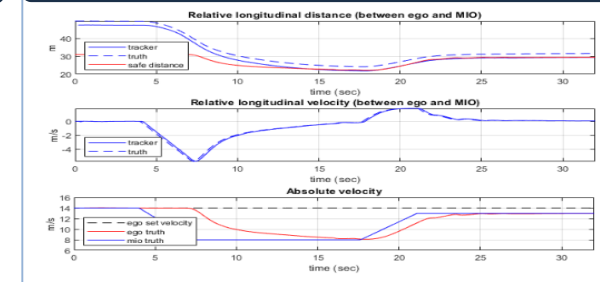
Detekcia vozidiel



Sledovanie & Fúzia

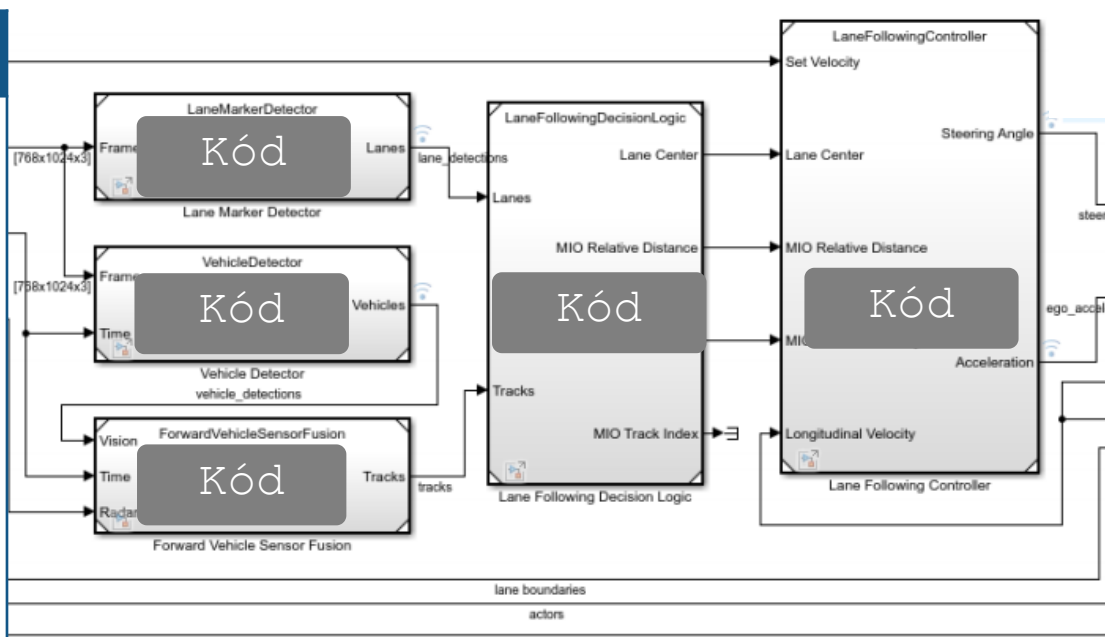


Rozhodovanie & Riadenie



Highway Lane Following Test Bench

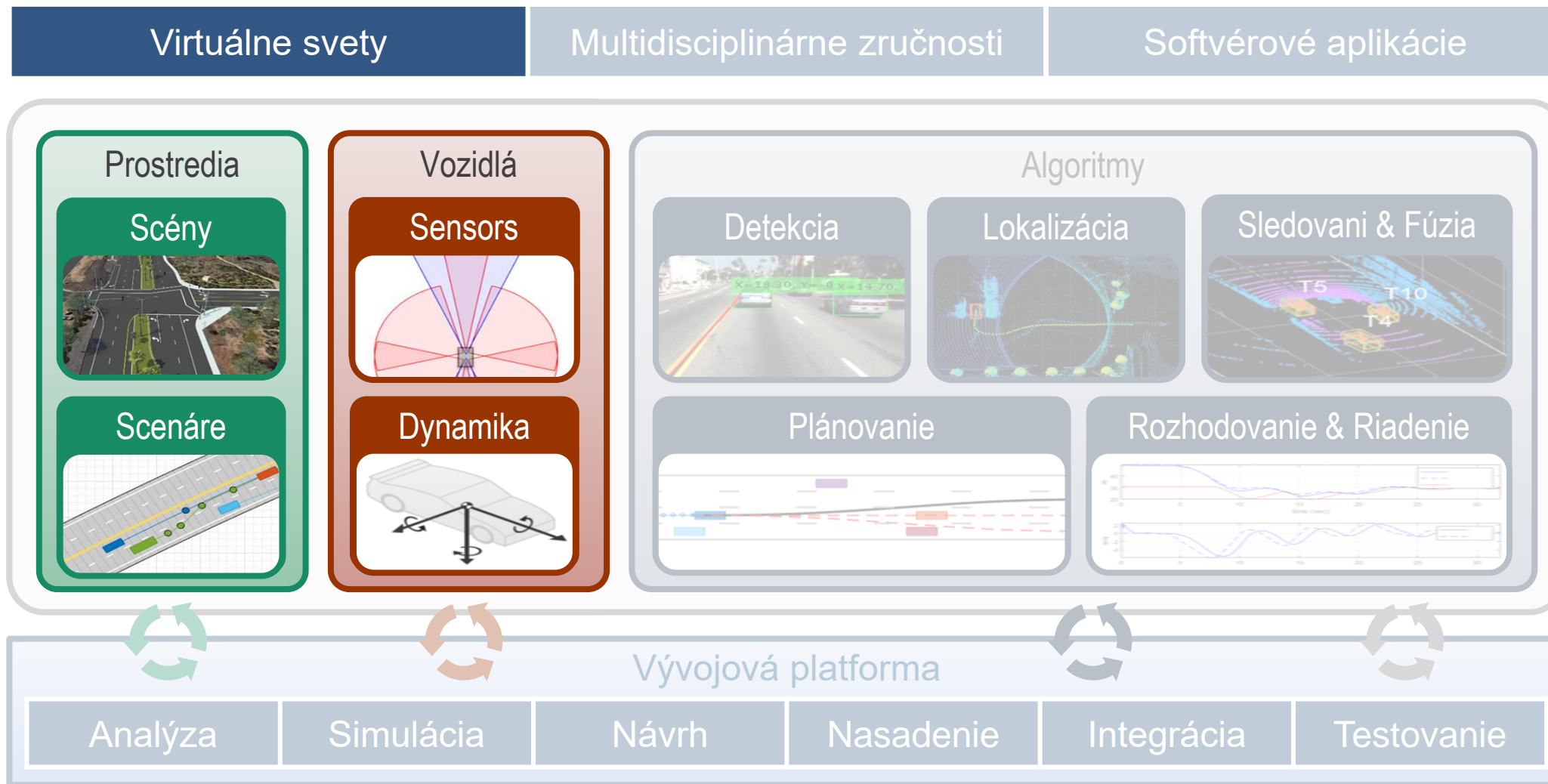
Správa testov



Reportovanie

Summary Name	Outcome
HighwayLaneFollowingMetricAssessments	10/10
Test Scenarios	10/10
scenario LFACC 01 Curve DecelTarget	✓
scenario LFACC 02 Curve AutoRetarget	✓
scenario LFACC 03 Curve StopnGo	✓
scenario LFACC 04 Curve CutInOut	✓
scenario LFACC 05 Curve CutInOut TooClo	✓
scenario LFACC 06 Straight StopandGoLea	✓
scenario LF 01 Straight RightLane	✓
scenario LF 02 Straight LeftLane	✓
scenario LF 03 Curve LeftLane	✓
scenario LF 04 Curve RightLane	✓

Vývoj virtuálnych svetov

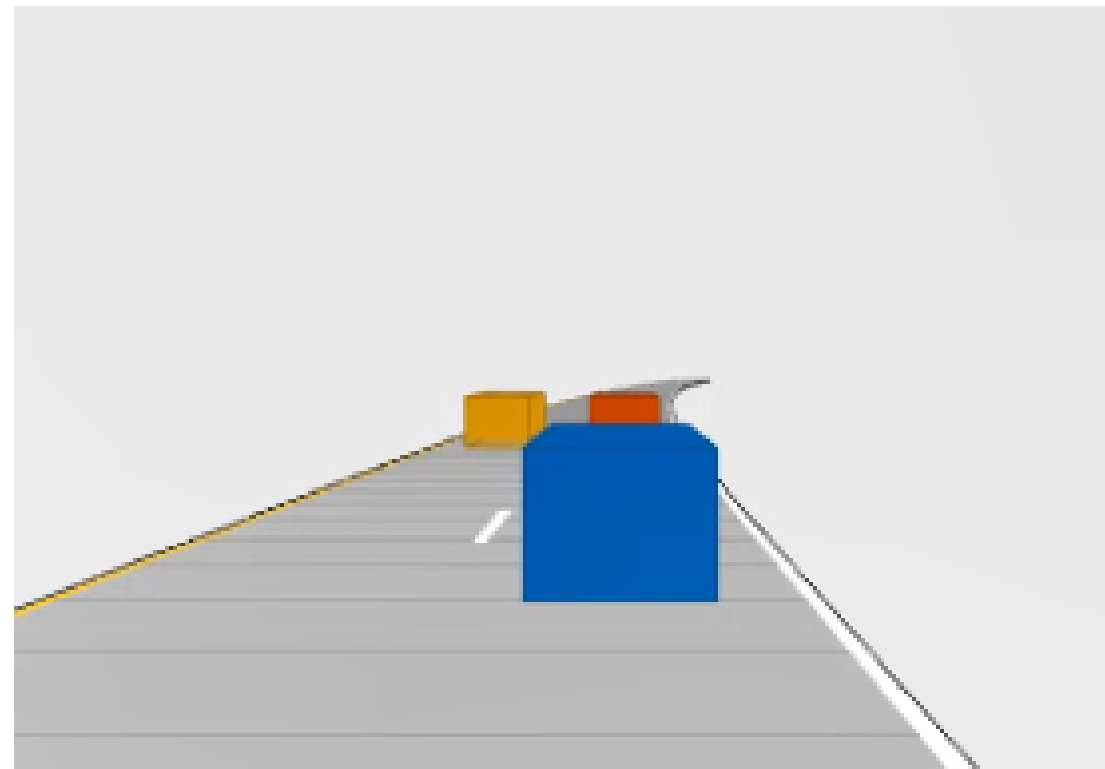


Typy virtuálních světů

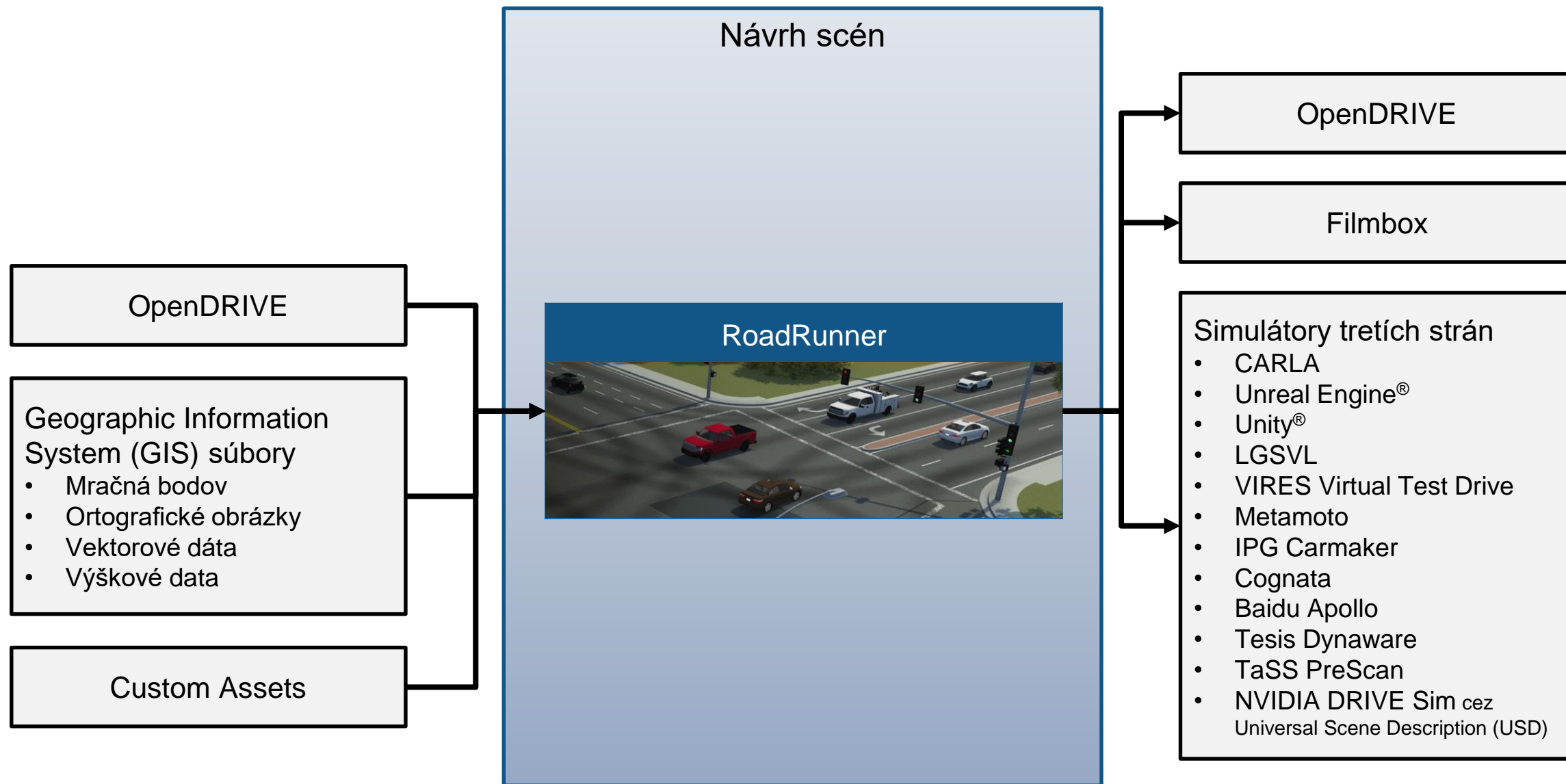
Unreal Engine



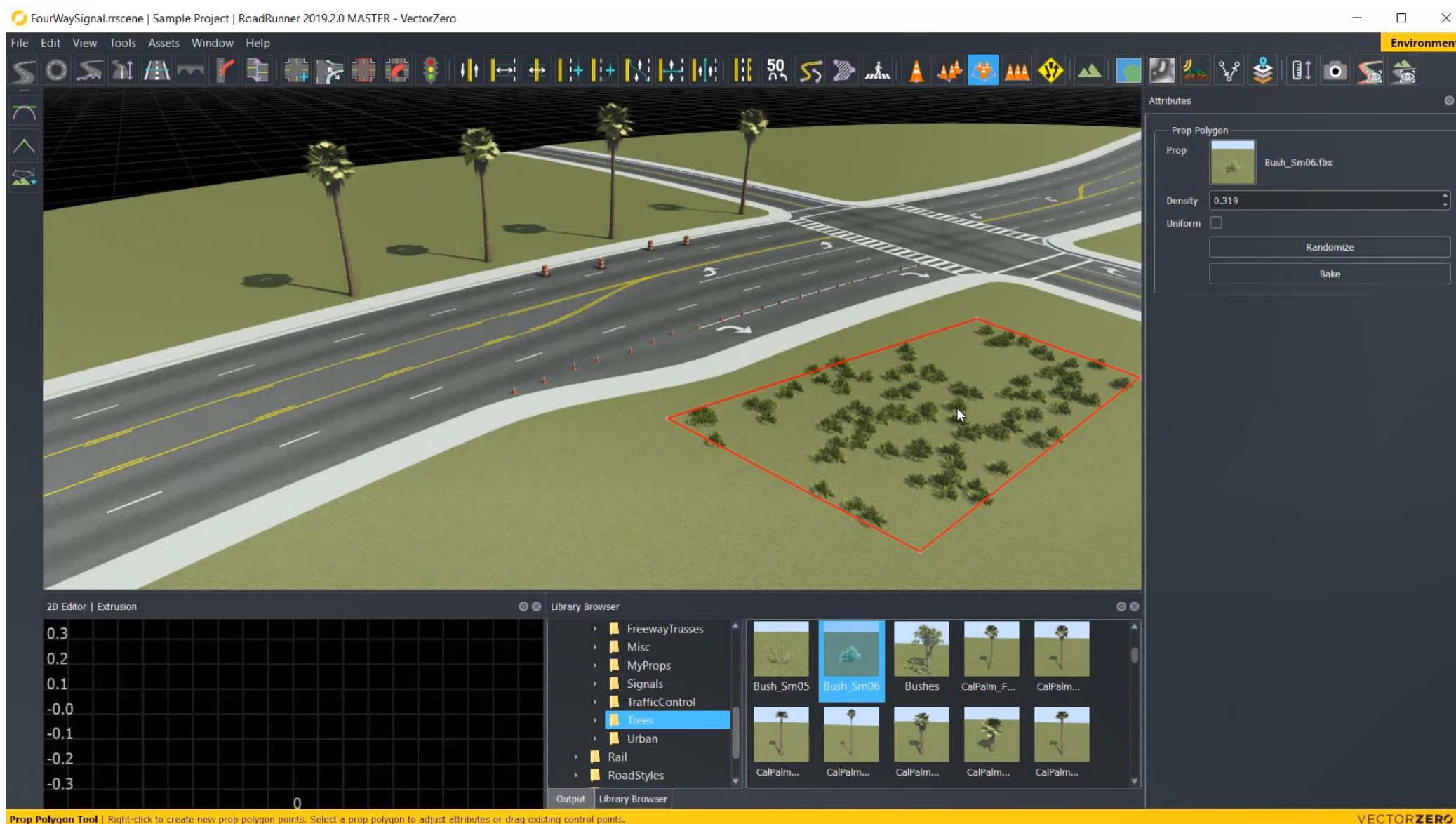
Cuboid



Tvorba 3D scén

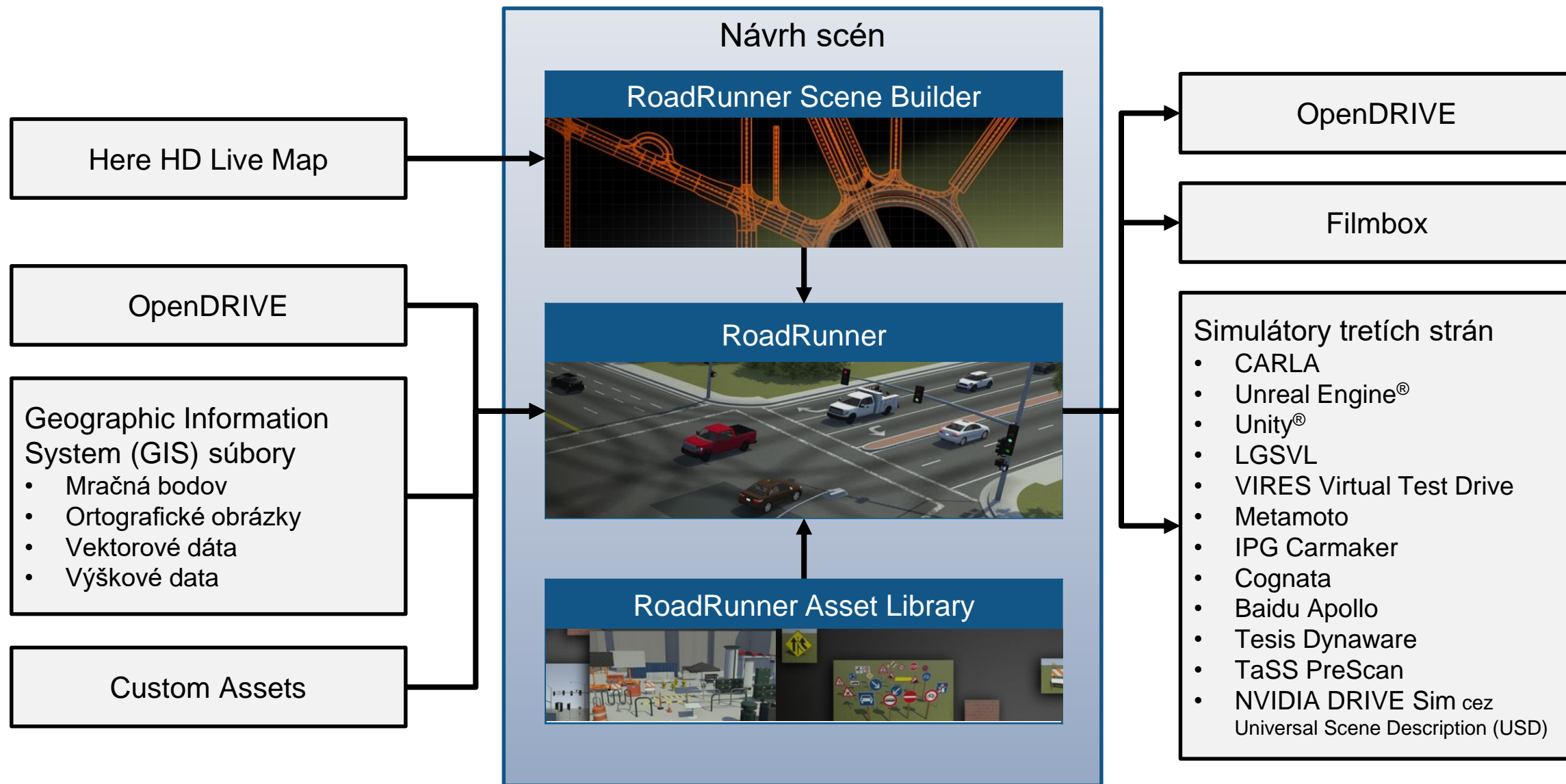


Interaktívny návrh 3D scén v RoadRunner



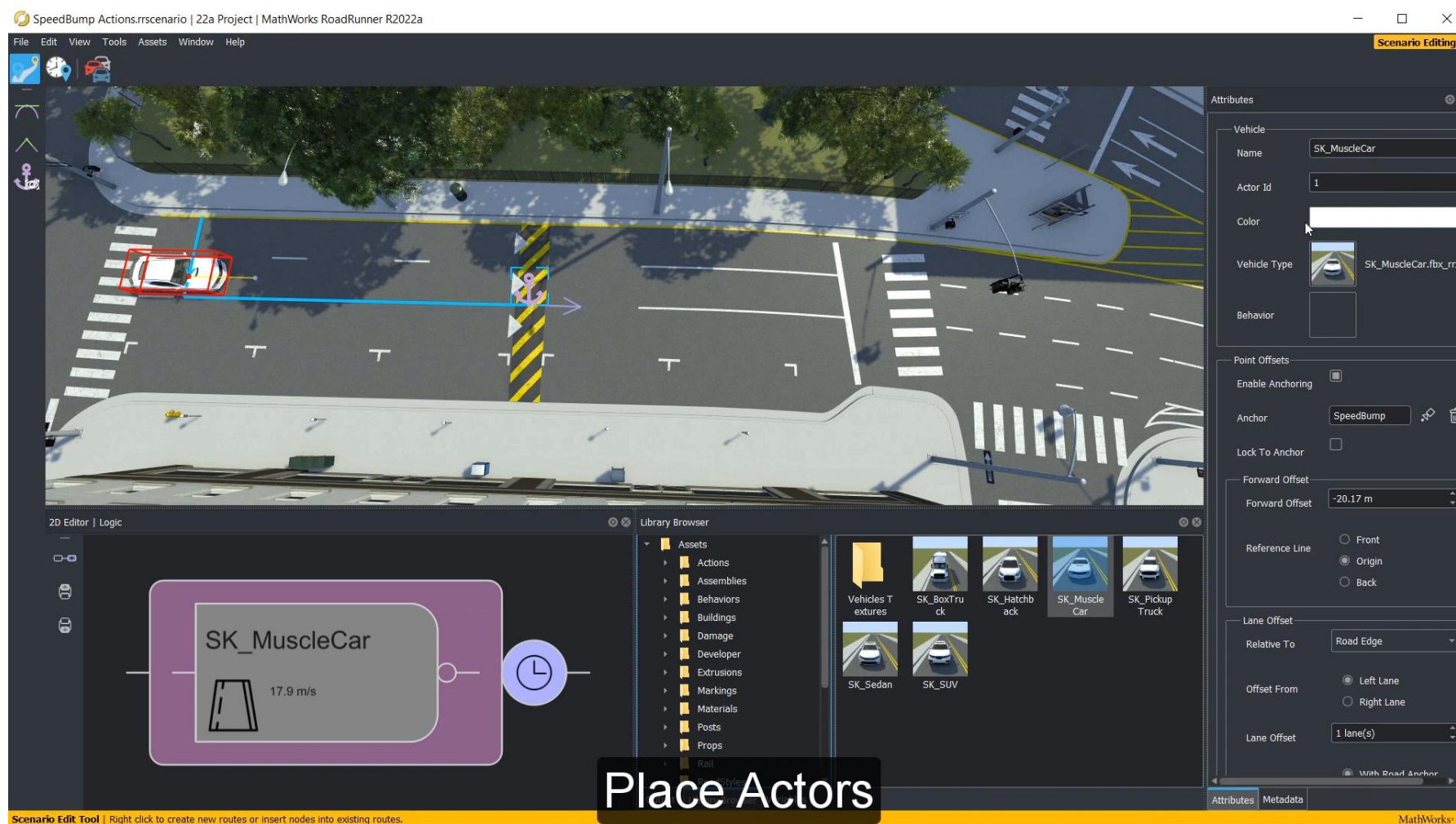
Prop Polygon Tool | Right-click to create new prop polygon points. Select a prop polygon to adjust attributes or drag existing control points.

Tvorba 3D scén



Interaktívny návrh pomocou RoadRunner Scenario

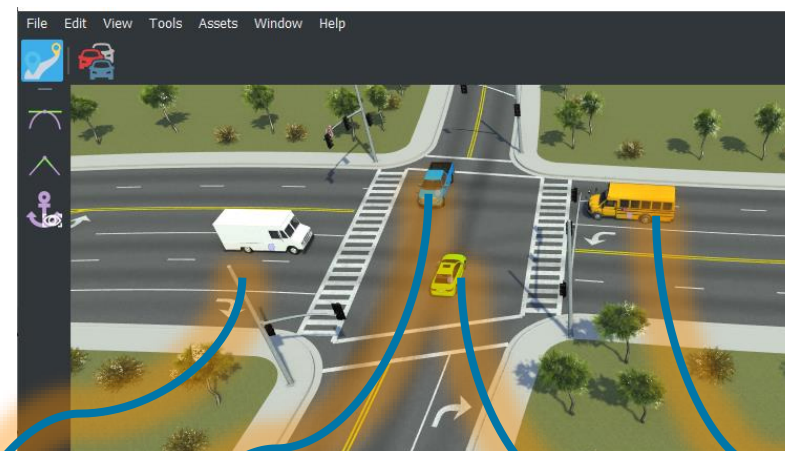
- Pridanie vozidiel
- Sledovanie cesty
- Zmena rýchlosti
- Zmena pruhu
- Laterálna zmena



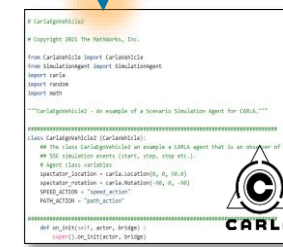
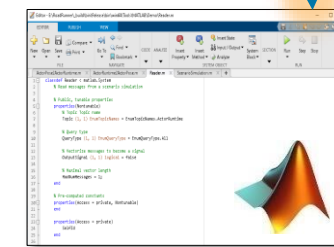
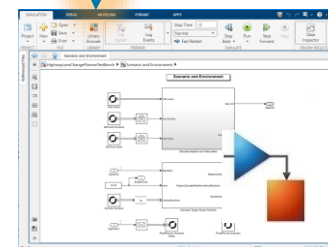
[Scenario Edit Tool](#)
RoadRunner Scenario

Simulácia scenárov vo viacerých prostrediach

- MATLAB, Simulink, CARLA
- Zmena stavu
 - Póza a rýchlosť v každom kroku
- Čítanie stavu
 - príkazy (cesta, rýchlosť, zmena pruhu, laterálna zmena)
 - Póza a rýchlosť účastníkov
 - Rozmery účastníkov
 - Mapovanie čiar

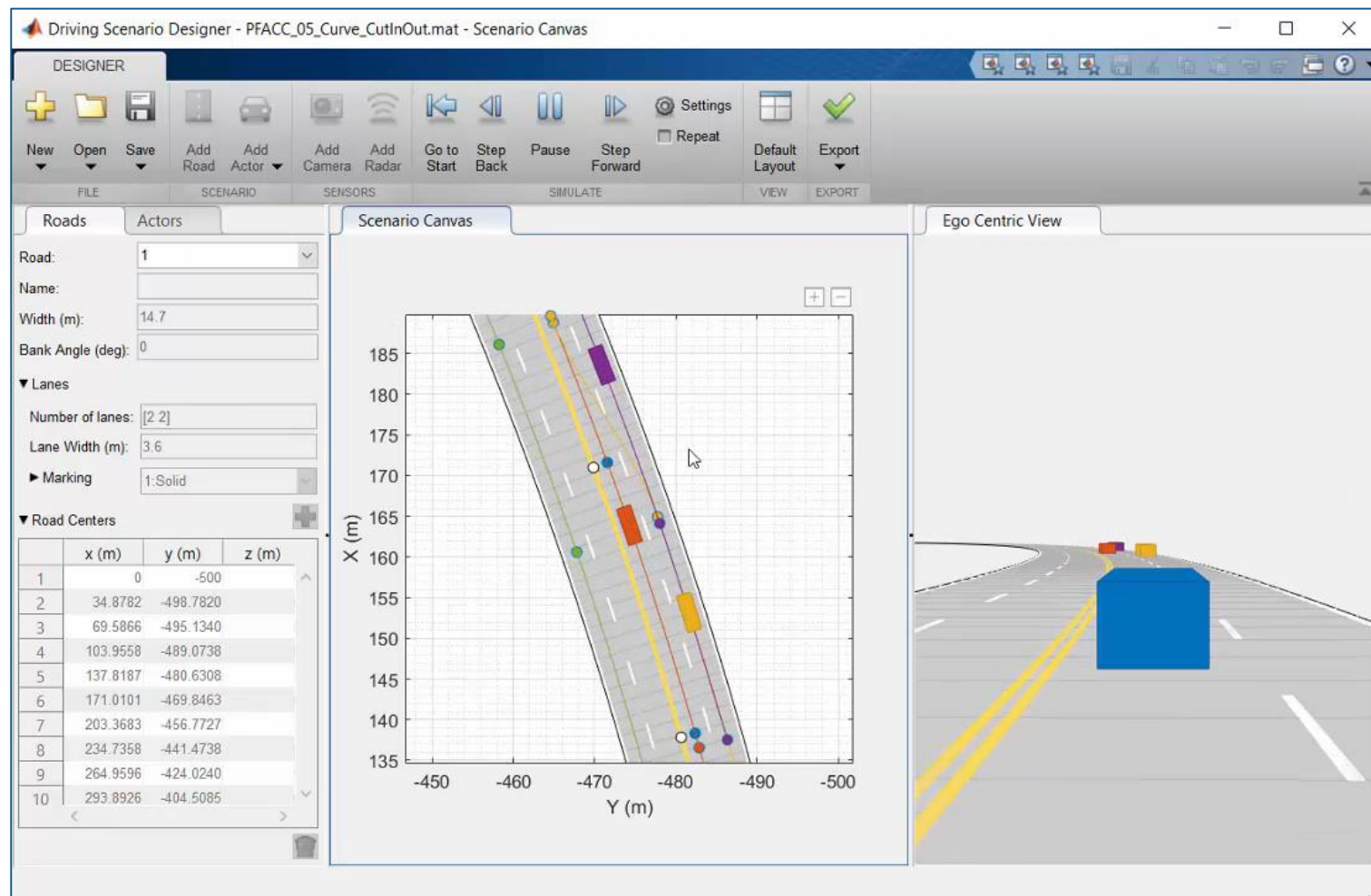


Built-in Agents



Grafický návrh scenárov pomocou Driving Scenario Designer

- Návrh scén
 - Cesty, čiary
 - Hotové (Euro NCAP)
- Import ciest
 - OpenDRIVE, HERE HD Live
- Pridávanie aktorov
 - Tvar, snímače
 - Trajektórie
- Export scenárov
 - MATLAB, Simulink model

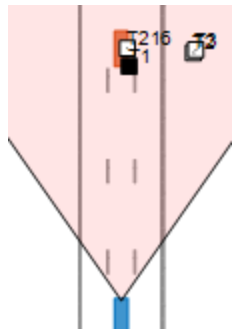


[Driving Scenario Designer](#)
Automated Driving Toolbox™

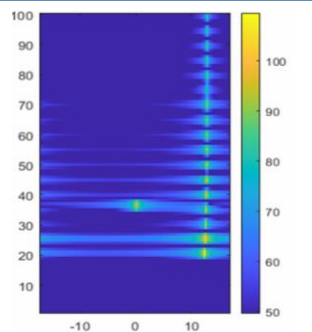
Simulácia snímačov

Cuboid snímače

Radarové sledovanie

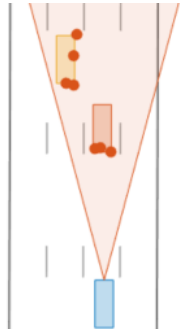


Radarové IQ signály

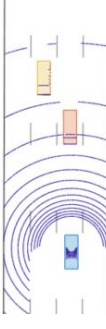


Cuboid a Unreal Engine

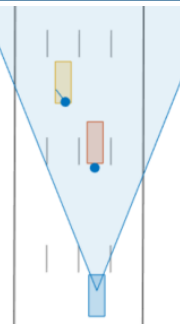
Radarové detekcie



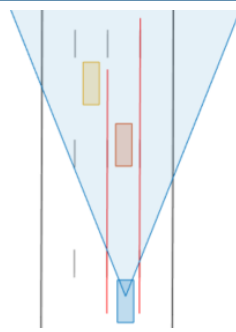
Lidar



Detekcie obrazu



Detekcie čiary

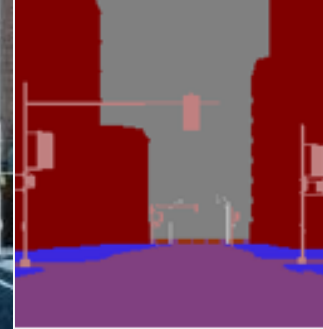


Unreal Engine Sensors

Monokulárna kamera



Sémantická segmentácia



Hĺbková



Fisheye kamera



Snímače polohy

Enkóder kolies

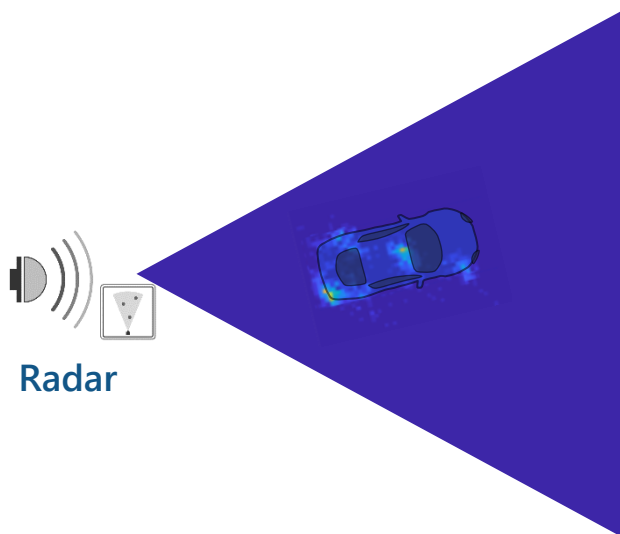
Global Positioning System (GPS)

Inertial Measurement Unit (IMU)

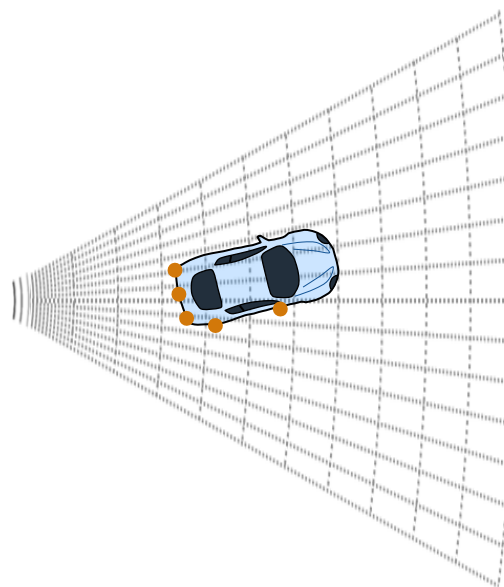
Inertial Navigation System (INS)

Simulácia radaru na rôznych úrovniach

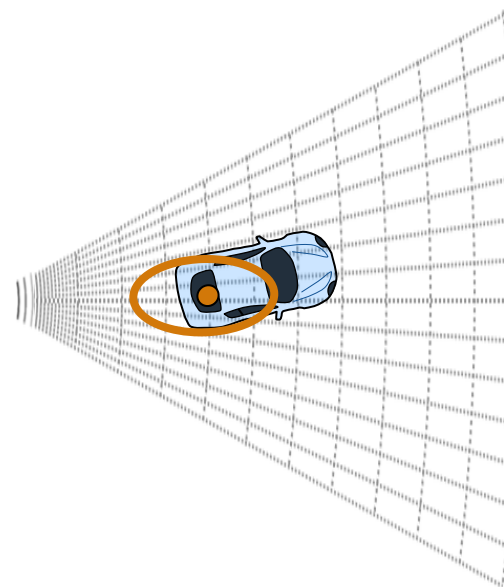
Surové IQ signály



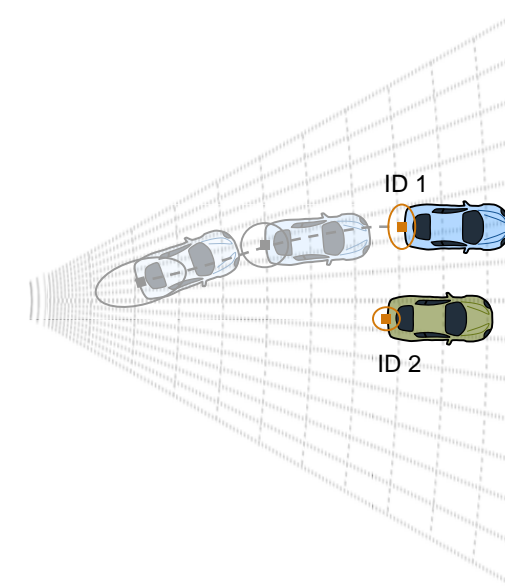
Detekcie



Kláster



Sledovania



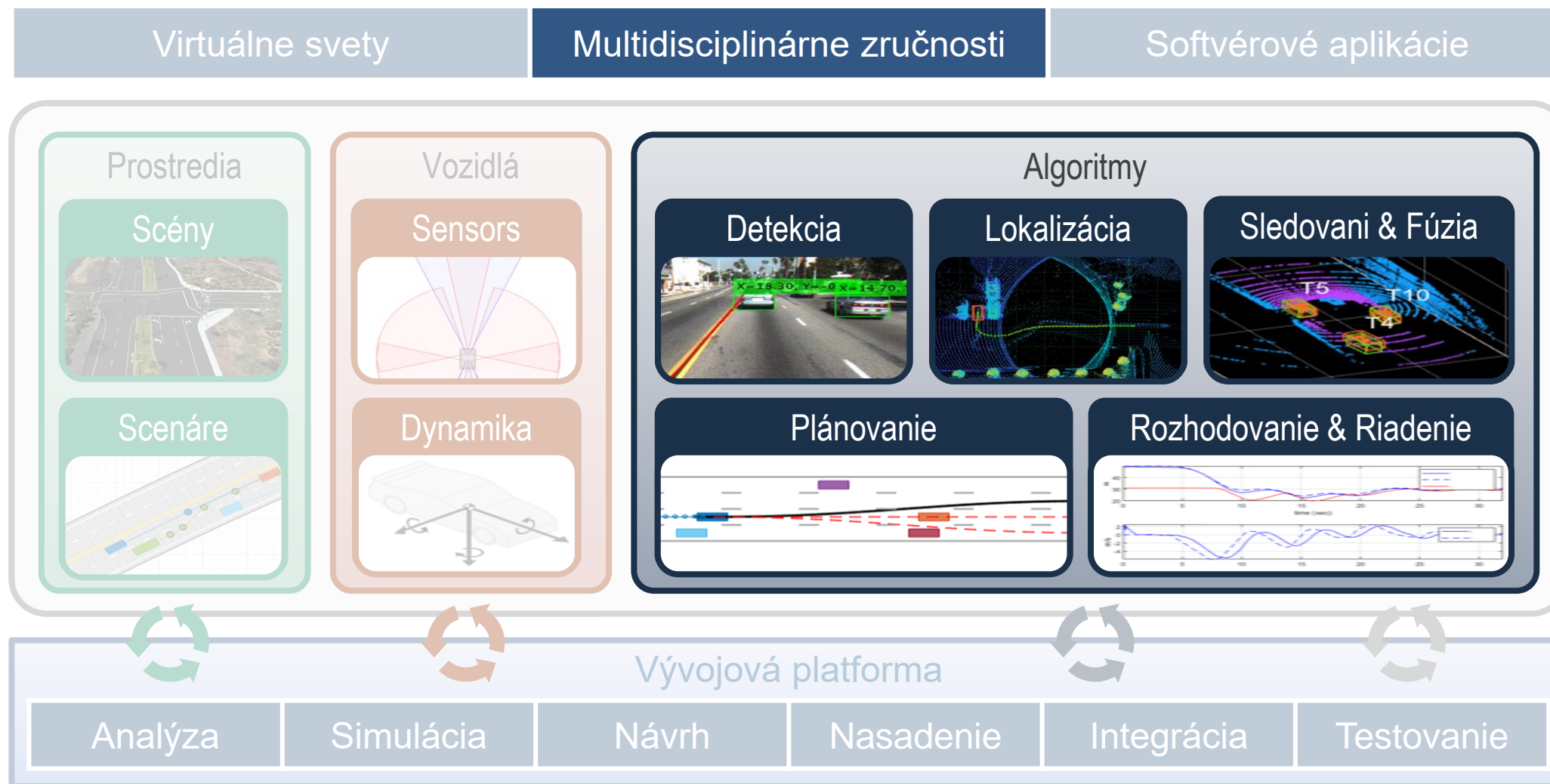
Waveform-level Model

[Radar Transceiver](#)
Radar Toolbox


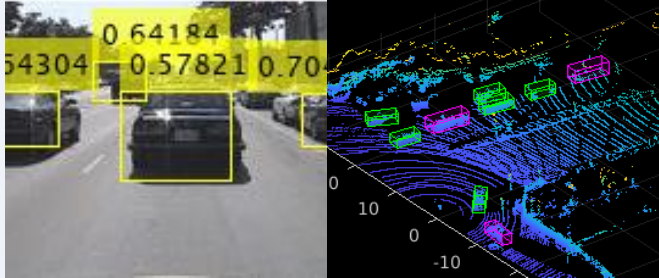
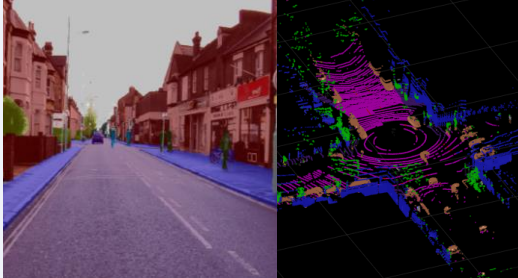
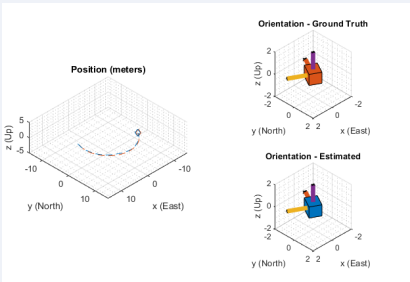
Measurement-level Model

[Driving Radar Data Generator](#)
Automated Driving Toolbox™, Radar Toolbox

Vývoj multidisciplinárnych zručností



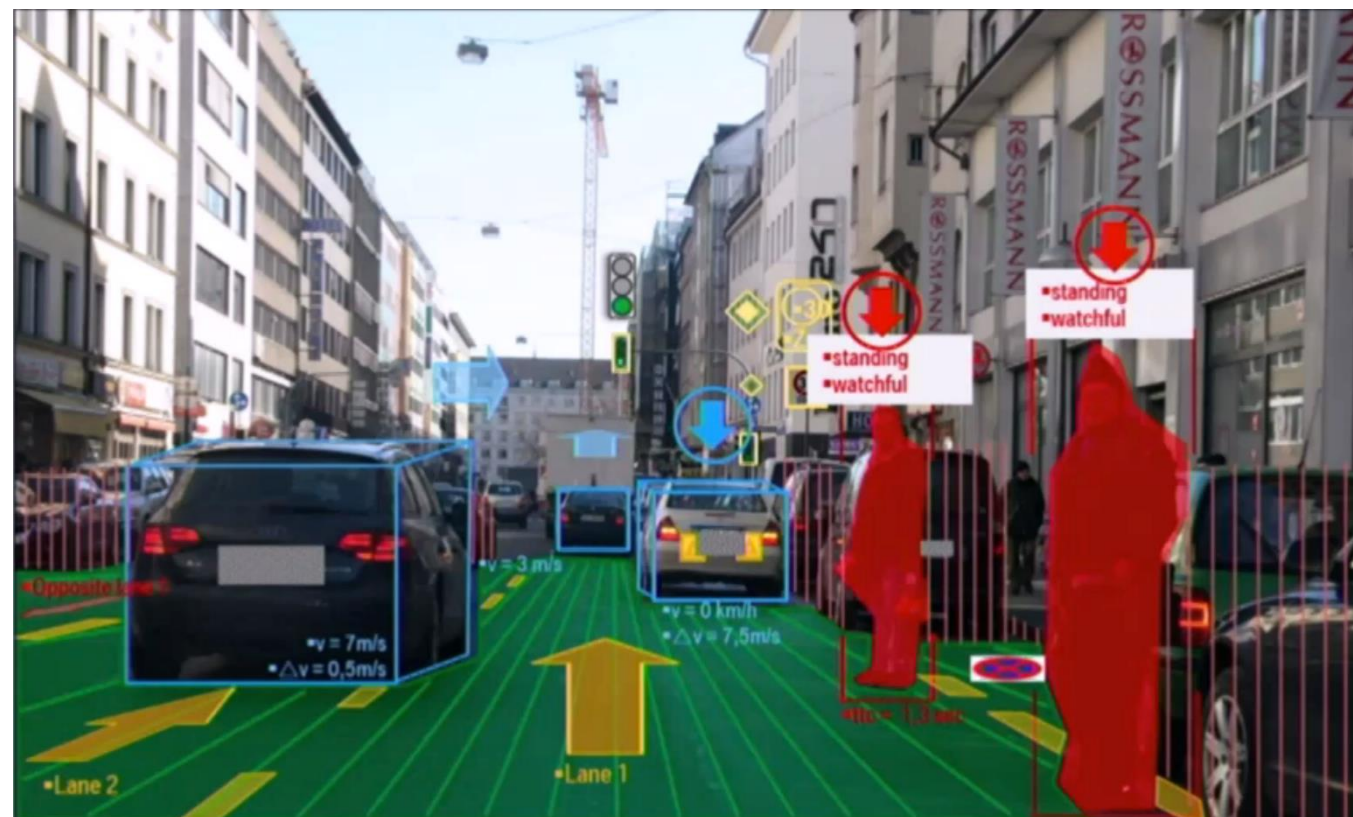
Algoritmy detekcie a lokalizácie

Čiary	Objekty	Sémantická segmentácia
		
SLAM	Mapy	Inerciálna fúzia
		

Často využívané nástroje: Automated Driving Toolbox, Computer Vision, Lidar Toolbox, Radar Toolbox, Deep Learning Toolbox, Navigation Toolbox

Komplexné vnímanie pomocou AI

- Jazdný pruh / cesta
- Čiary a značky na ceste
- Semafóry
- Iní účastníci
 - Vozidlá
 - Chodci
 - Bicyklisti
- Úlohy
 - Detekcia a predikcia správania
- Tradičné algoritmy nemusia fungovať pre viaceré scenáre



Úlohy vnímania pre AI

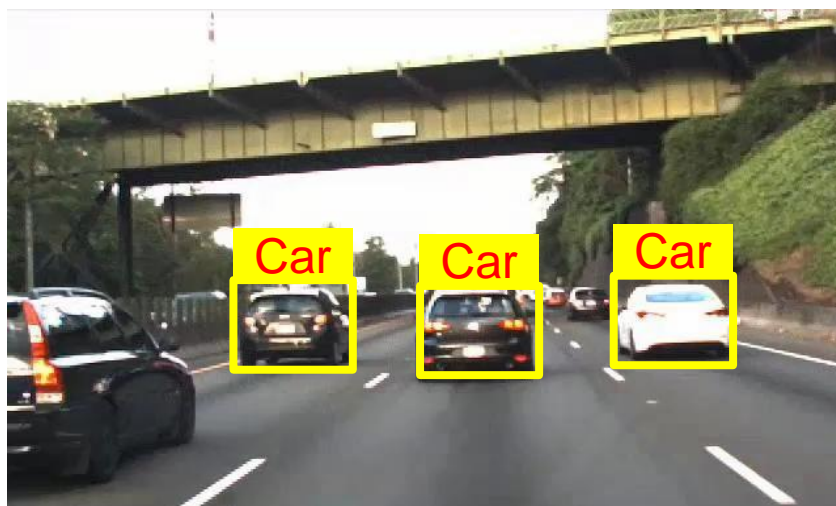
Klasifikácia



Regresia



Detekcia

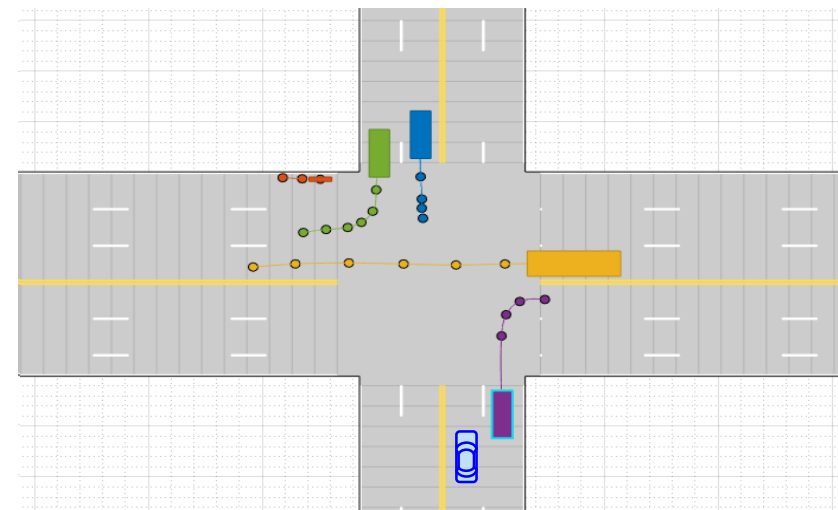
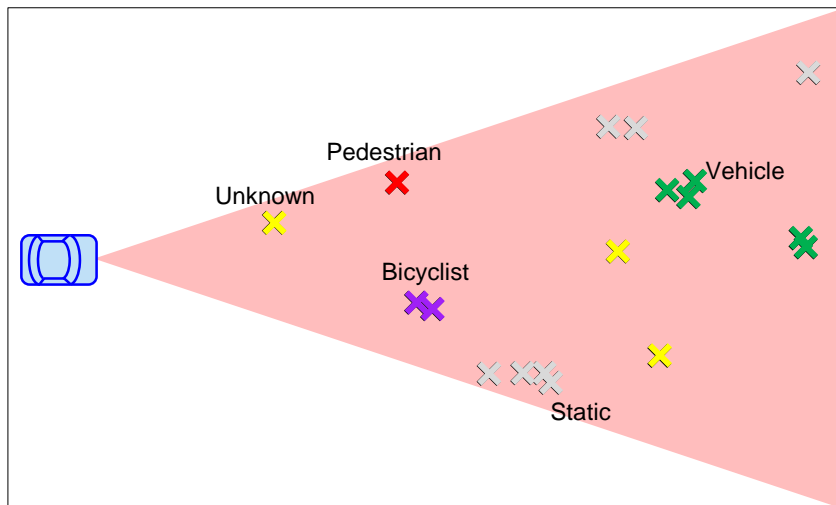


Sémantická segmentácia



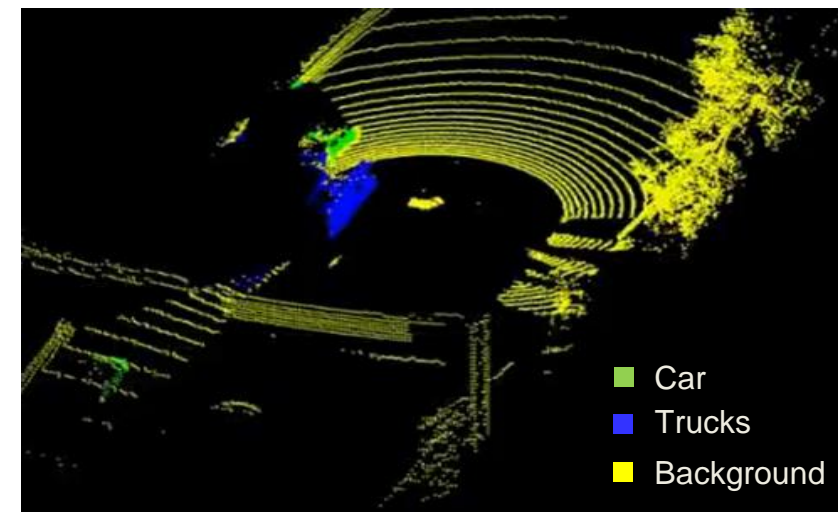
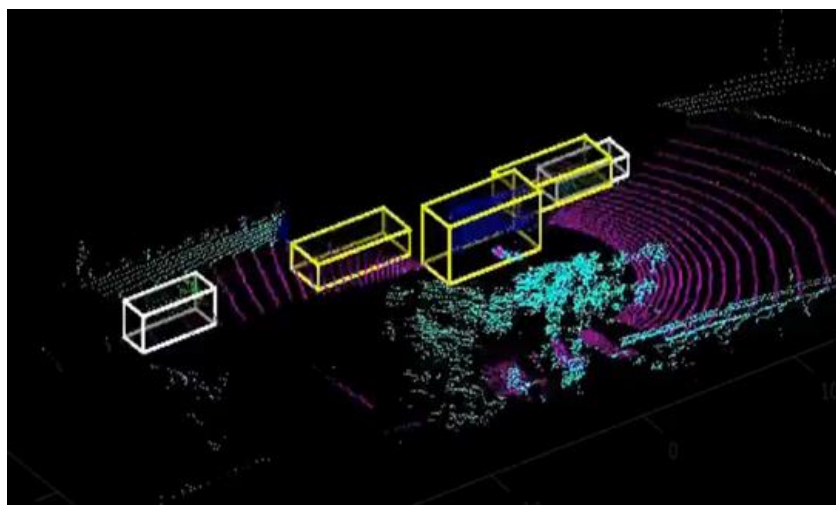
Úlohy vnímania pre AI

Klasifikácia radaru



Predikcia cesty (Regresia)

Detekcie lidaru

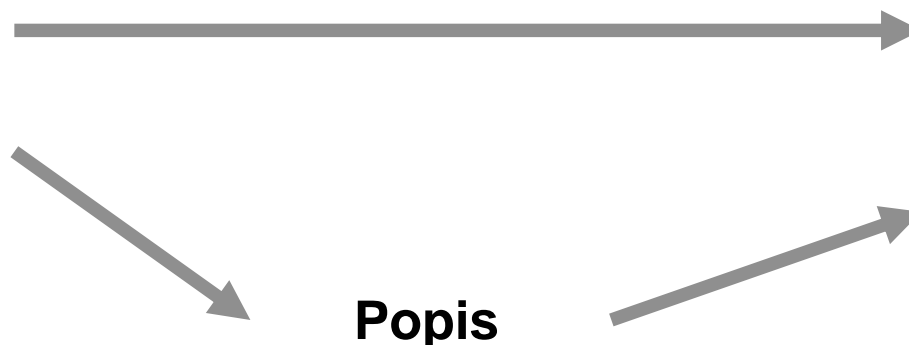


Sémantická segmentácia lidaru

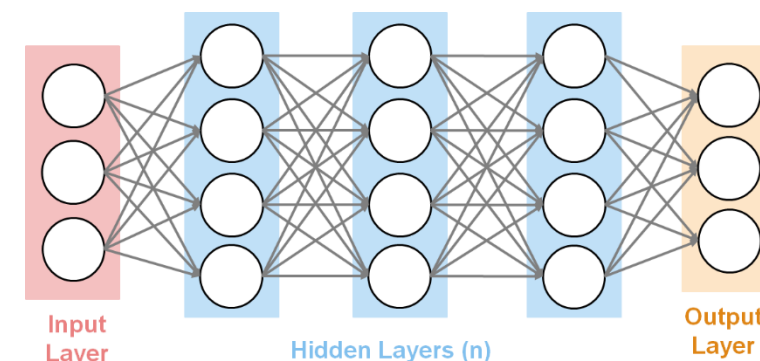
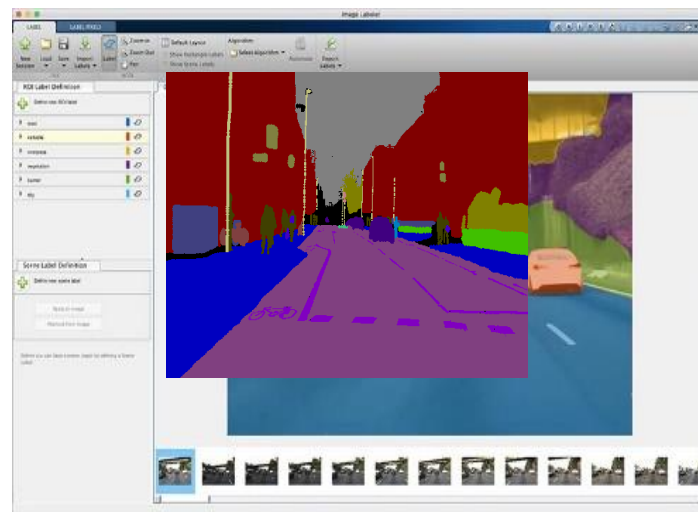
Pracovný postup



Dáta



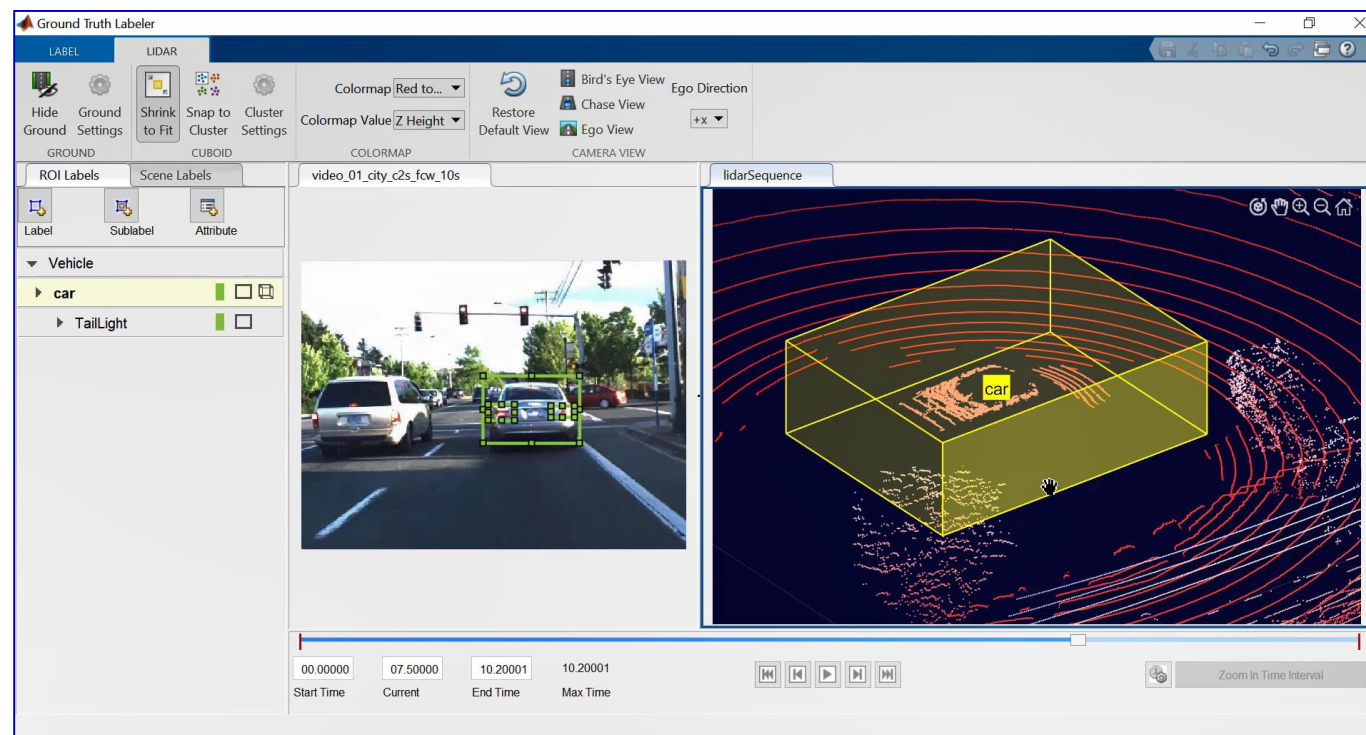
Popis



**Trénovanie
AI modelu**

Popis dát pomocou Ground Truth Labeler App

- Interaktívny popis dát
 - Rectangular ROI
 - Polygon ROI
 - Polyline ROI
 - Pixel ROI (sémantick segment.)
 - Cuboid (lidar)
- Vstavané a vlastné algoritmy
- Vizualizácie
- Export popisov



[Ground Truth Labeler](#)

Automated Driving Toolbox™

Návrh a tréovanie modelov strojového učenia

Classification Learner - Scatter Plot

CLASSIFICATION LEARNER VIEW

+ New Session FILE
 Feature Selection FEATURES
 PCA
 Misclassification Costs OPTIONS

Data Browser

History

1 Tree
Last change: Disabled PCA

DECISION TREES
 Fine Tree Medium Tree Coarse Tree All Trees Optimizable Tree

DISCRIMINANT ANALYSIS
 Linear Discriminant Quadratic Discriminant All Discrimina... Optimizable Discriminant

LOGISTIC REGRESSION CLASSIFIERS
 Logistic Regression

NAIVE BAYES CLASSIFIERS
 Gaussian Naive Bayes Kernel Naive Bayes All Naive Bayes Optimizable Naive Bayes

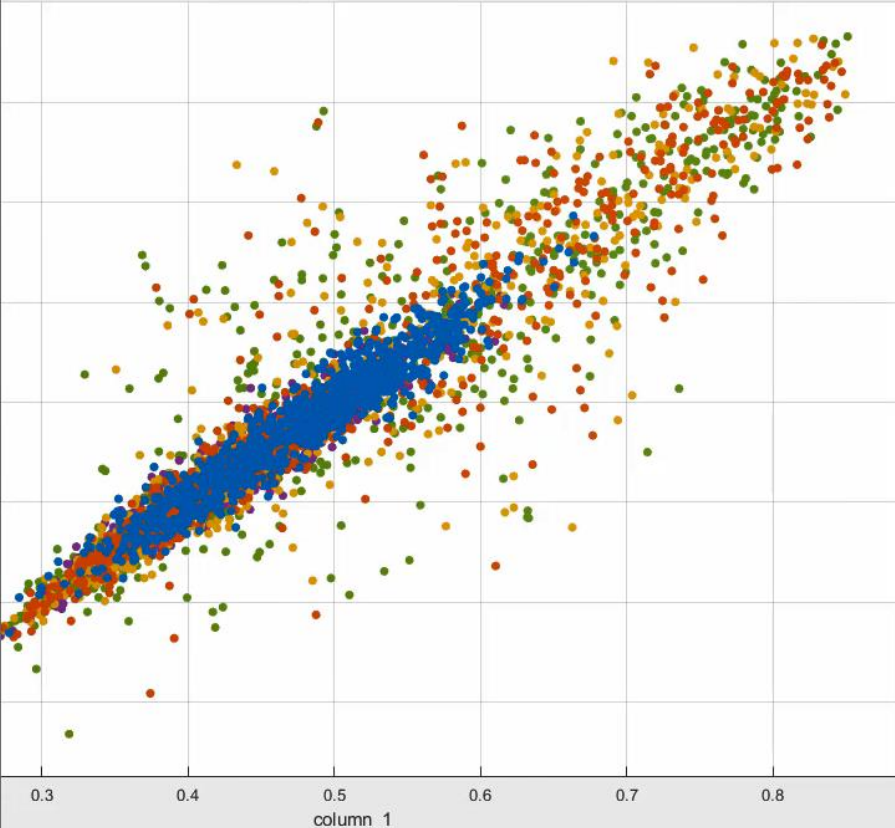
SUPPORT VECTOR MACHINES
 Linear SVM Quadratic SVM Cubic SVM Fine Gaussian ... Medium Gaussian ... Coarse Gaussian ...
 All SVMs Optimizable SVM

NEAREST NEIGHBOR CLASSIFIERS
 Fine KNN Medium KNN Coarse KNN Cosine KNN Cubic KNN Weighted KNN
 All KNNs Optimizable KNN

ENSEMBLE CLASSIFIERS
 Boosted Trees Bagged Trees Subspace Discriminant Subspace KNN RUSBoosted Trees All Ensembles

Current Model
 Model 1: Draft
Model Type
 Preset: Fine Tree
 Maximum number of splits: 100
 Split criterion: Gini's diversity index
 Surrogate decision splits: Off
Optimizer Options
 Hyperparameter options disabled
Feature Selection
 All features used in the model, before PCA

Scatter Plot Confusion Matrix ROC Curve Parallel Coordinates Plot Min Classification Error Plot Export Plot to Figure Generate Function Export Model

Original data set: d


Plot
 Data
 Model predictions

Predictors
 X: column_1
 Y: column_2

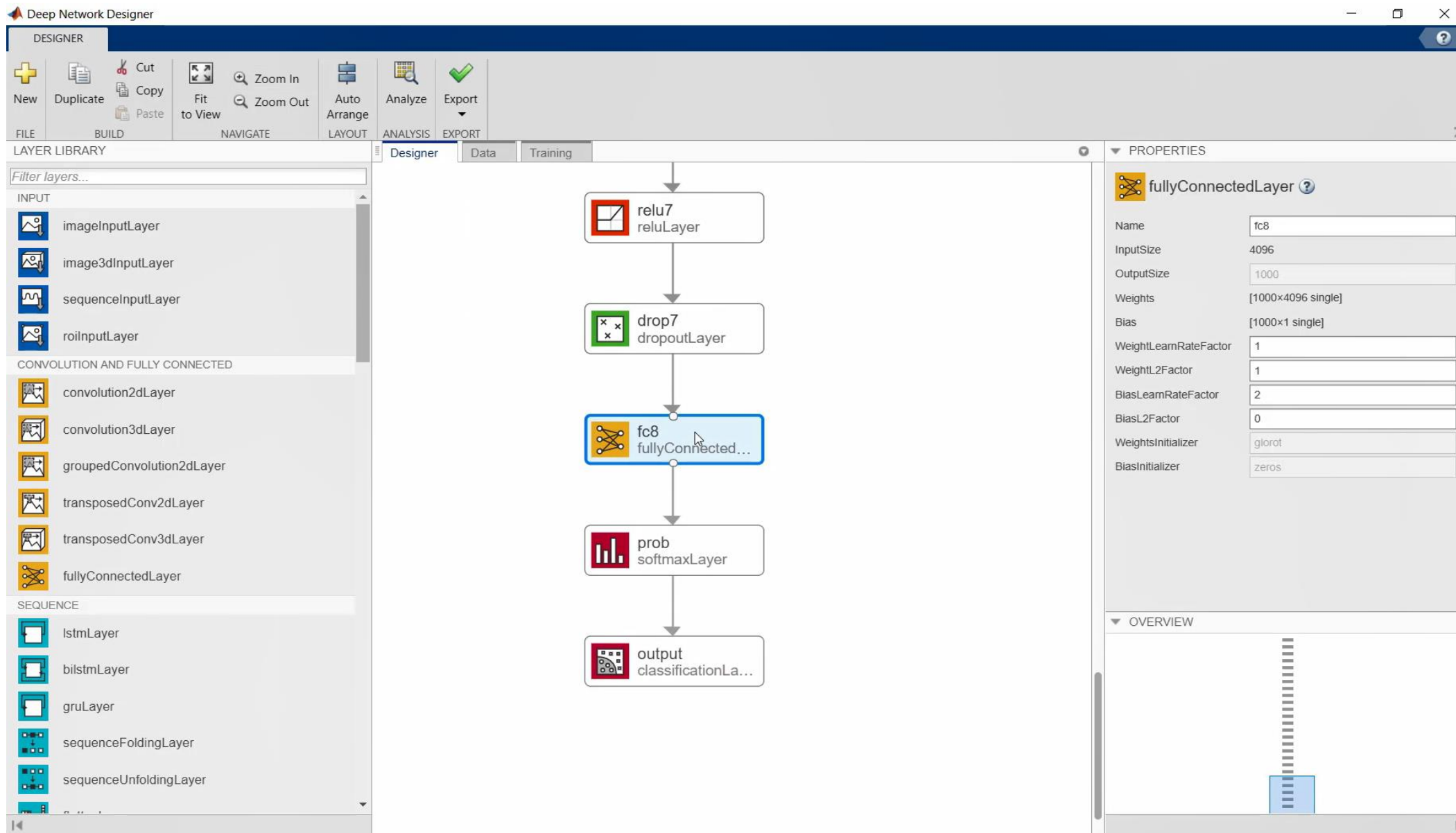
Classes Move to Front

Show	Order
<input checked="" type="checkbox"/>	ped
<input checked="" type="checkbox"/>	bic
<input checked="" type="checkbox"/>	ped+bic
<input checked="" type="checkbox"/>	ped+ped
<input checked="" type="checkbox"/>	bic+bic

How to investigate features

Data set: d Observations: 5000 Size: 31 Validation: 5-fold Cross-Validation

Návrh a tréovanie konvolučných neurónových sietí



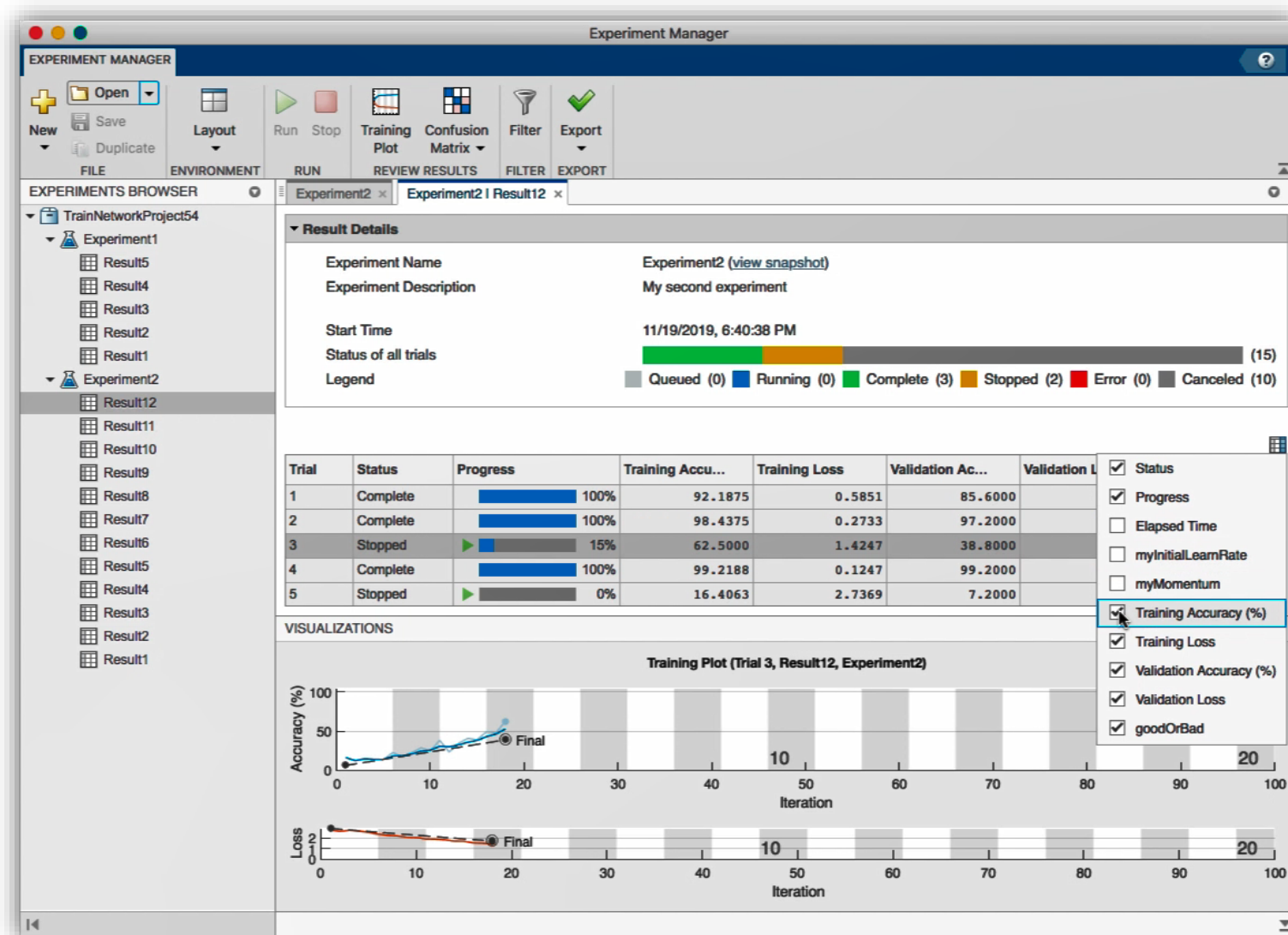
The screenshot displays the Deep Network Designer interface. The central workspace shows a vertical flow of layers: **relu7 reluLayer**, **drop7 dropoutLayer**, **fc8 fullyConnected...** (highlighted with a blue border), **prob softmaxLayer**, and **output classificationLa...**. The left sidebar contains a **LAYER LIBRARY** with categories: **INPUT** (imageInputLayer, image3dInputLayer, sequenceInputLayer, roiInputLayer), **CONVOLUTION AND FULLY CONNECTED** (convolution2dLayer, convolution3dLayer, groupedConvolution2dLayer, transposedConv2dLayer, transposedConv3dLayer, fullyConnectedLayer), and **SEQUENCE** (lstmLayer, bilstmLayer, gruLayer, sequenceFoldingLayer, sequenceUnfoldingLayer). The right sidebar shows the **PROPERTIES** for the selected **fullyConnectedLayer** (fc8):

Name	fc8
InputSize	4096
OutputSize	1000
Weights	[1000x4096 single]
Bias	[1000x1 single]
WeightLearnRateFactor	1
WeightL2Factor	1
BiasLearnRateFactor	2
BiasL2Factor	0
WeightsInitializer	glorot
BiasInitializer	zeros

The **OVERVIEW** section at the bottom right shows a vertical bar chart representing the layer structure.

Hľadanie najlepšieho modelu

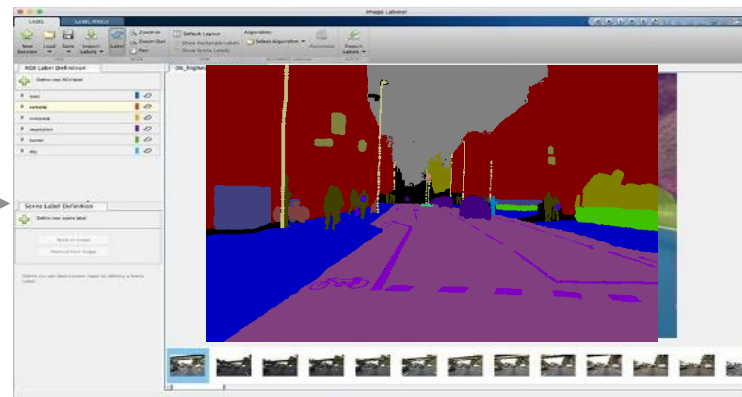
- Hľadanie parametrov
 - Zoznam hodnôt
 - Bayesian optimization
- Porovnanie
 - Architektúr
 - Dátových setov
- Vlastná metrika vyhodnocovania modelov
- Vizualizácie
 - Graf tréovania
 - Confusion matrix



Urýchlenie popisovania



Dáta



Popisok

**Natrénovaný
AI model**

Trénovanie

**Manuálne
overenie**



**Návrh
popiskov**

Generovanie obrázkov rôzneho času dňa



Detaily trénovania

- 370 obrázkov
- CAMVID dataset
 - Obrázky dňa: 263
 - Obrázky súmraku: 107
- Na učenie sa nepoužívajú časové informácie



Unsupervised Day-To-Dusk Image Translation Using UNIT

Perform domain translation between images acquired during daytime and dusk conditions using an unsupervised image-to-image

[Link to Example](#)

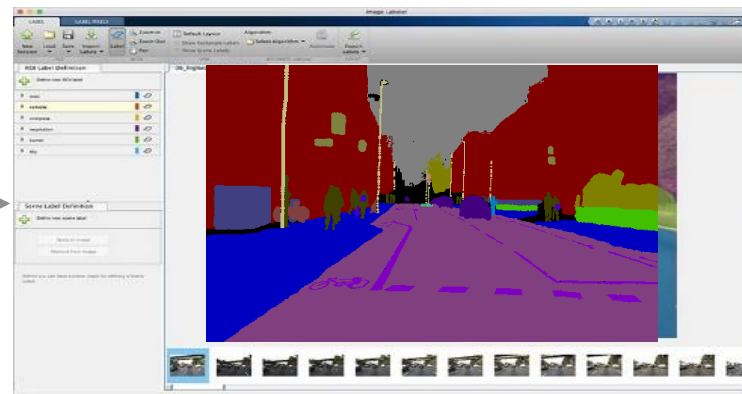


Generovanie popísaných dát zo simulácie

Tradičný postup DL



Dáta



Popis

Trénovanie

**Natrénovaný
AI model**

Simulation Environment

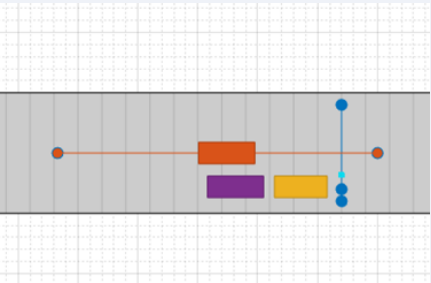
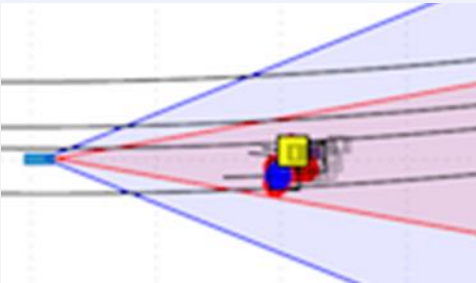
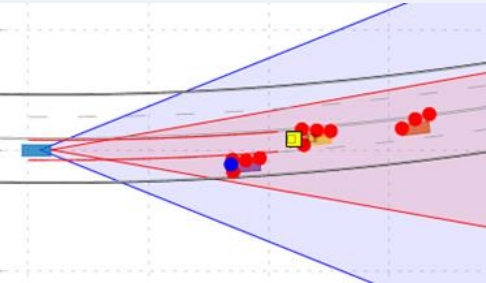
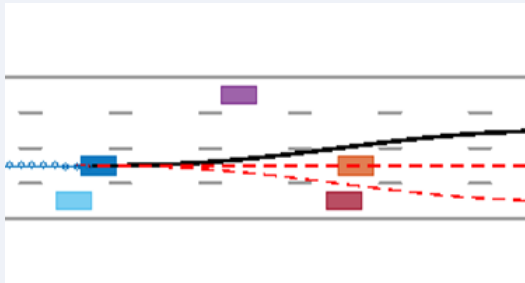
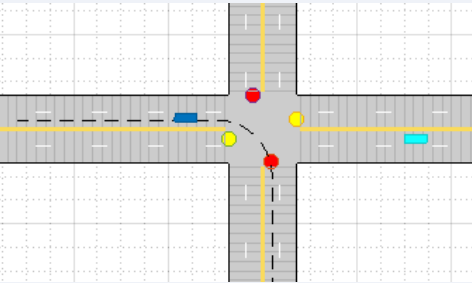
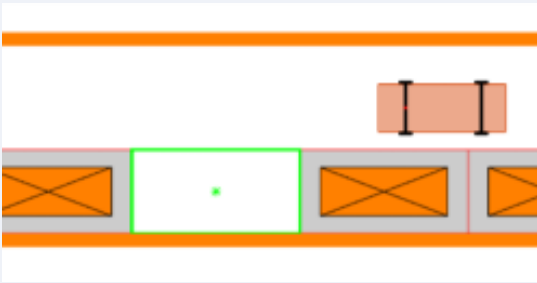
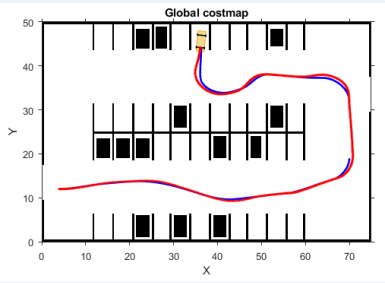
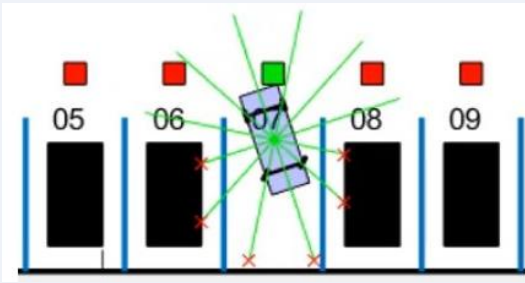


Simulácia

Automatický popis

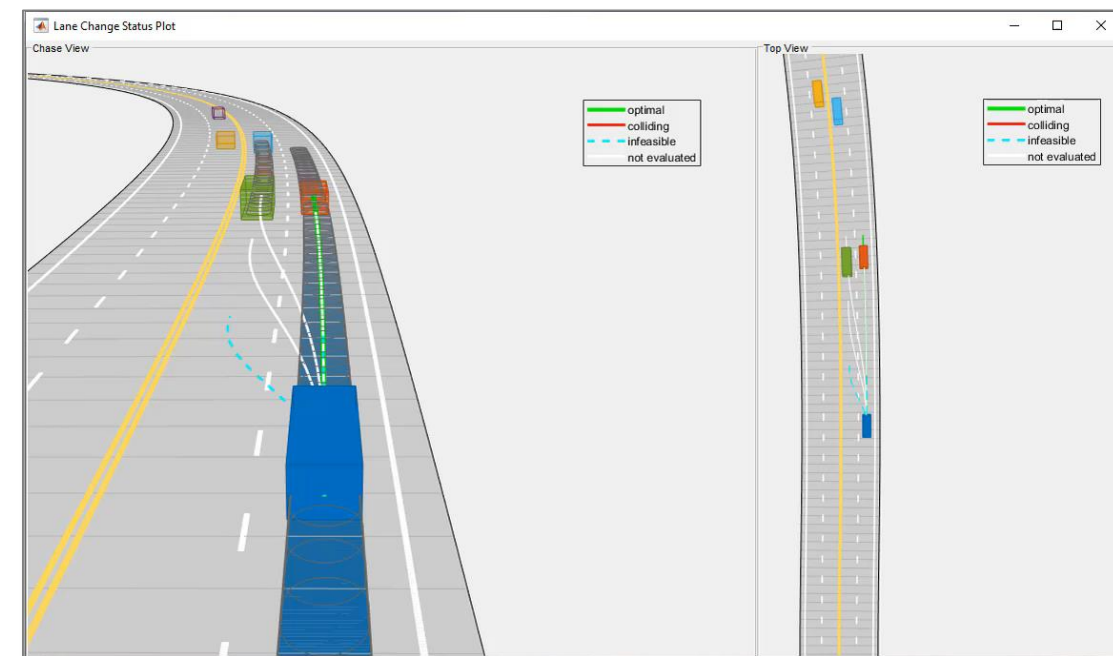
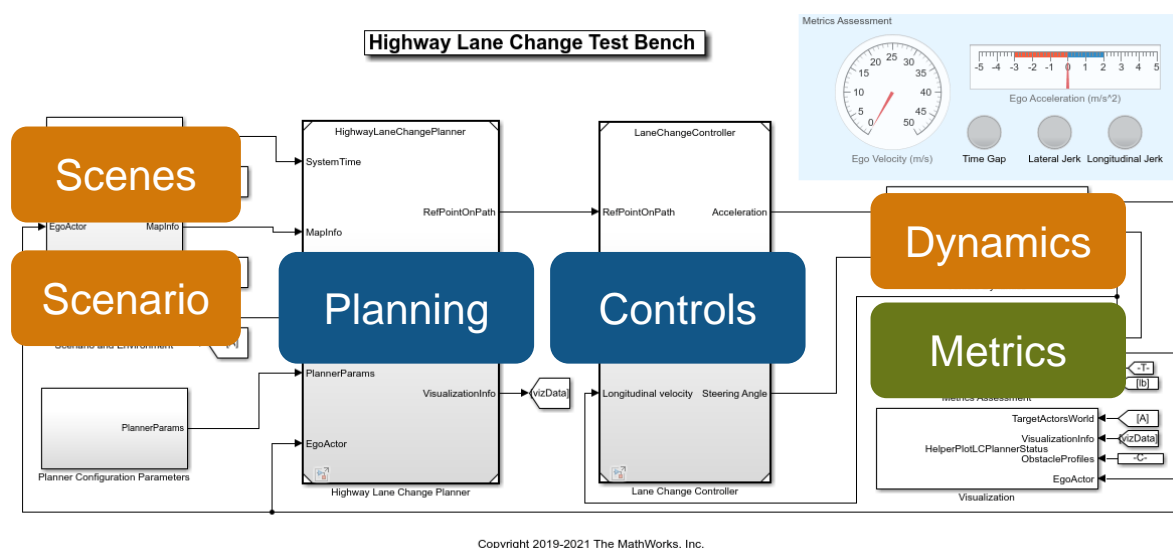
Trénovanie

Návrh algoritmov plánovania a riadenia

<p>Núdzové brzdenie</p> 	<p>Adaptive Cruise Control</p> 	<p>Sledovanie čiar</p> 	<p>Zmena pruhu</p> 
<p>Svetelná signalizácia</p> 	<p>Paralelné parkovanie</p> 	<p>Parkovisko</p> 	<p>Reinforcement Learning</p> 

Často využívané nástroje: Automated Driving Toolbox, Model Predictive Control Toolbox, Stateflow, Navigation Toolbox, Reinforcement Learning, Robotics System Toolbox

Návrh plánovania a riadenia zmeny jazdného pruhu

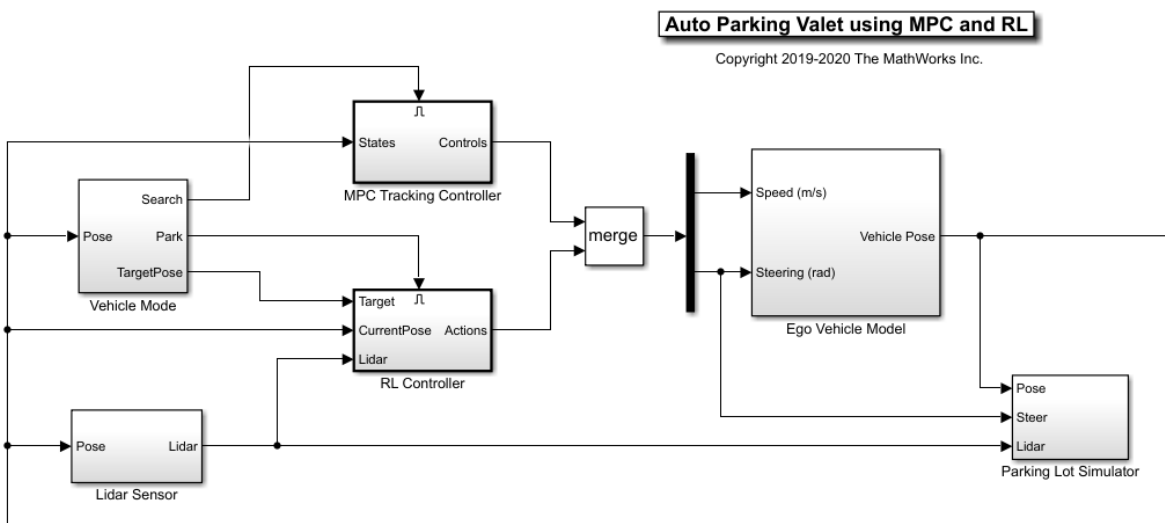


- Generovanie optimálnej trajektórie v priestore Frenet
- Implementácia manévra v závislosti na okolí
- Kontrola kolízií

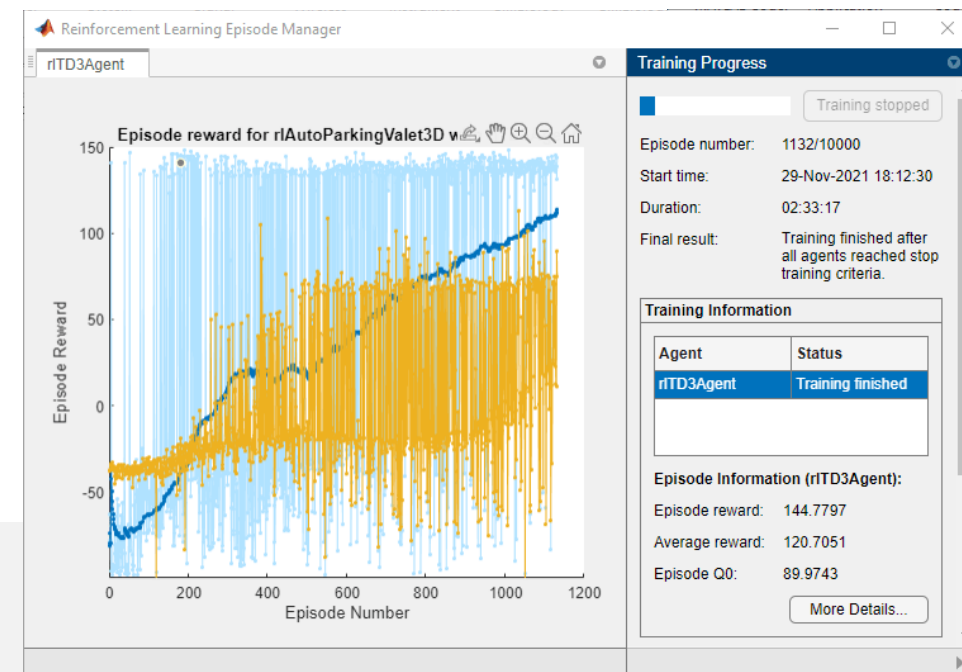
Highway Lane Change

Navigation Toolbox™, Model Predictive Control Toolbox™, Automated Driving Toolbox™

Parkovanie vozidla



- Hybridný regulátor na sledovanie trajektórie a parkovanie
- Model Predictive Control – sledovanie referenčnej trajektórie
- Reinforcement Learning – parkovací menéver

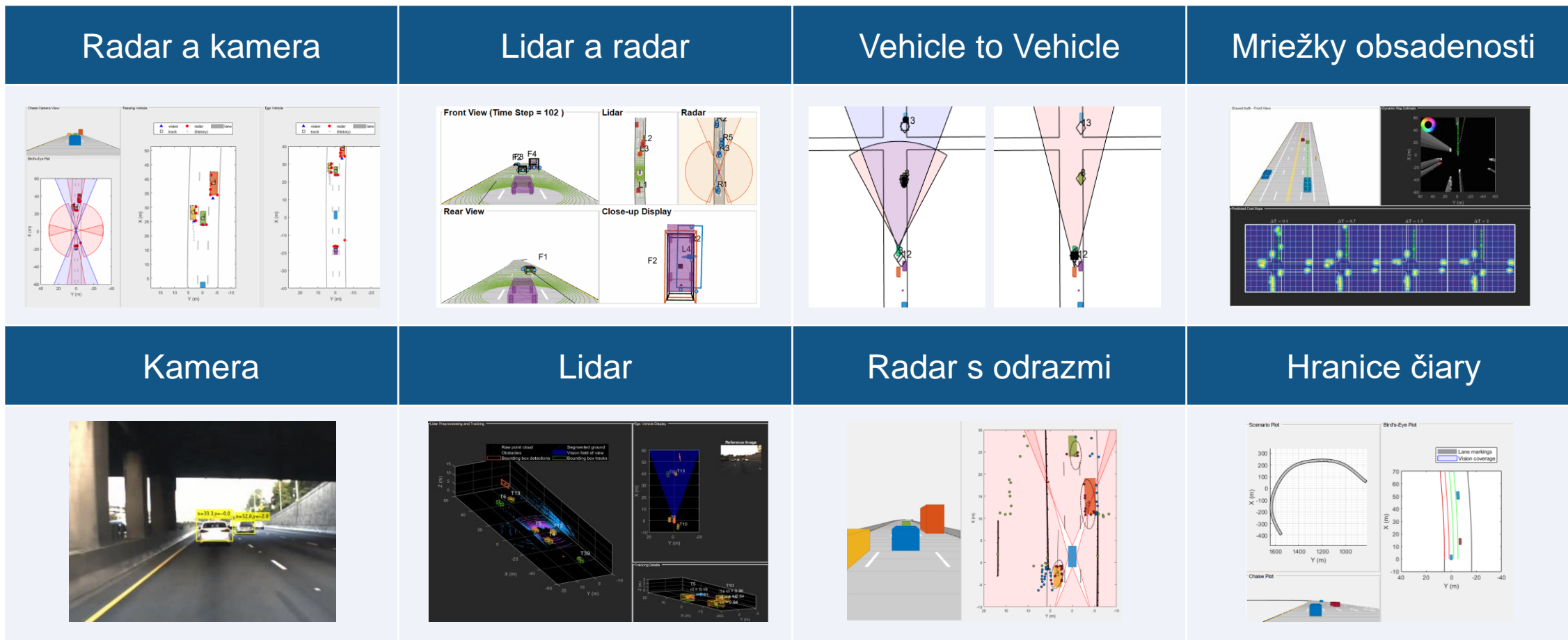


[Train PPO Agent for Automatic Parking Valet](#)

[Automatic Parking Valet with Unreal Engine Simulation](#)

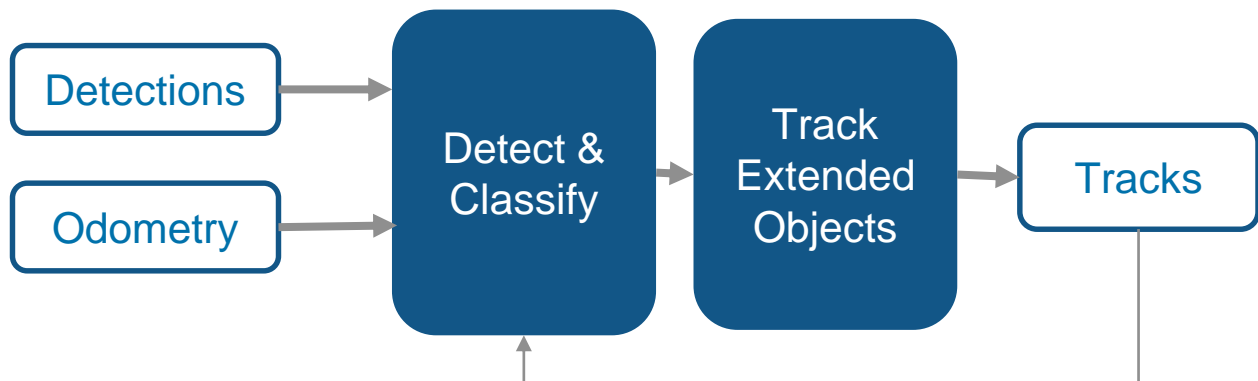
Reinforcement Learning Toolbox™, Model Predictive Control Toolbox™

Algoritmy sledovania a fúzie



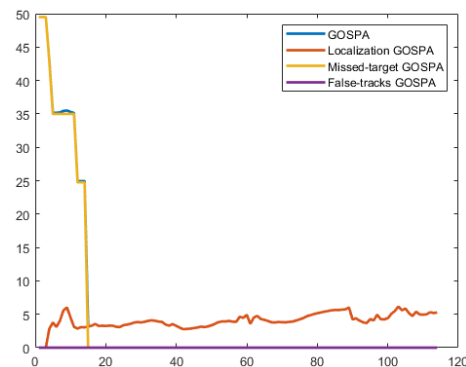
Často využívané nástroje: Automated Driving Toolbox, Tracking and Fusion Toolbox, Radar Toolbox

Sledovanie vozidiel v prítomnosti odrazov radaru

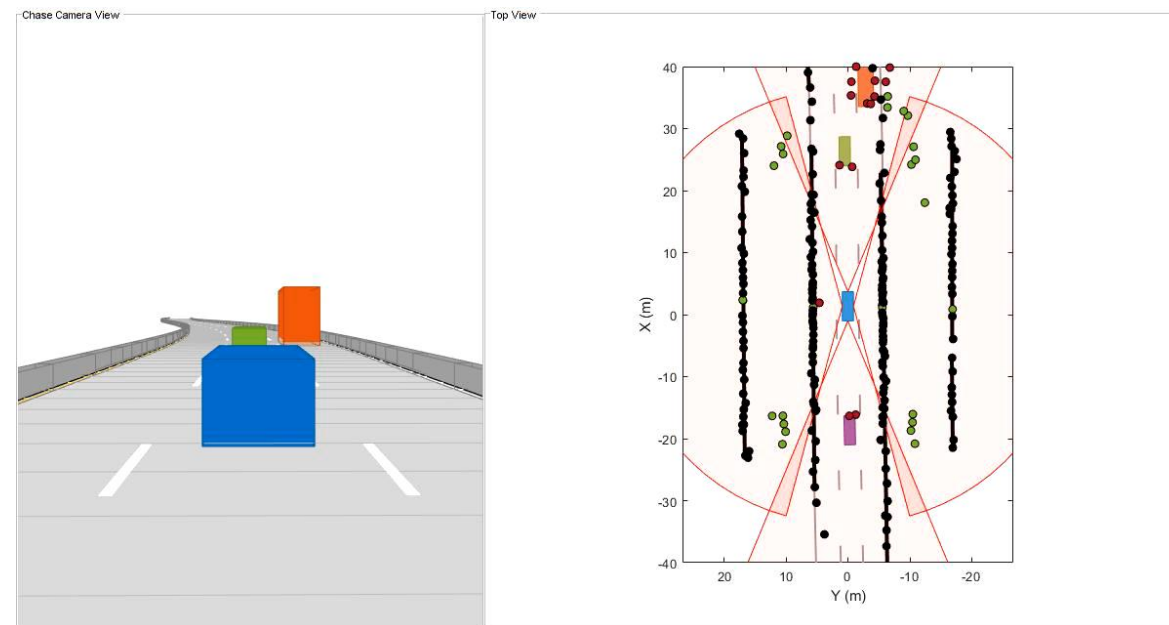


True Class	Clutter	Ghosts (D)	Ghosts (S)	Static	Targets
Clutter		20.0%	62.0%	1.3%	16.7%
Ghosts (D)		64.9%			35.1%
Ghosts (S)		15.0%	75.6%	0.4%	9.0%
Static		2.6%	3.1%	93.4%	0.9%
Targets		4.4%	1.1%	0.5%	94.1%

Classification metrics



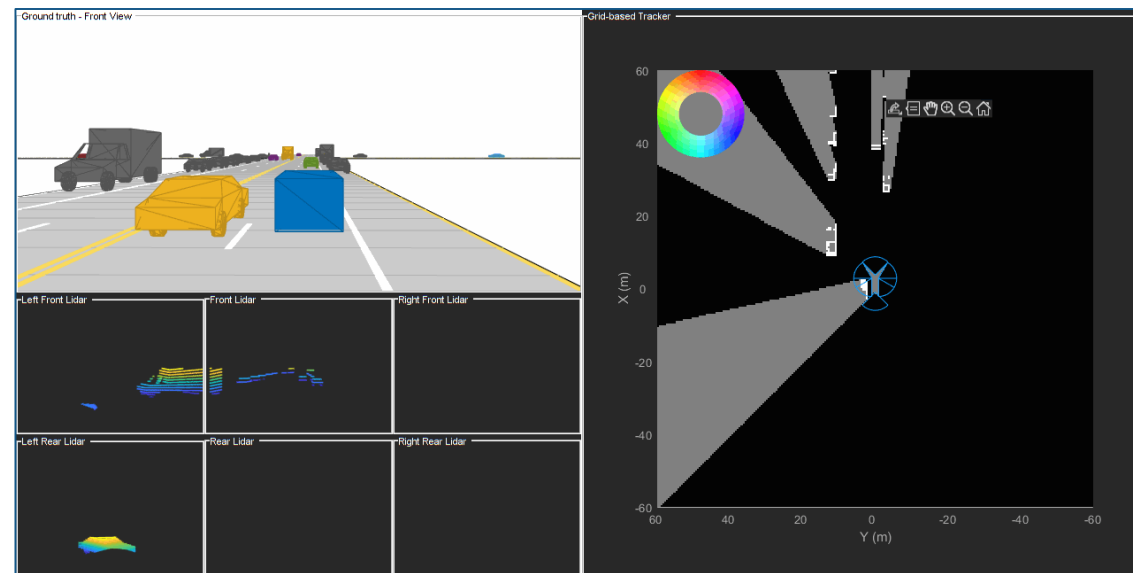
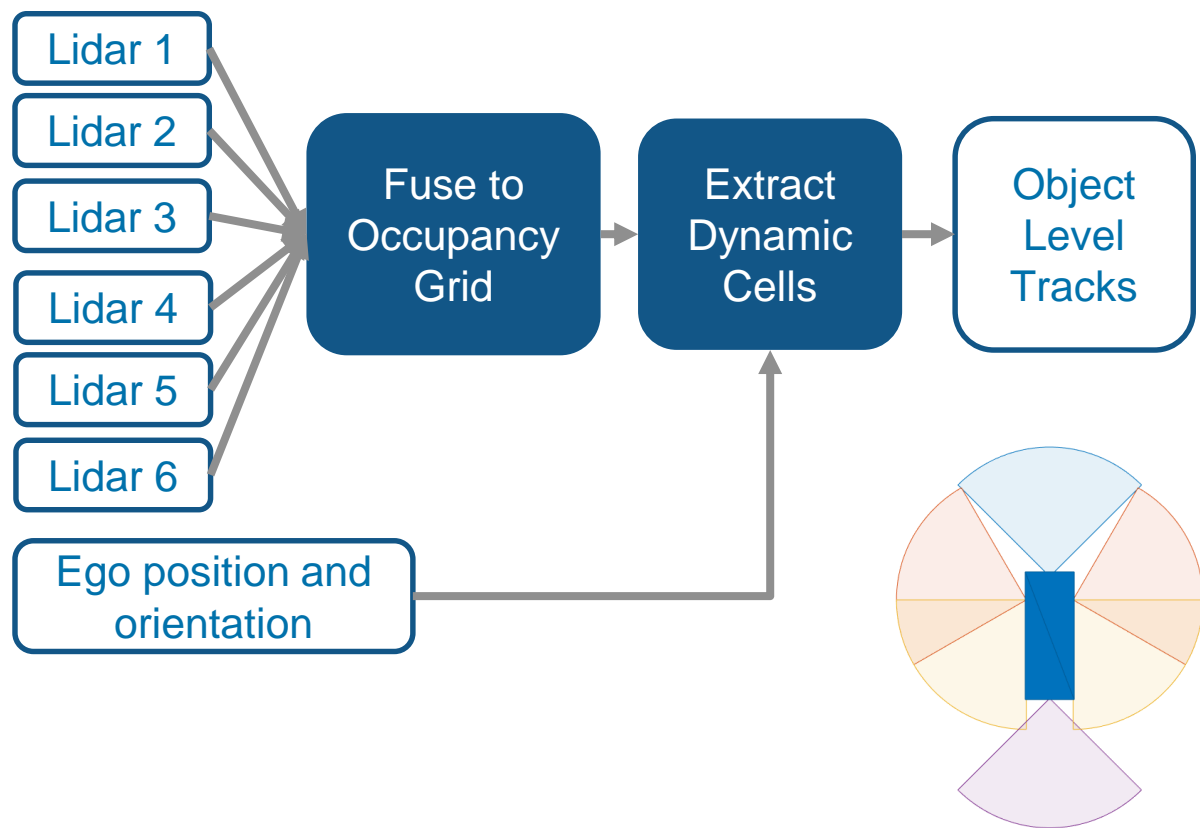
Tracker metrics



[Highway Vehicle Tracking with Multipath Radar Reflections](#)

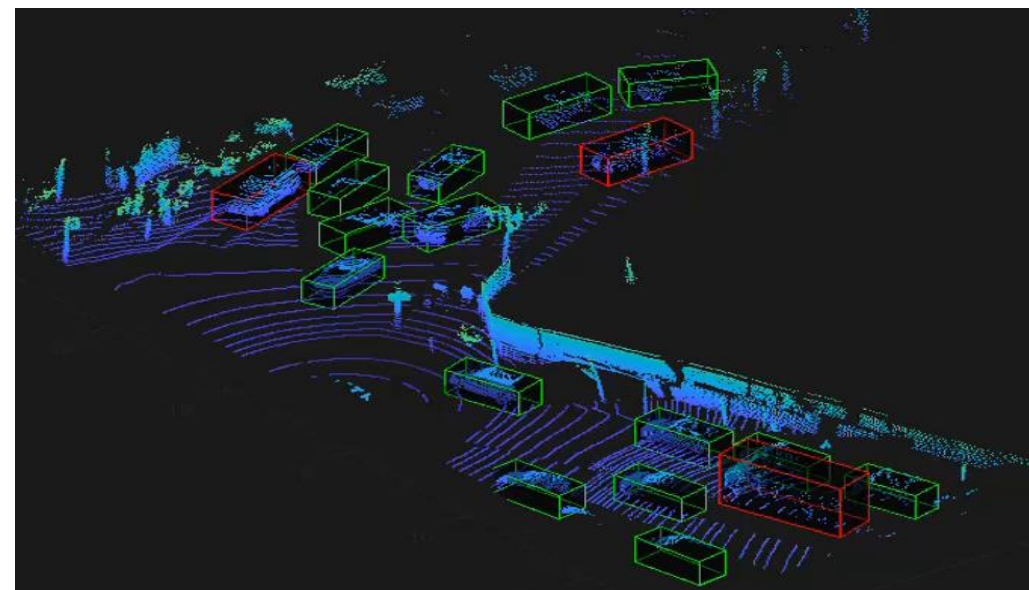
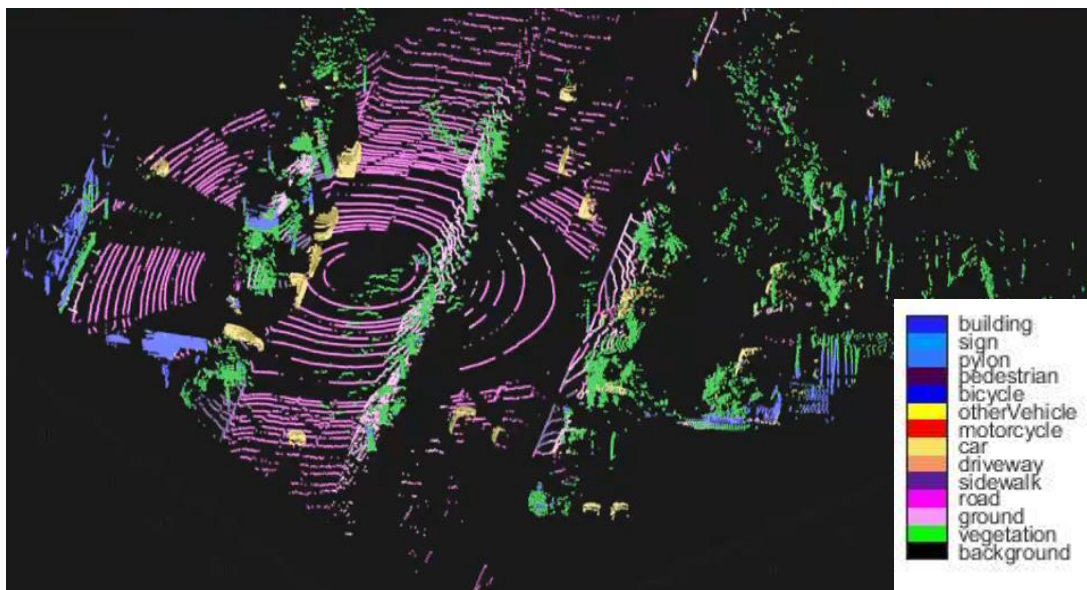
Automated Driving Toolbox™, Sensor Fusion and Tracking Toolbox™, Radar Toolbox™

Sledovanie objektov v prostredí



Grid-based Tracking in Urban Environments Using Multiple Lidars
Automated Driving Toolbox™, Sensor Fusion and Tracking Toolbox™

Detekcia objektov a sémantická segmentácia s lidarom

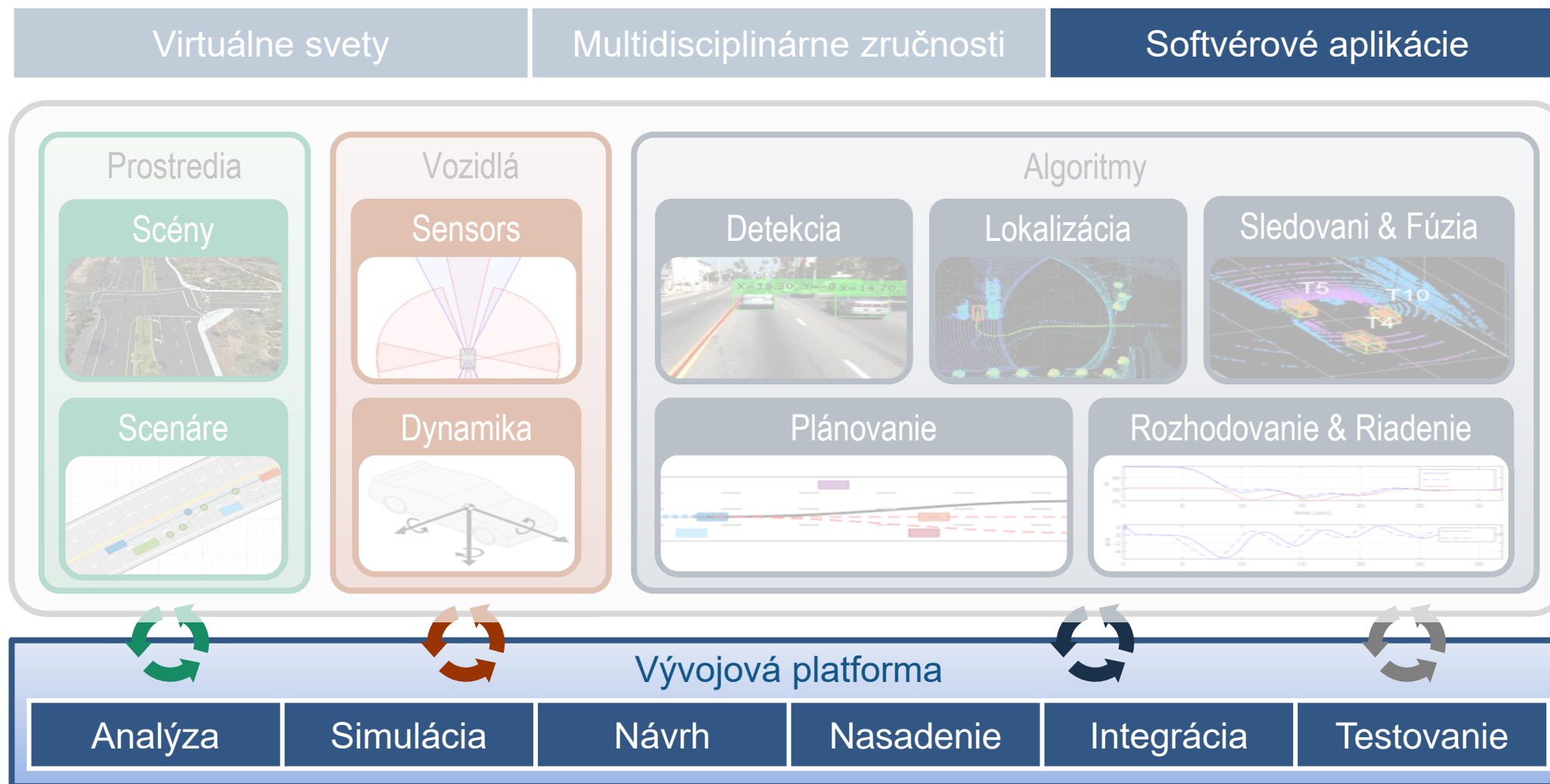


- Detekcia a klasifikácia viacerých objektov
- Podpora viacerých sietí: SalsaNet, RangeNet++, SqueezeSegv2, PointNet
- Funkcie pre prácu s PointCloudom a podpora generovania kódu

[Lidar 3-D Object Detection Using PointPillars Deep Learning](#)

Lidar Toolbox™

Vývoj systémov autonómneho riadenia

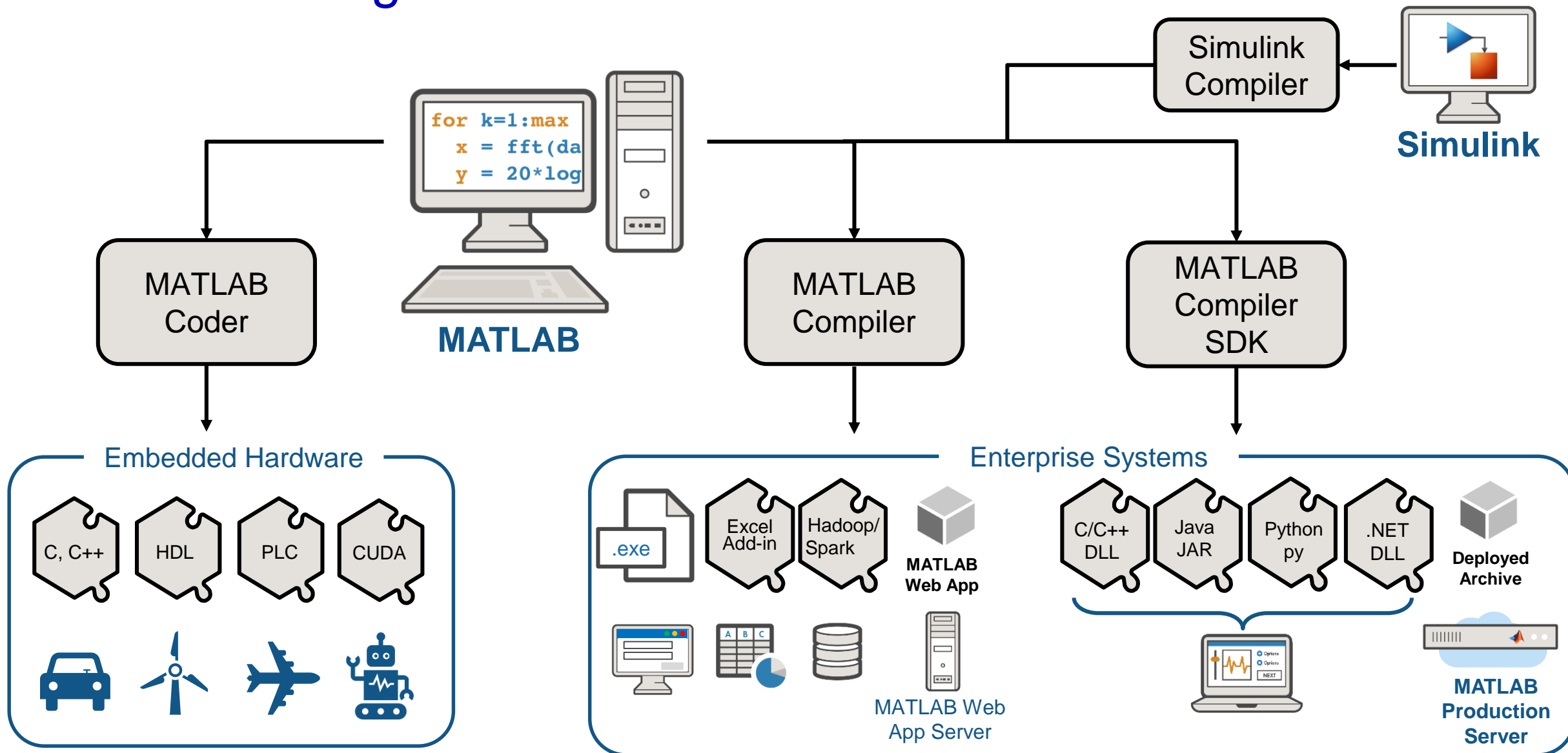


Vývoj softvérových aplikací

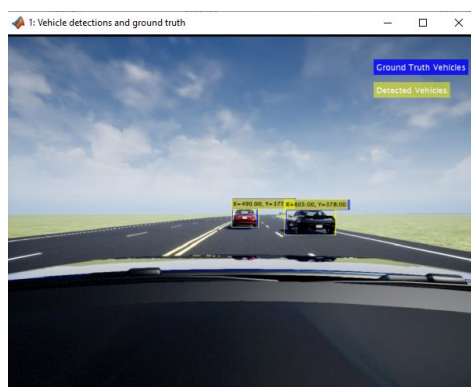
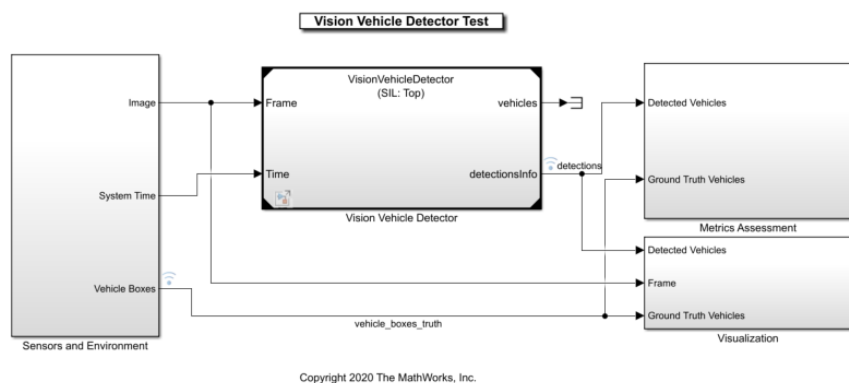
Kód	ROS / ROS 2.0	AUTOSAR	DDS
Continuous Integration	Automatické testovanie	Analýza kódu	ISO 26262

Často využívané nástroje: MATLAB Coder, Embedded Coder, GPU Coder, HDL Coder, ROS Toolbox, AUTOSAR Blockset, DDS Blockset, Simulink Test, Simulink Coverage, Polyspace, IEC Certification Kit,

Nasadenie algoritmov



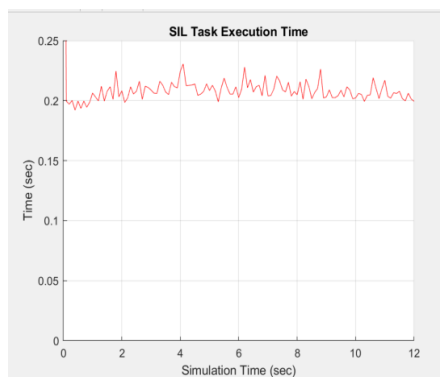
Generovanie C/C++ a GPU kódu v Simulinku



- Generovanie kódu, verifikácia funkcie a meranie času vykonávania pomocou Software-In-the Loop (SIL)

CPU: Intel® Xeon® @ 3.60GHz, GPU: Quadro K620

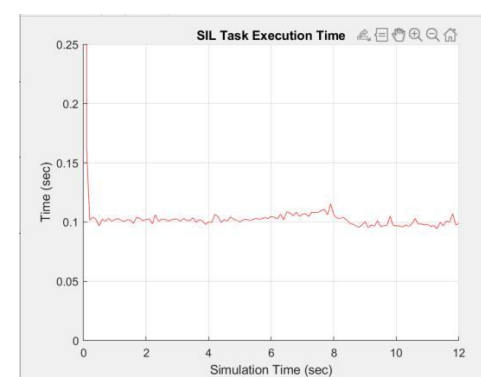
YOLOv2
CPU - MKLDNN



YOLOv2
GPU - cuDNN



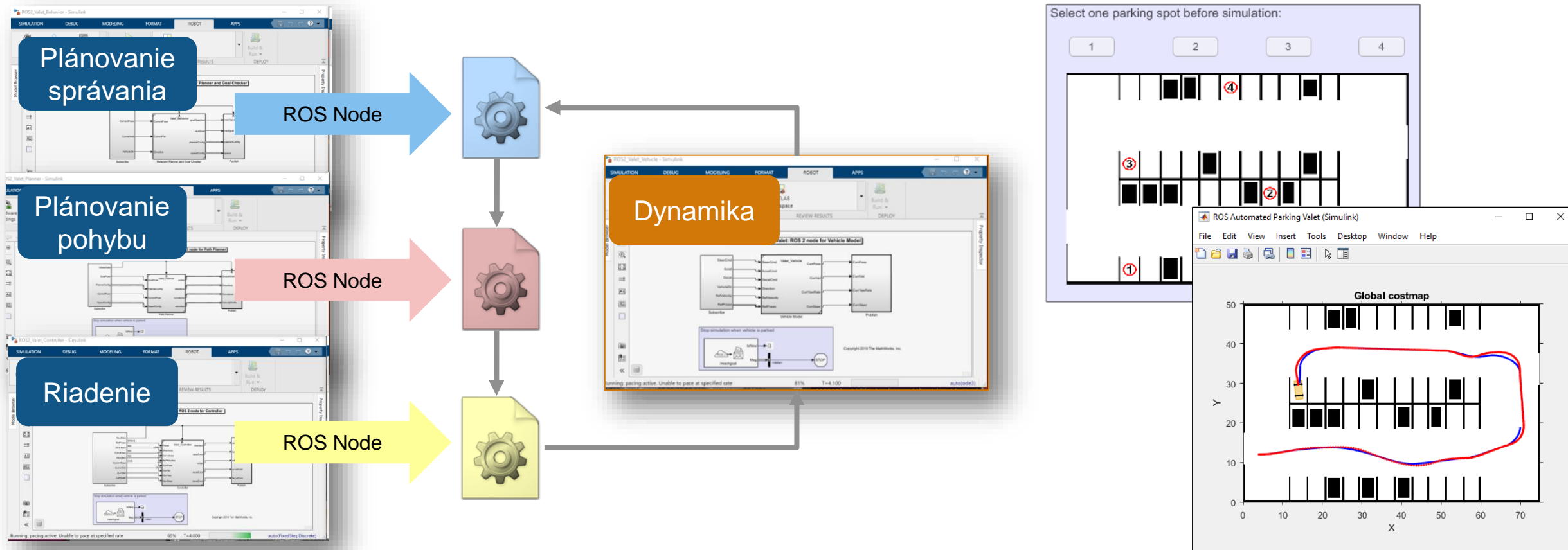
YOLOv2
GPU - tensorRT



[Generate Code for Vision Vehicle Detector](#)

Automated Driving Toolbox™, Embedded Coder®, Computer Vision Toolbox

Nasadenie plánovania a riadenia do ROS / ROS 2.0

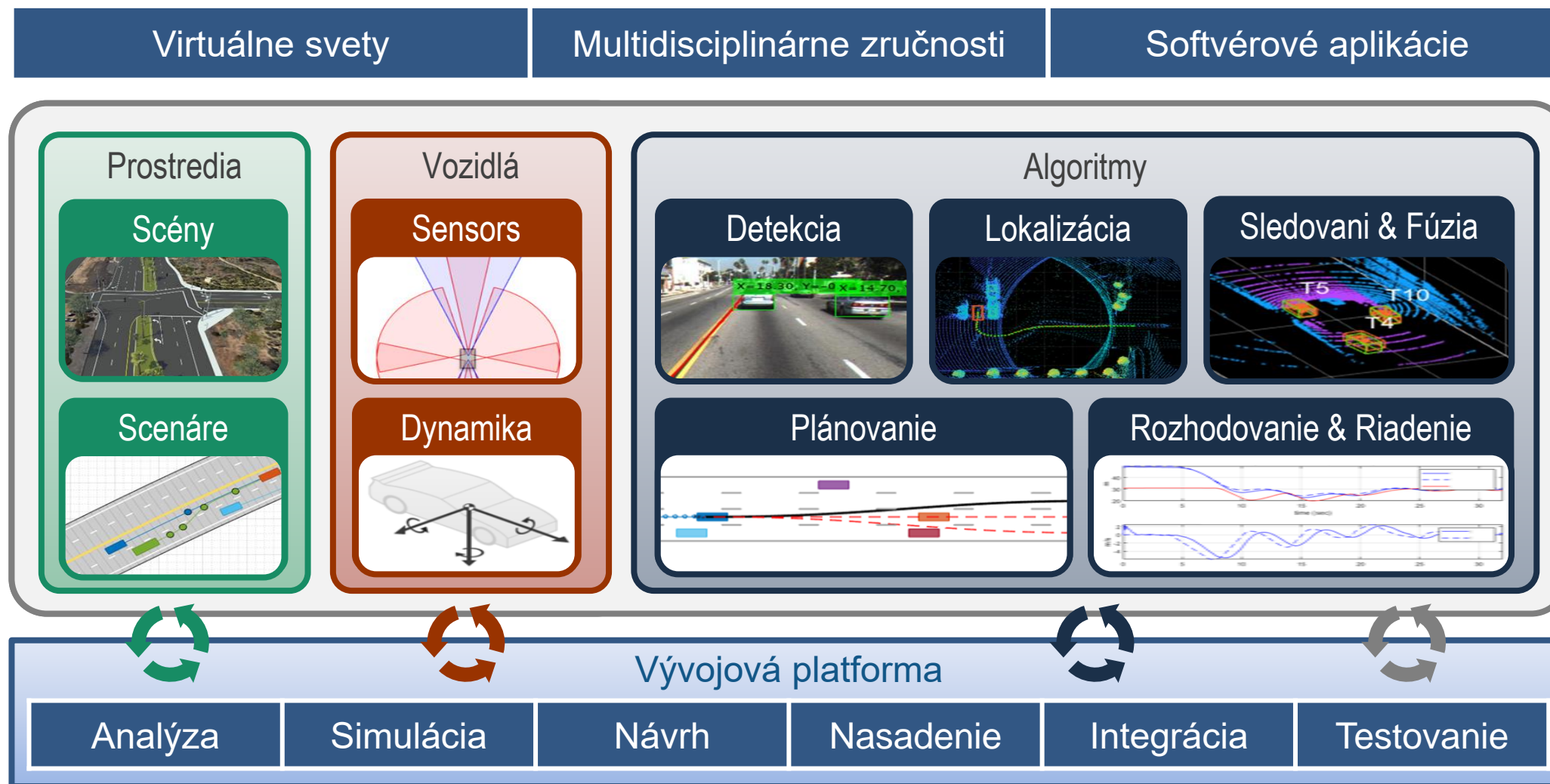


[Automated Parking Valet with ROS in Simulink](#)

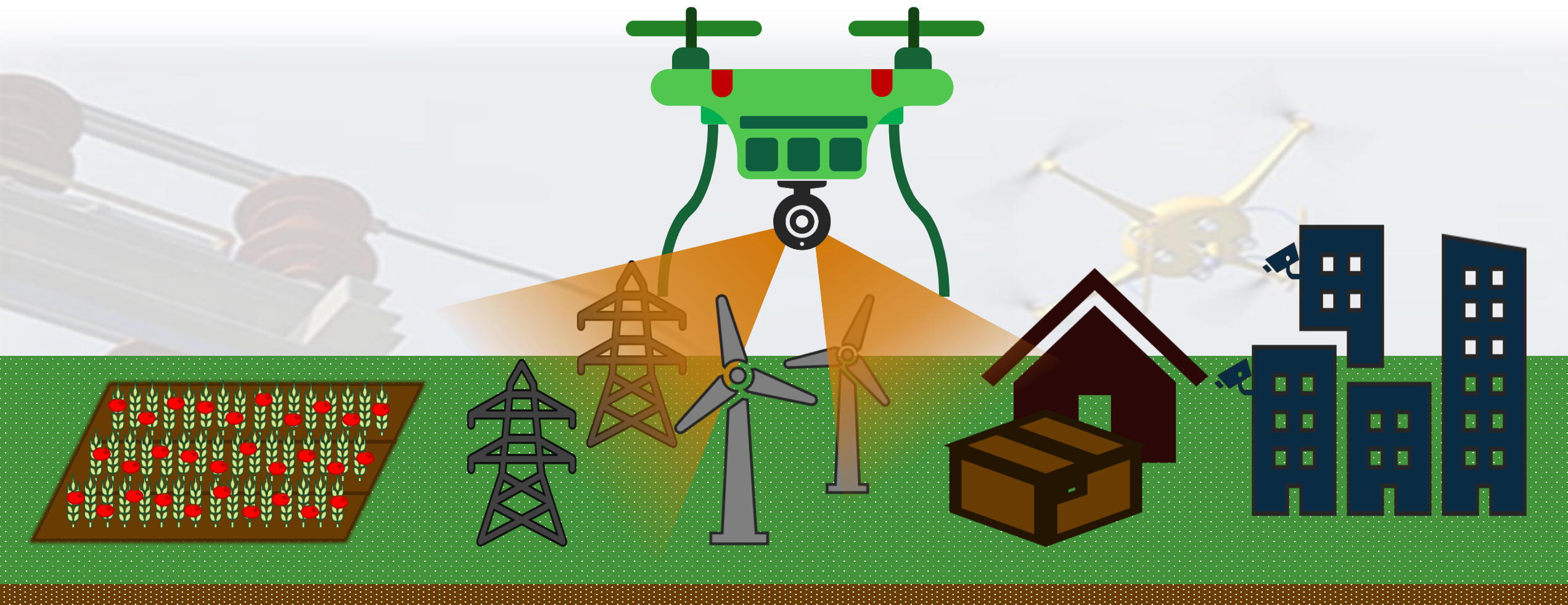
[Automated Parking Valet with ROS 2 in Simulink](#)

ROS Toolbox, Embedded Coder[®], Automated Driving Toolbox[™], Model Predictive Control Toolbox[™]

Vývoj systémov autonómneho riadenia



Autonómne UAV



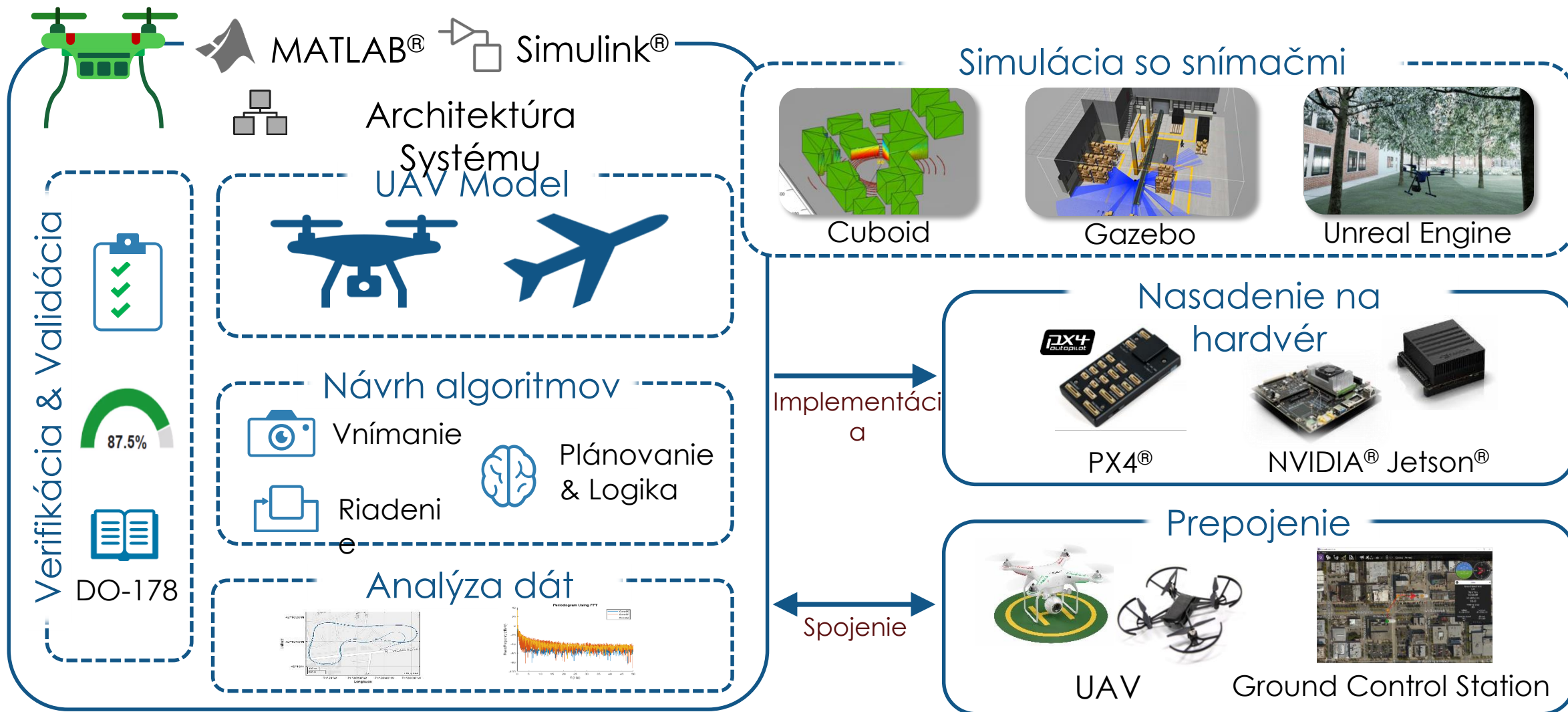
Mapovanie a
prieskum

Inšpekcie a
monitorovanie

Doručovanie a
doprava

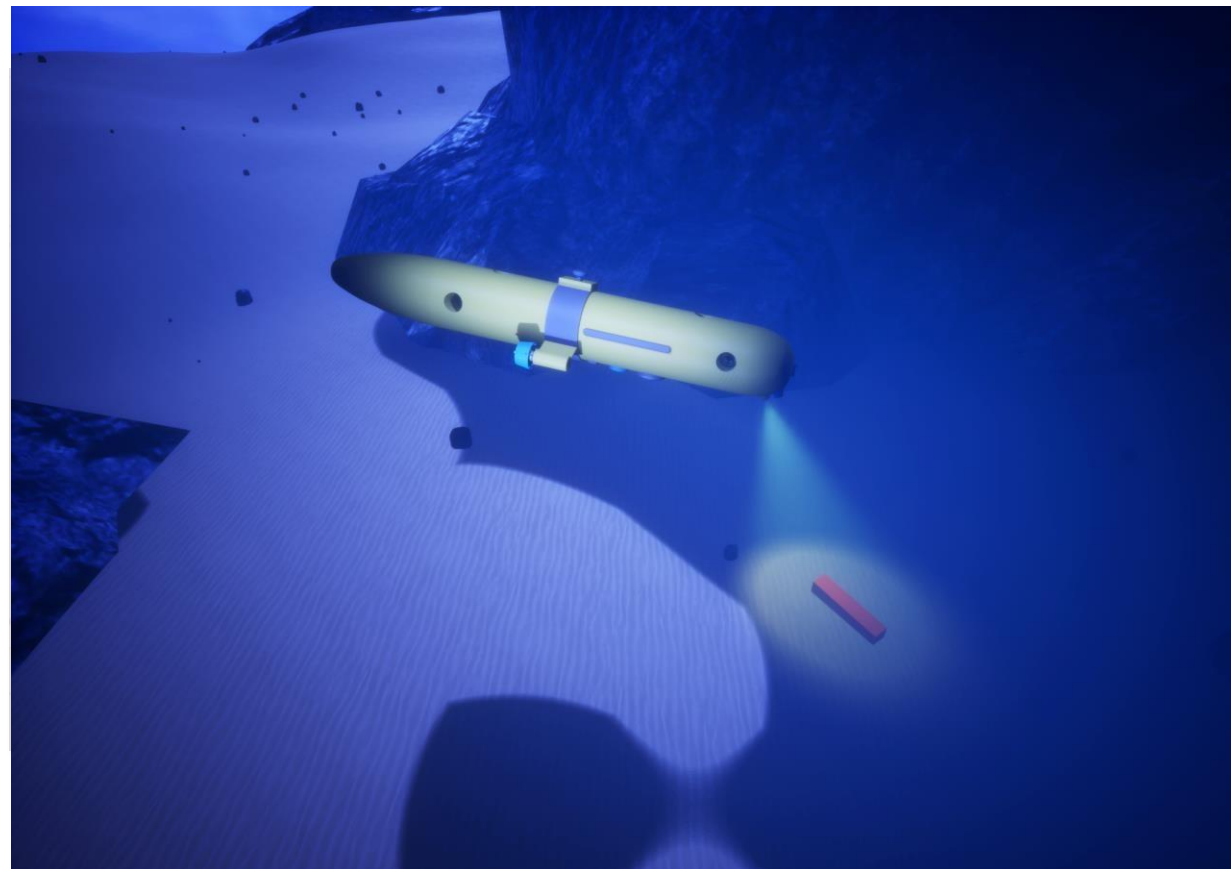
Bezpečnosť a
obrana

Vývoj UAV aplikácií



Vývoj AUV aplikácií

- Nástroje pomáhajú vývoj AUV aplikácií
 - Systems engineering
 - Modelovanie platformy
 - Prostredie a snímače
 - Autonómne algoritmy
- Hľadanie objektu pod vodou
 - Navigácia na miesto
 - Vyhýbanie prekážkam
 - Skenovanie plochy
 - Spojenie s povrchom



Vývoj AUV

Návrh systému

Požiadavky Architektúra Verifikácia a Validácia Certifikáty

Autonómny algoritmus

Snímanie

IMU GPS
 Kamera Sila/Moment
 Tlak Sonar
 Vytekanie DVL

Vnímanie

Mapovanie prostredia
 Objekty Detekcia/Sledovanie

Map Produced by Sonar Visualize Mission Progress

Plánovanie

Localizácia
 Trasa
 Prekážky

Riadenie

Spätná väzba
 Stavová log.
 Gain Scheduling
 Trajektória

Nasadenie

Generovanie kódu ROS DDS

Platforma

Model systému Hardware-in-the-loop Software-in-the-loop Hardvér

Ďakujem za pozornosť