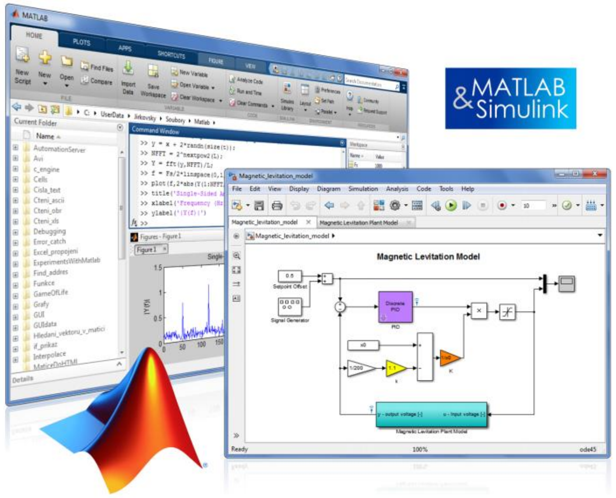
09.09.2021 Brno

TCC 2021

Vývoj autonómnych systémov



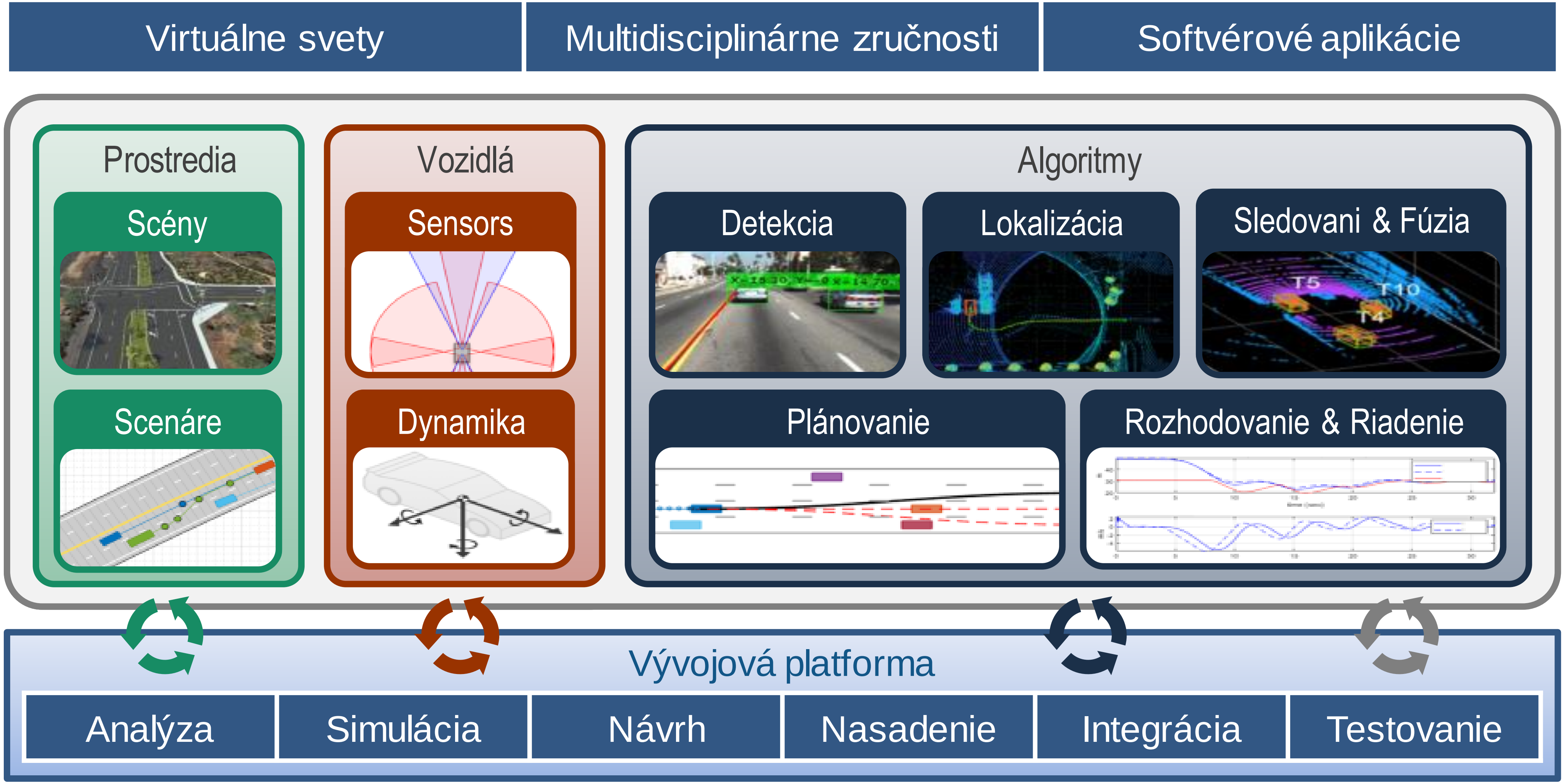
Michal Blaho

blaho@humusoft.cz

www.humusoft.cz
info@humusoft.cz

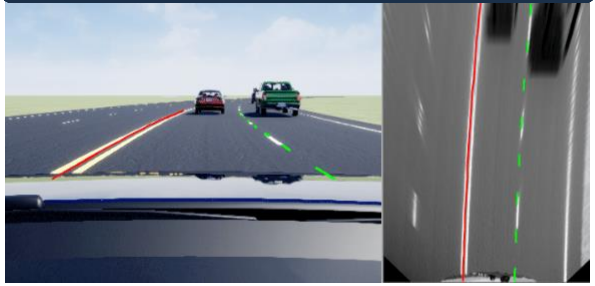
www.mathworks.com

Vývoj systémov autonómneho riadenia



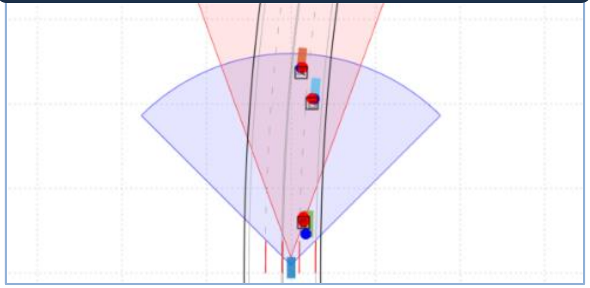
Simulácia autonómneho riadenia vo virtuálnom svete

Detekcia čiar

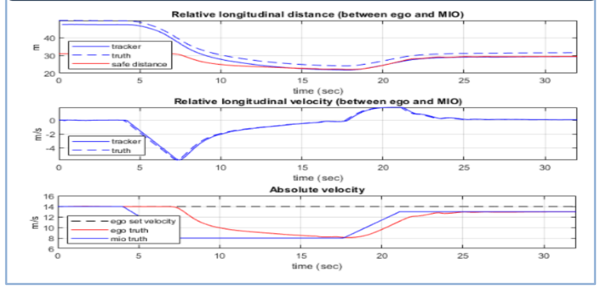


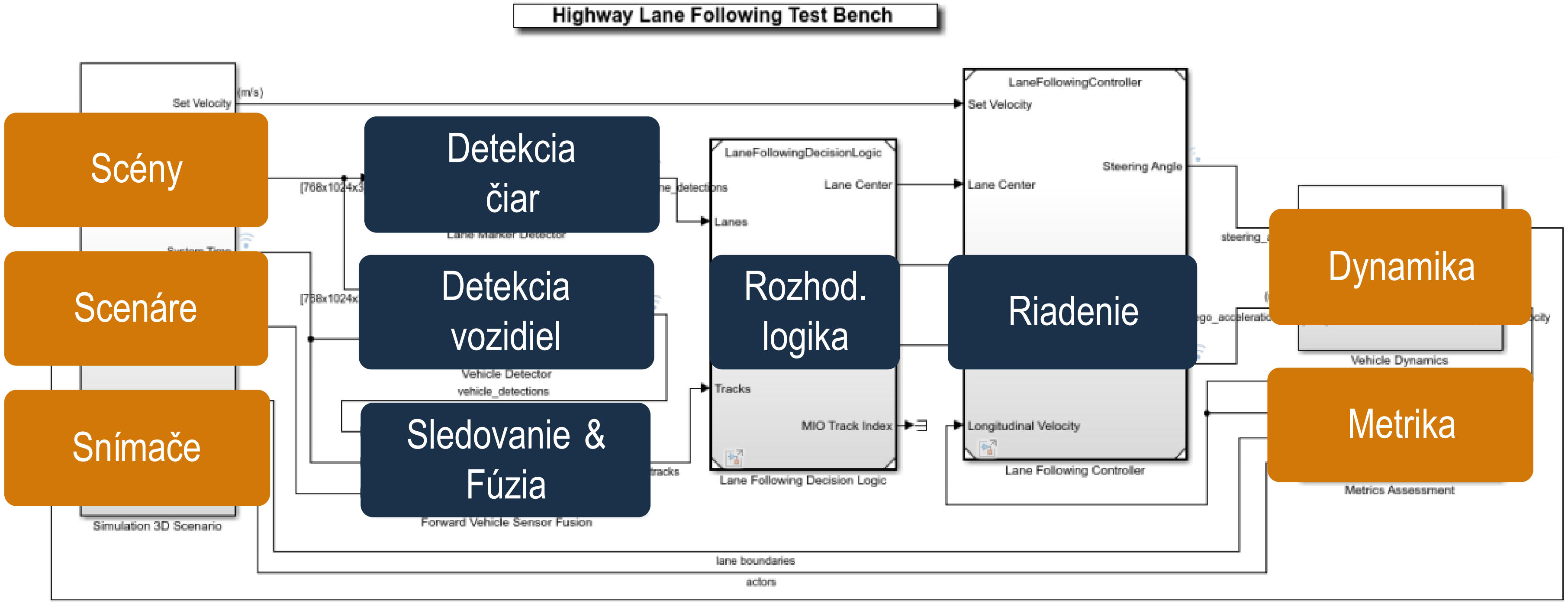
Detekcia vozidiel

Sledovanie & Fúzia



Rozhodovanie & Riadenie





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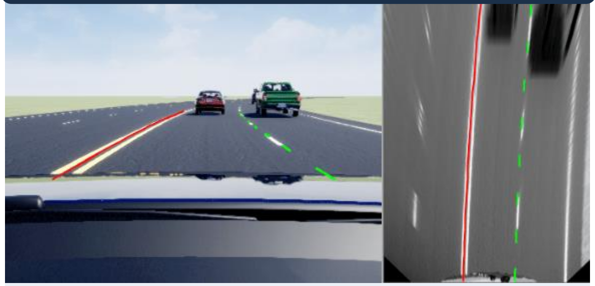
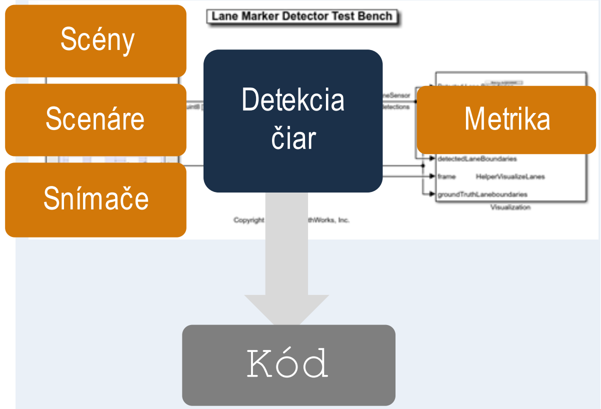
[Highway Lane Following]

Vývoj algoritmov pre viaceré disciplíny

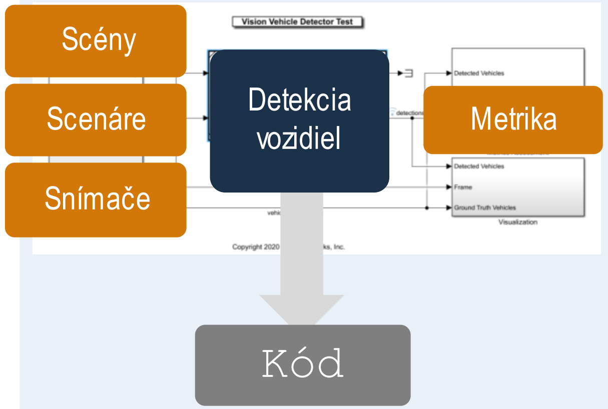
Detekcia čiar





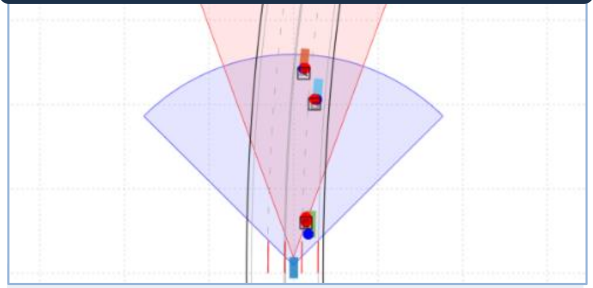
[Lane Detector](#)

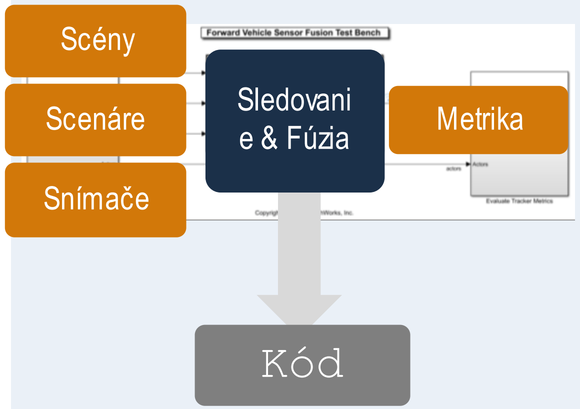
Detekcia vozidiel



[Vehicle Detector](#)

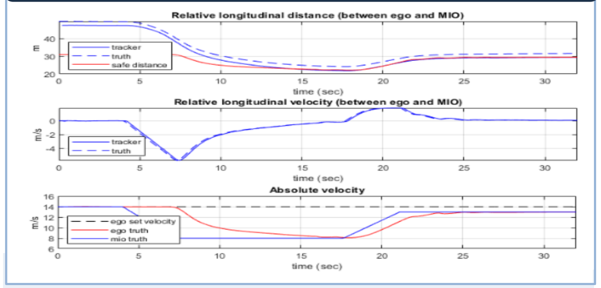
Sledovanie & Fúzia

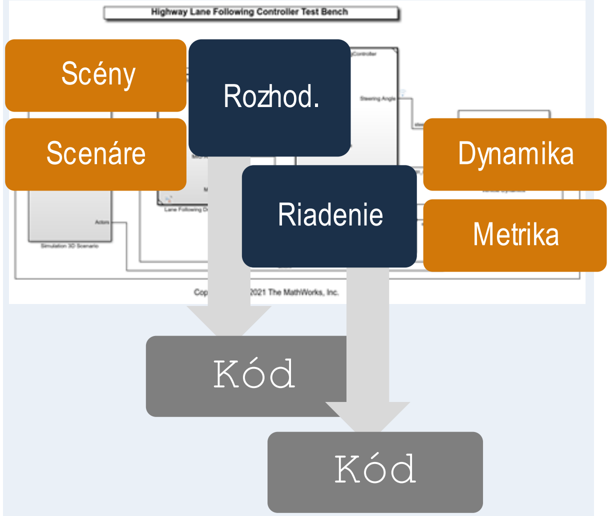




[Vehicle Sensor Fusion](#)

Rozhodovanie & Riadenie

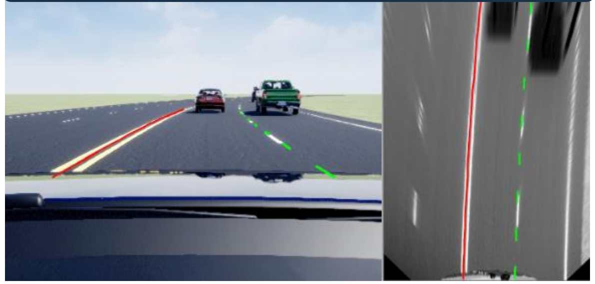




[Decision and Controls](#)

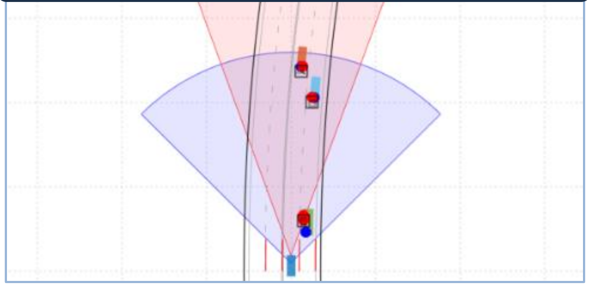
Vývoj softvéru pre autonómne riadenie

Detekcia čiar

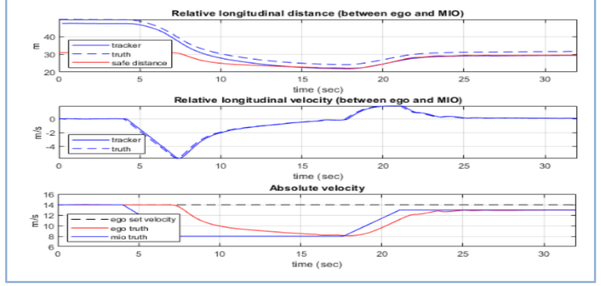


Detekcia vozidiel

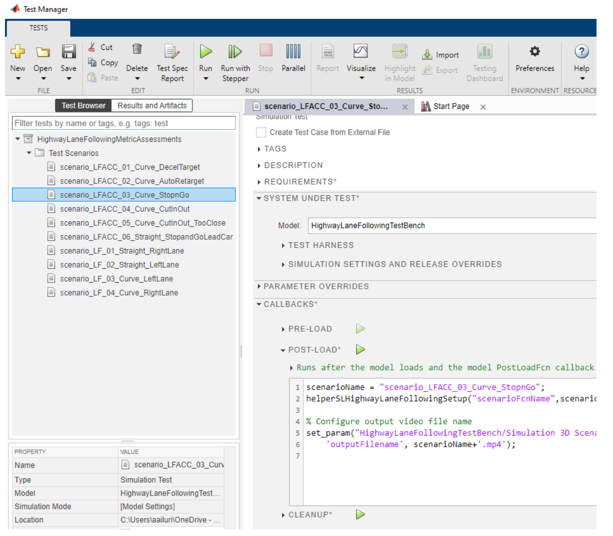
Sledovanie & Fúzia

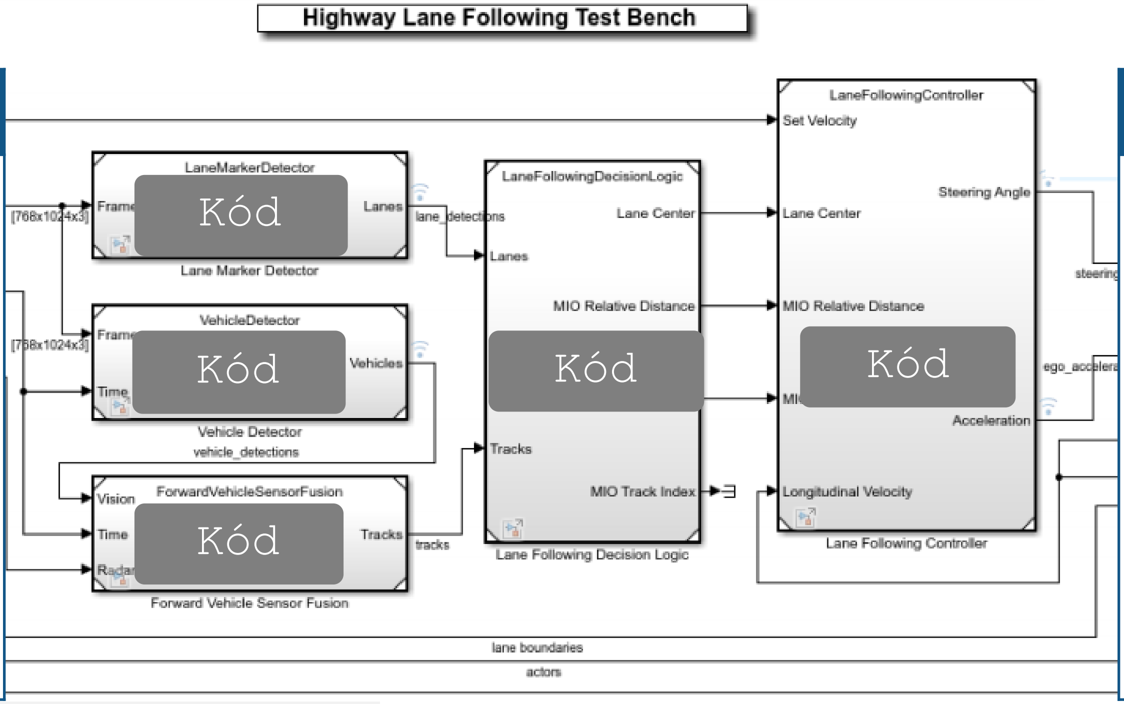


Rozhodovanie & Riadenie



Správa testov





Reportovanie

[Automate Testing of Highway Lane Following]

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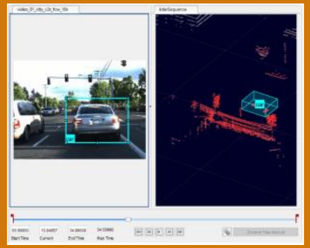
Rozšírenie postupov na identifikáciu nových scenárov

Identifikácia scenára zo zaznamenaných dát

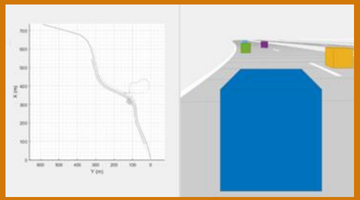
Zaznamenané dáta vozidla

Označenie dát



Identifikácia zaujímavých scenárov

Vytvorenie scenára so zaznamenaných dát



Identifikácia scenára z rôznych variácií

Tvorba scenáru

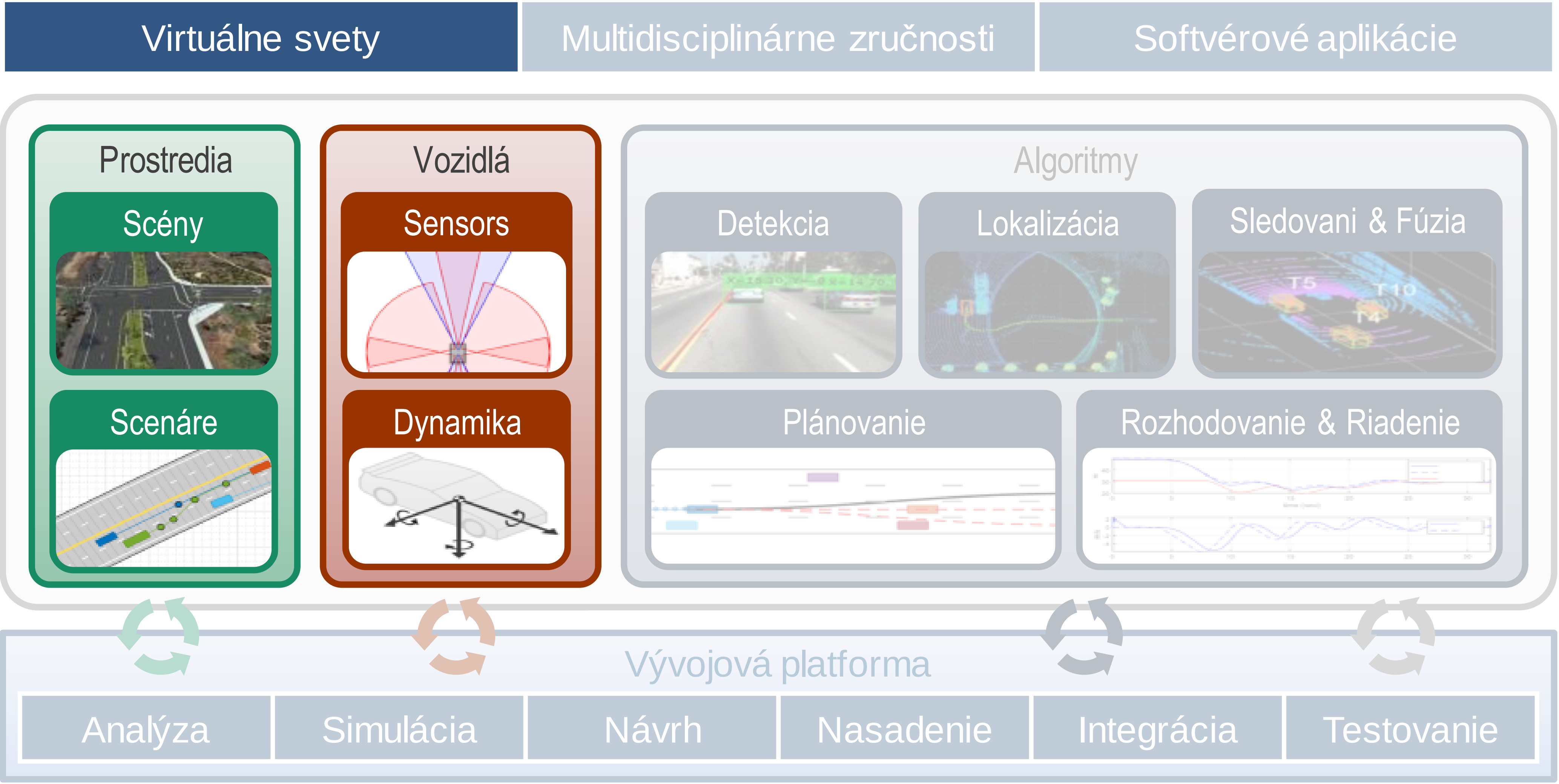
Tvorba variácií scenárov

`drivingScenario()`

Identifikácia zaujímavých scenárov

Pridanie scenára do testov

Vývoj virtuálnych svetov



Tvorba 3D scén

OpenDRIVE

Geographic Information System (GIS) súbory
- Mračná bodov
- Ortografické obrázky
- Vektorové dáta
- Výškové data

Custom Assets

Návrh scén

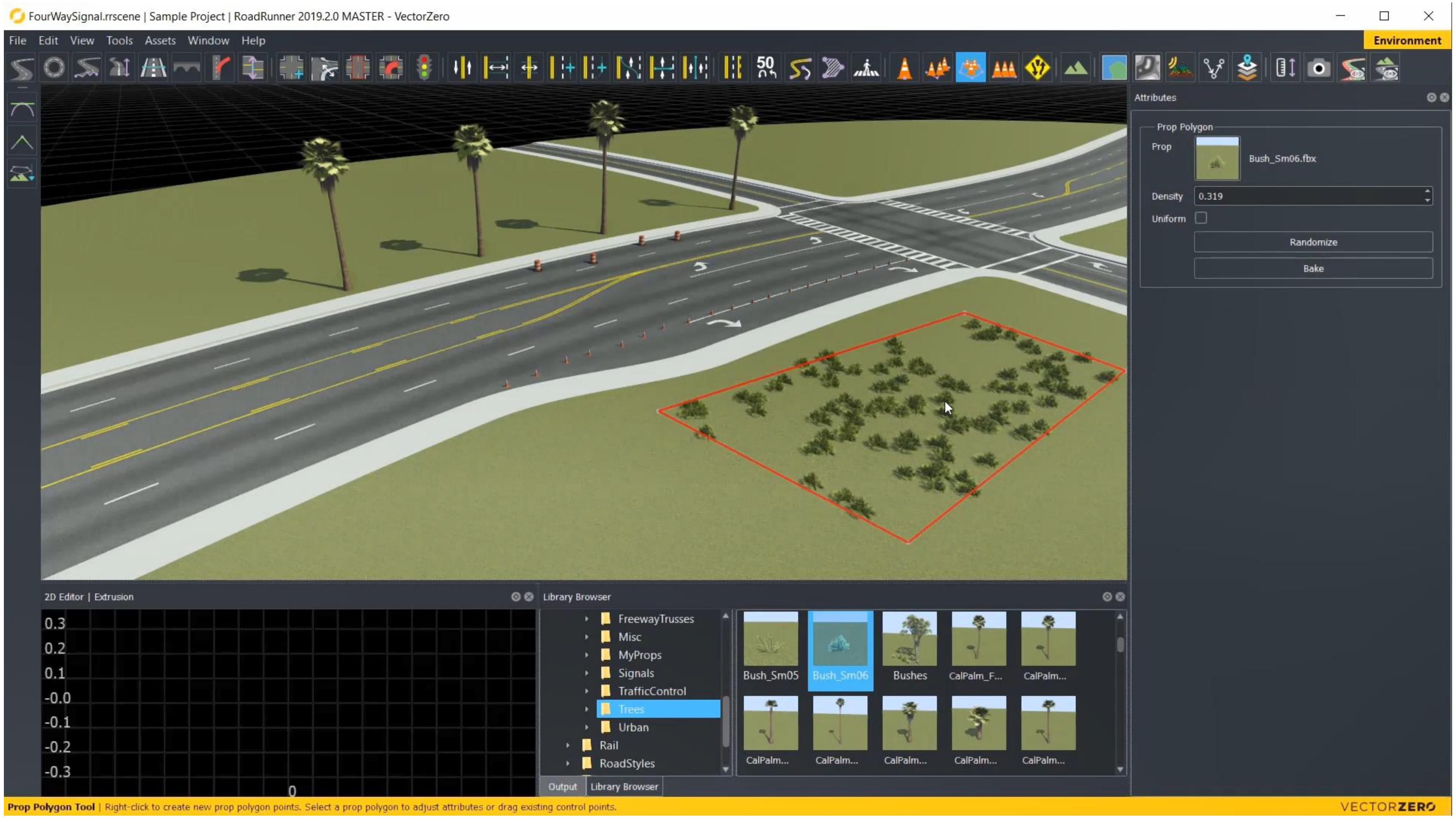
RoadRunner

OpenDRIVE

Filmbox

Simulátory tretích strán
- CARLA
- Unreal Engine®
- Unity®
- LGSVL
- VIRES Virtual Test Drive
- Metamoto
- IPG Carmaker
- Cognata
- Baidu Apollo
- Tesis Dynaware
- TaSS PreScan
- NVIDIA DRIVE Sim cez Universal Scene Description (USD)

Interaktívny návrh 3D scén v RoadRunner



Tvorba 3D scén

Here HD Live Map

OpenDRIVE

Geographic Information System (GIS) súbory
- Mračná bodov
- Ortografické obrázky
- Vektorové dáta
- Výškové data

Custom Assets

Návrh scén

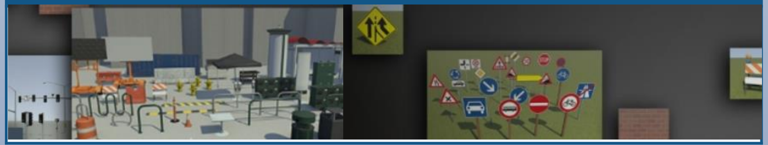
RoadRunner Scene Builder

R2020b

RoadRunner

R2020a

RoadRunner Asset Library



R2020a

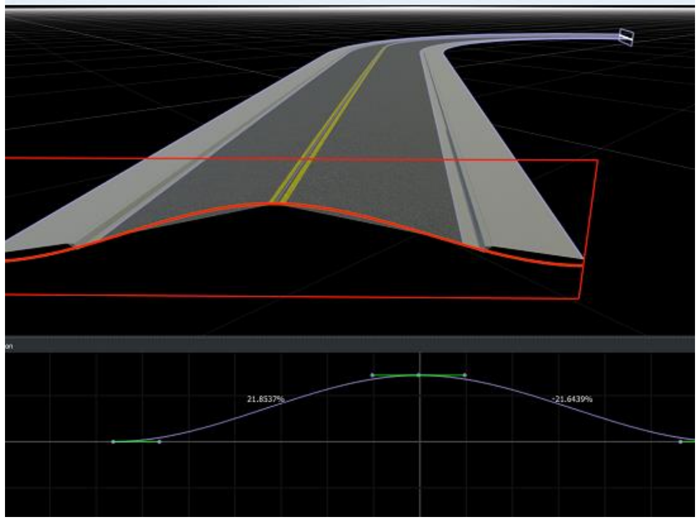
OpenDRIVE

Filmbox

Simulátory tretích strán
- CARLA
- Unreal Engine®
- Unity®
- LGSVL
- VIRES Virtual Test Drive
- Metamoto
- IPG Carmaker
- Cognata
- Baidu Apollo
- Tesis Dynaware
- TaSS PreScan
- NVIDIA DRIVE Sim cez Universal Scene Description (USD)

Nové možnosti návrhu 3D scén

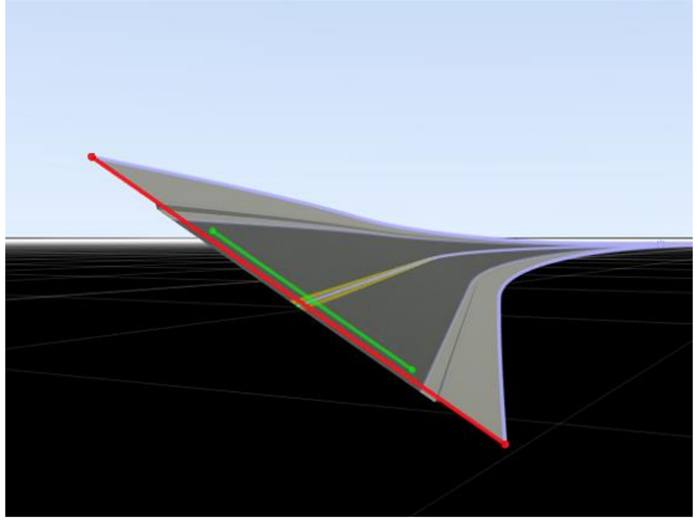
Návrh laterálneho profilu



Cross Section Tool
RoadRunner

R2021a

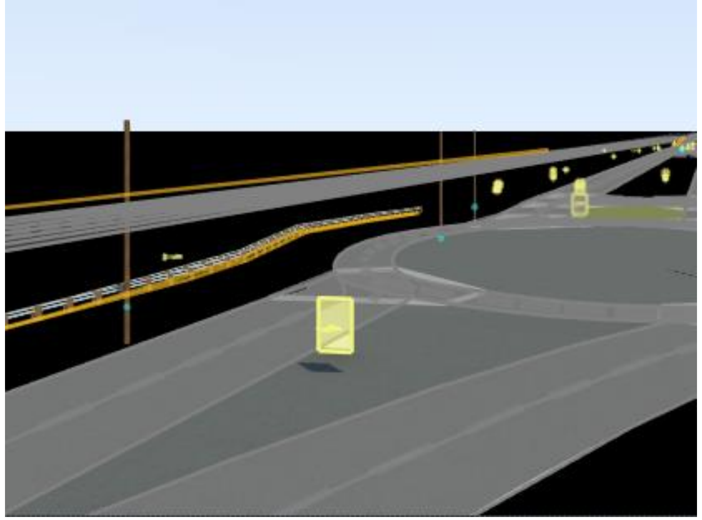
Návrh superelevácie



Road Superelevation Tool
RoadRunner

R2021a

Import značiek, stĺpov a bariér z HERE



Configure Assets to Use for Imported HERE HD Live Map Data
RoadRunner Scene Builder

R2021a

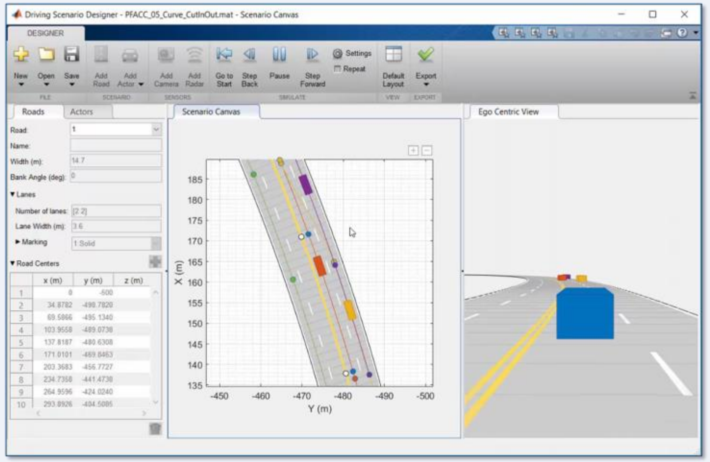
Návrh scén a scenárov

OpenDRIVE
OpenStreetMap
HERE HD Maps
Zenrin SD

Vlastné meshe

Návrh scenárov jazdy

Driving Scenario Designer App



Driving Scenario API

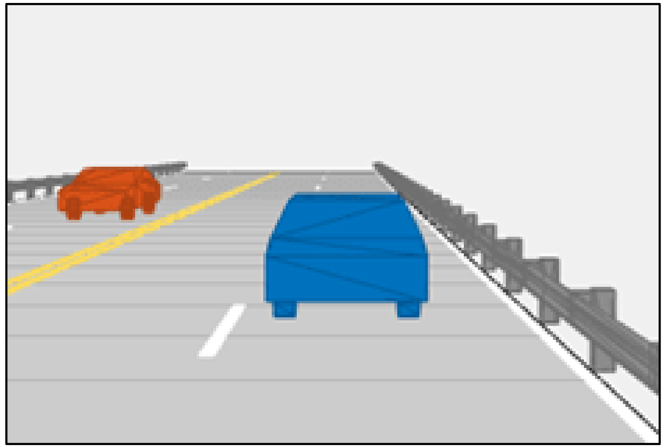
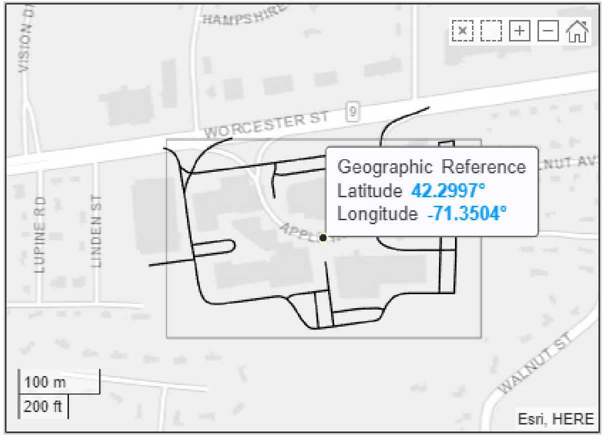
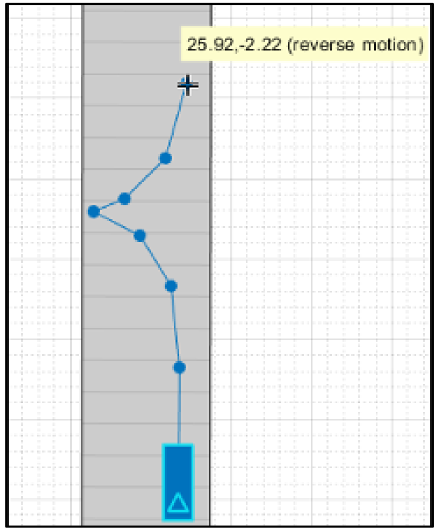
```
ds = drivingScenario();
```

Scenár jazdy
- Cesty
- Čiary
- Zábrany a zábradlia
- Trajektórie vozidiel

OpenDRIVE

OpenSCENARIO

Nové príklady návrhu scén a scenárov

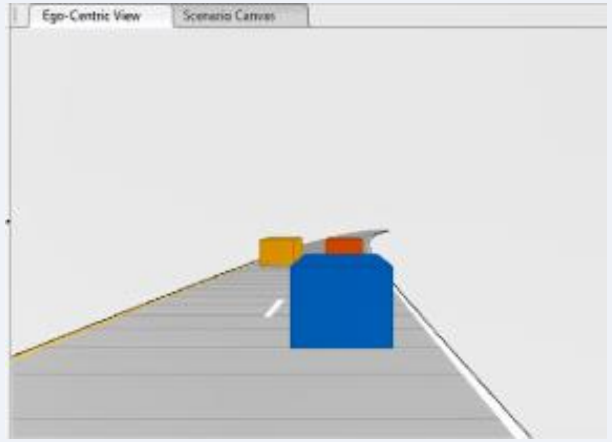
Pridávanie zábran a zábradlí	Import OpenStreetMap	Spätný pohyb
		
Driving Scenario Designer *Automated Driving Toolbox™*	Import OpenStreetMap Data into Driving Scenario *Automated Driving Toolbox™*	Create Reverse Motion Driving Scenarios Interactively *Automated Driving Toolbox™*
R2021a	R2021a	R2020b

Simulácia scén a scenárov

Návrh scén s RoadRunnerom

Návrh scenárov jazdy

Simulácia s cuboidmi



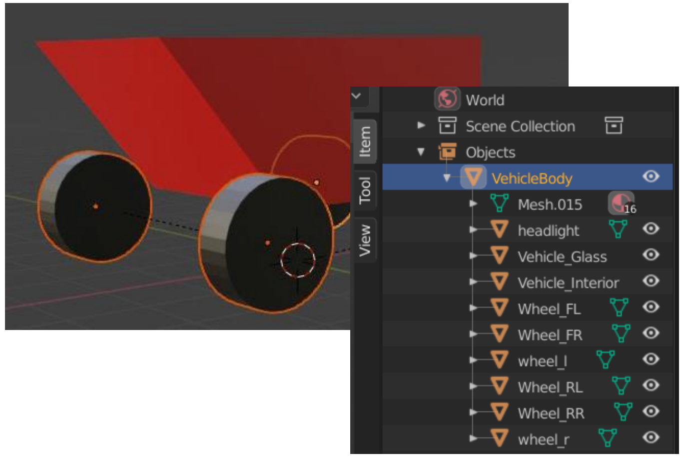
Využitie:
- Simulácia riadenia, plánovania, sledovania a fúzie
- Simulácia systémov vyžadujúcich skutočné alebo detegované senzory

Simulácia s Unreal Engine® od Epic Games®

Využitie:
- Simulácia systémov zahŕňajúca detekcie a lokalizáciu
- Vizualizácia systémov, kde simulácia je tvorená pomocou cuboidov

Nové možnosti simulácie s Unreal Enginom

Vlastné meshe



Prepare Custom Vehicle Mesh for the Unreal Editor

Automated Driving Toolbox™

R2021a

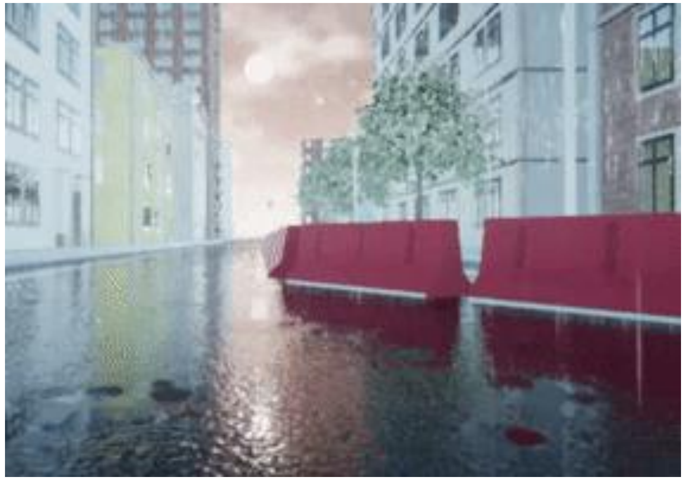
Svetlá vozidla

Simulation 3D Vehicle with Ground Following

Automated Driving Toolbox™

R2021a

Počasie a poloha slnka



Simulation 3D Scene Configuration

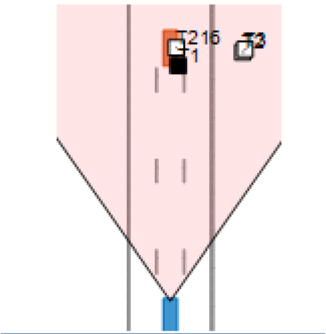
Automated Driving Toolbox™

R2021a

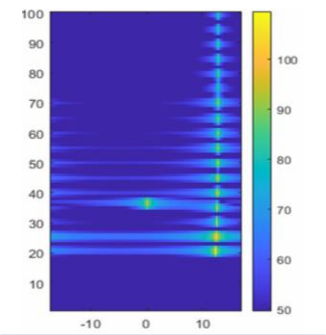
Simulácia snímačov

Cuboid snímače

Radarové sledovanie

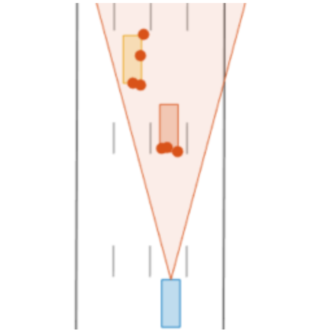


Radarové IQ signály

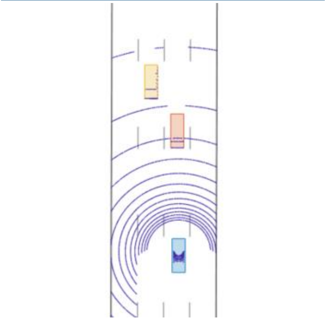


Cuboid a Unreal Engine

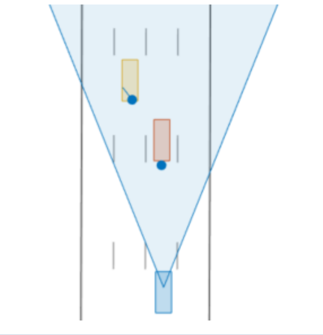
Radarové detekcie



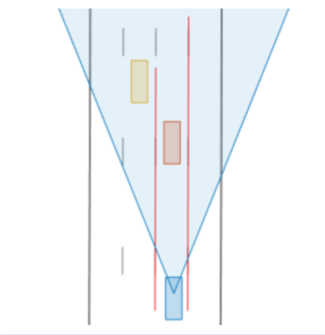
Lidar



Detekcie obrazu



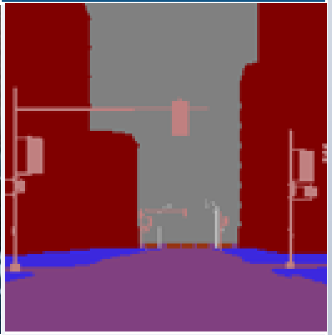
Detekcie čiary



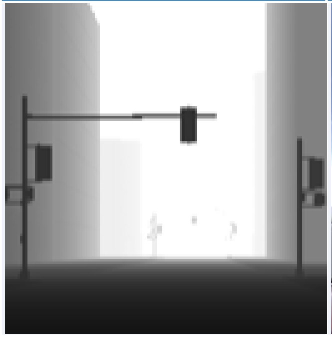
Unreal Engine Sensors

Monokulárna kamera

Sémantická segmentácia



Hĺbková



Fisheye kamera

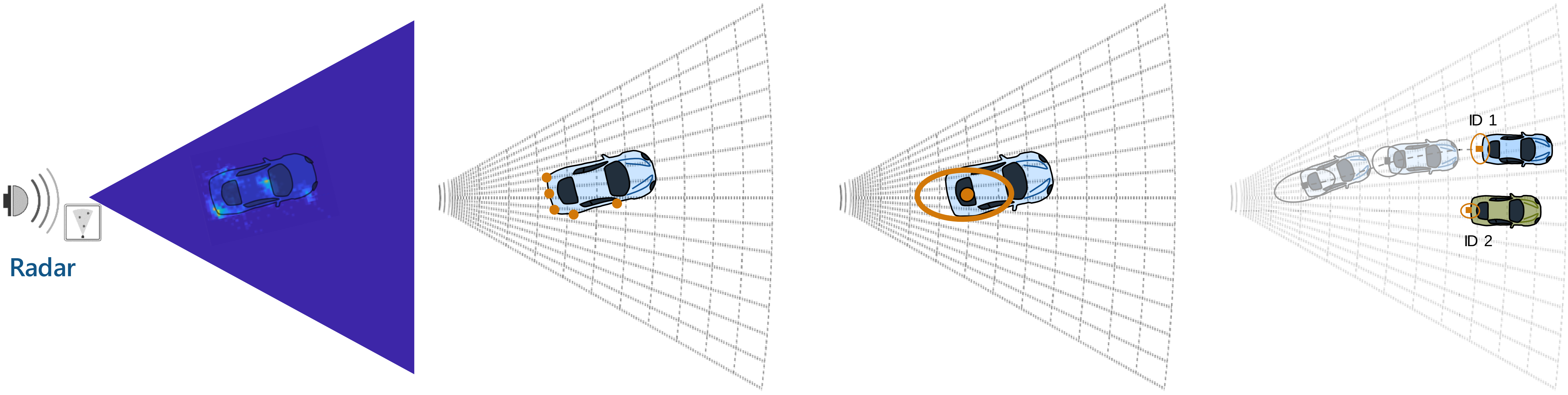
Snímače polohy

- Enkóder kolies
- Global Positioning System (GPS)
- Inertial Measurement Unit (IMU)
- Inertial Navigation System (INS)

Často využívané nástroje: Automated Driving Toolbox™, Radar Toolbox, Navigation Toolbox™

Simulácia radaru na rôznych úrovniach

Surové IQ signály | **Detekcie** | **Kláster** | **Sledovania**



Waveform-level Model	Measurement-level Model
Radar Transceiver *Radar Toolbox*	Driving Radar Data Generator *Automated Driving Toolbox™, Radar Toolbox*

R2021a

Označovanie zaznamenaných dát zo snímačov

Kamera

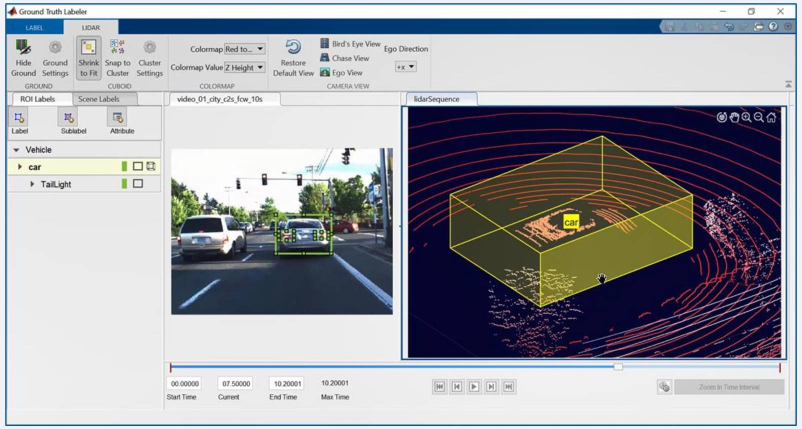
Lidar

Vlastné dáta

Vlastné algoritmy popisovania

Popisovanie dát zo znímačov

Ground Truth Labeler App



Automatizácia

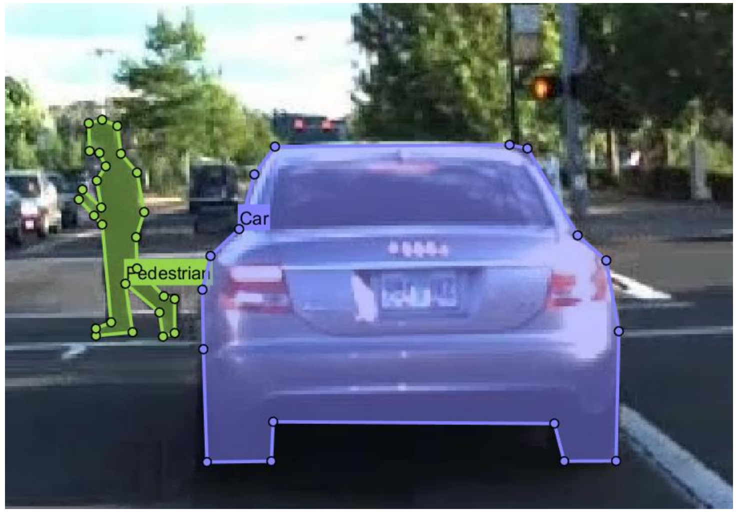
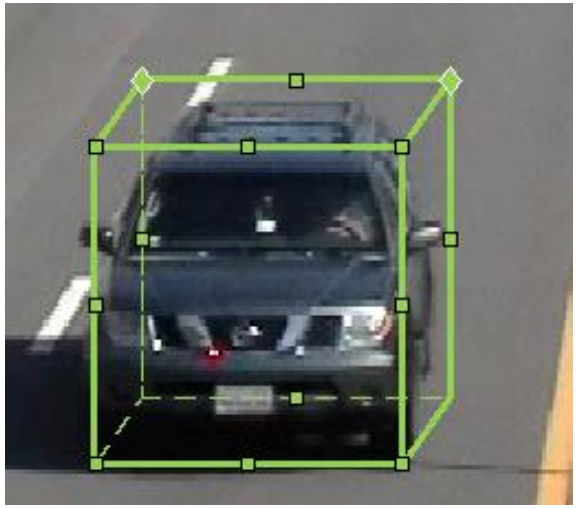
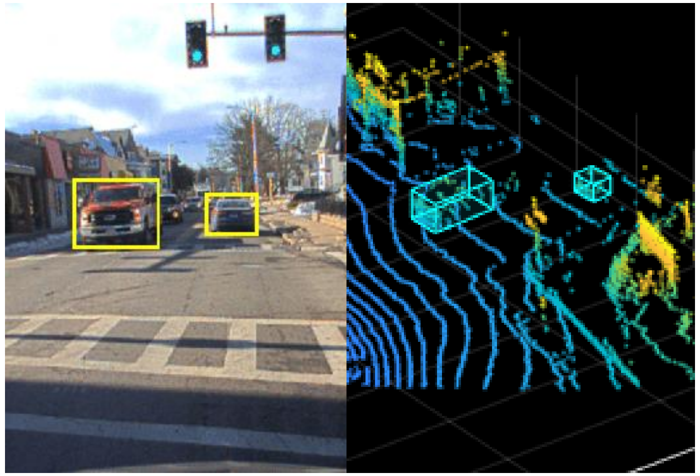
Vozidlá, ľudia, čiary,
sledovanie bodov, dočasný interpolátor

Popisky:

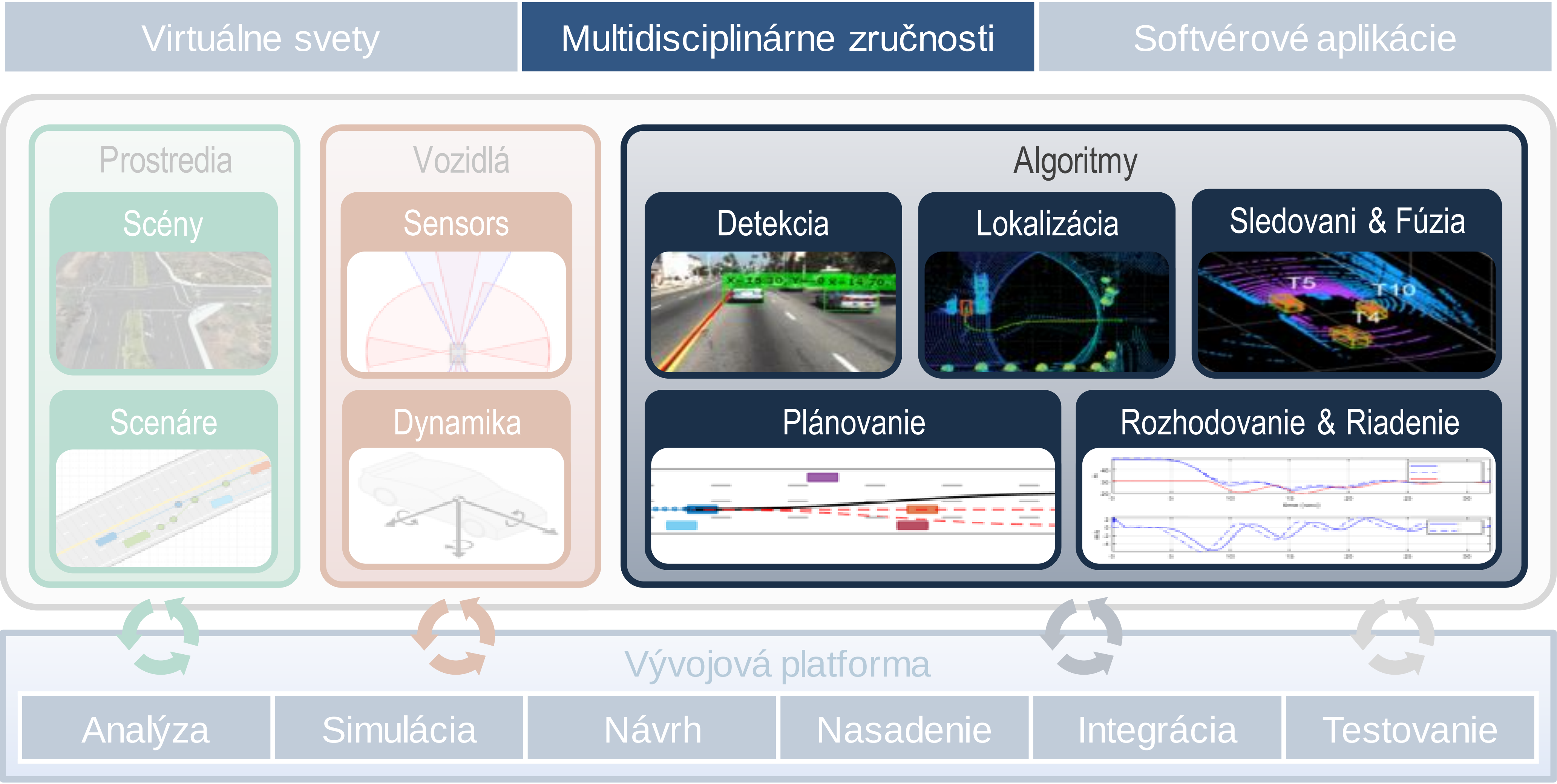
- Regions of Interest: cuboid, obdĺžnik, polygón, polyline
- Pixely (semant. segmentácia)
- Podskupiny
- Atribúty
- Scény (udalosti)

Vlastné používateľské rozhrania

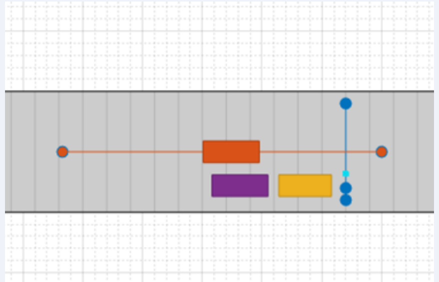
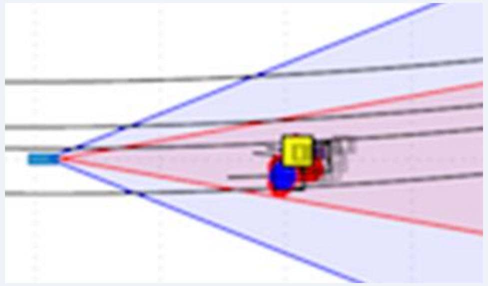
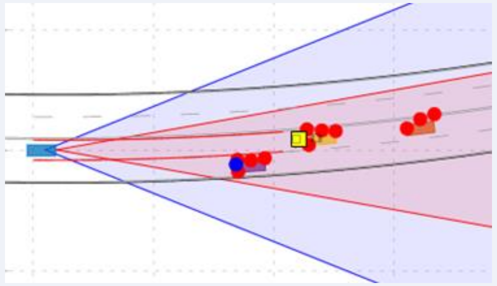
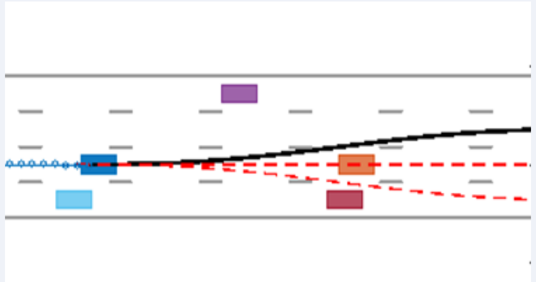
Nové príklady označovania dát

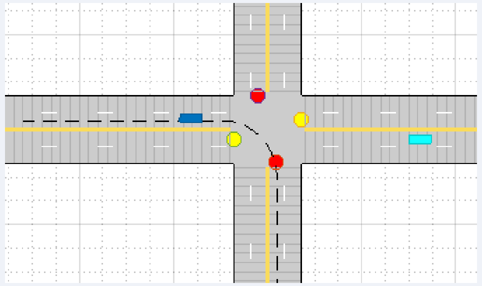
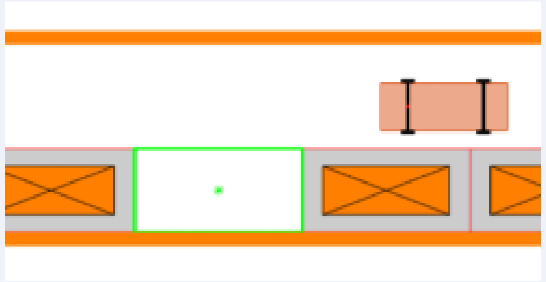
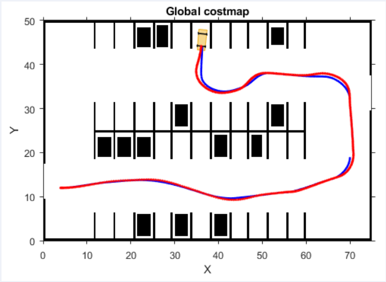
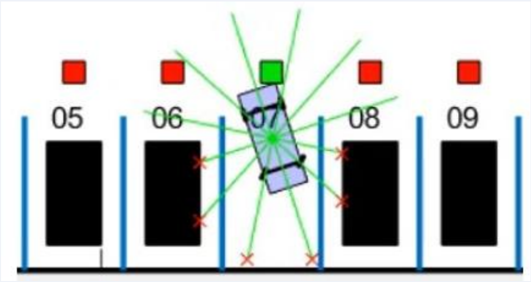
Označenie polygónov ROI	Označenie projektovaných cuboidov	Automatizácia označenia pre kameru a lidar
		
Label Objects Using Polygons *Automated Driving Toolbox™*	Ground Truth Labeler *Automated Driving Toolbox™*	Automate Ground Truth Labeling Across Multiple Signals *Automated Driving Toolbox™* *Lidar Toolbox™*
R2021a	R2020b	R2021a

Vývoj multidisciplinárnych zručností



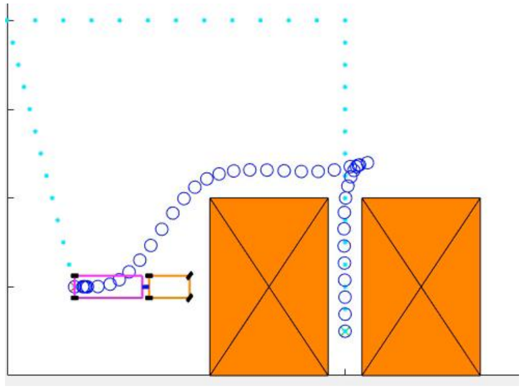
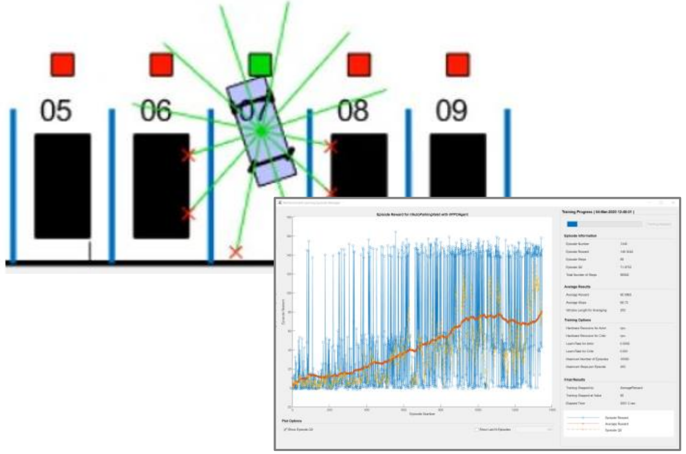
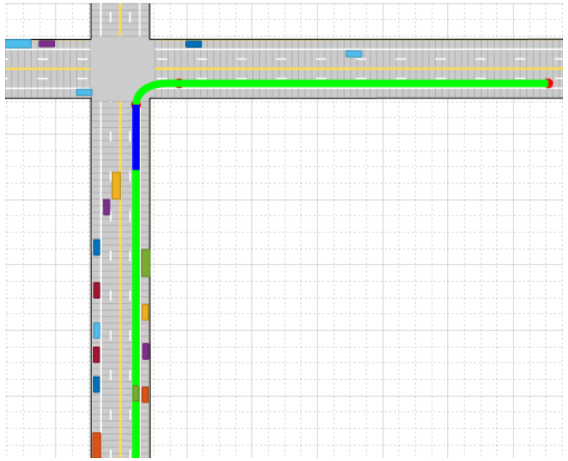
Návrh algoritmov plánovania a riadenia

Núdzové brzdenie	Adaptive Cruise Control	Sledovanie čiary	Zmena pruhu
			

Svetelná signalizácia	Paralelné parkovanie	Parkovisko	Reinforcement Learning
			

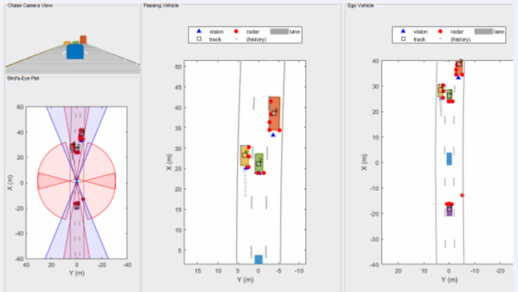
Často využívané nástroje: Automated Driving Toolbox, Model Predictive Control Toolbox, Stateflow, Navigation Toolbox, Reinforcement Learning, Robotics System Toolbox

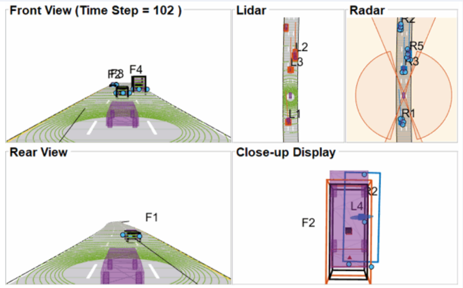
Nové príklady plánovania a riadenia

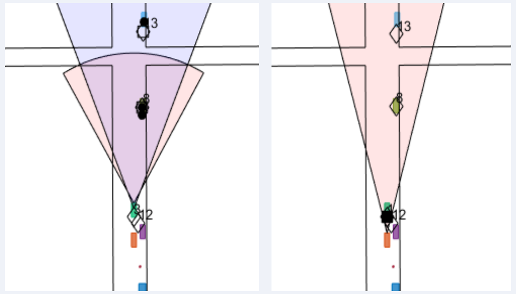
Plánovanie parkovania nákladného vozidla	Parkovanie metódou reinforcement learning	Plánovanie pre mestá
		
Truck and Trailer Automatic Parking Using Multistage Nonlinear MPC *Model Predictive Control Toolbox* *Robotics System Toolbox*	Train PPO Agent for Automatic Parking Valet *Reinforcement Learning Toolbox* *Model Predictive Control Toolbox*	Motion Planning in Urban Environments Using Dynamic Occupancy Grid Map *Automated Driving Toolbox,* *Navigation Toolbox,* *Sensor Fusion and Tracking Toolbox,*
R2021a	R2020b	R2021a

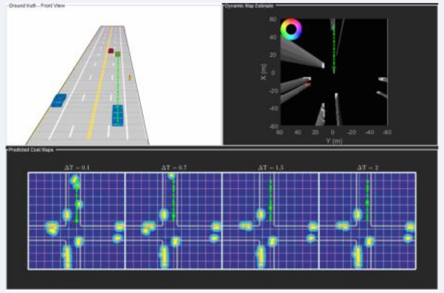
Algortimy sledovania a fúzie

Radar a kamera	Lidar a radar	Vehicle to Vehicle	Mriežky obsadenosti

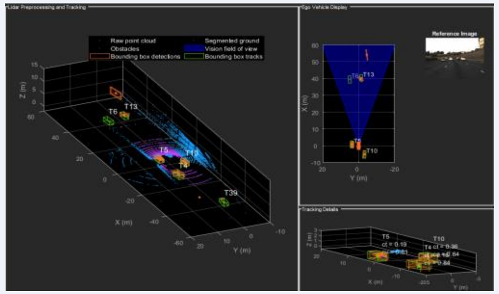


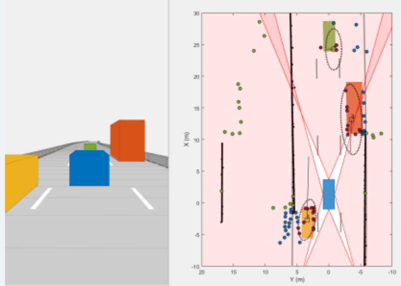


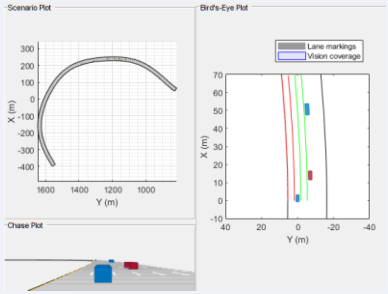




Kamera	Lidar	Radar s odrazmi	Hranice čiary





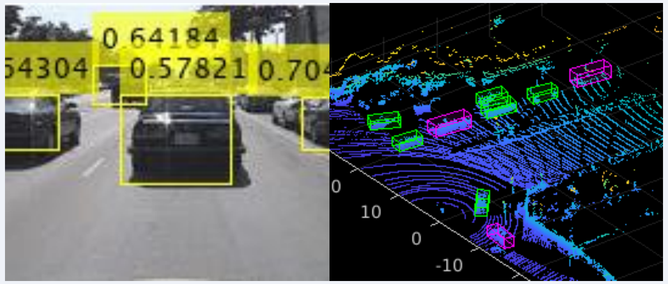


Často využívané nástroje: Automated Driving Toolbox, Tracking and Fusion Toolbox, Radar Toolbox

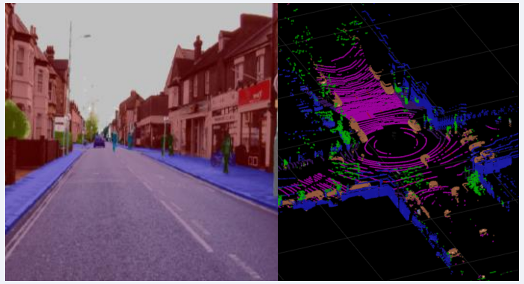
Algoritmy detekcie a lokalizácie

Čiary

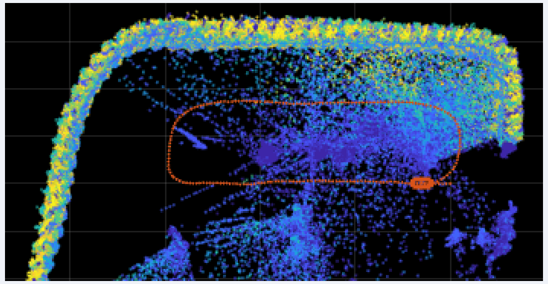
Objekty



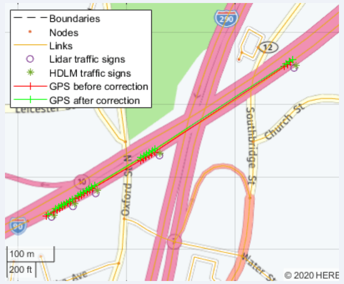
Sémantická segmentácia



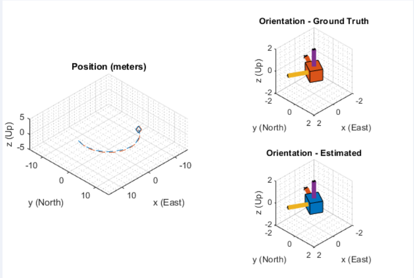
SLAM



Mapy



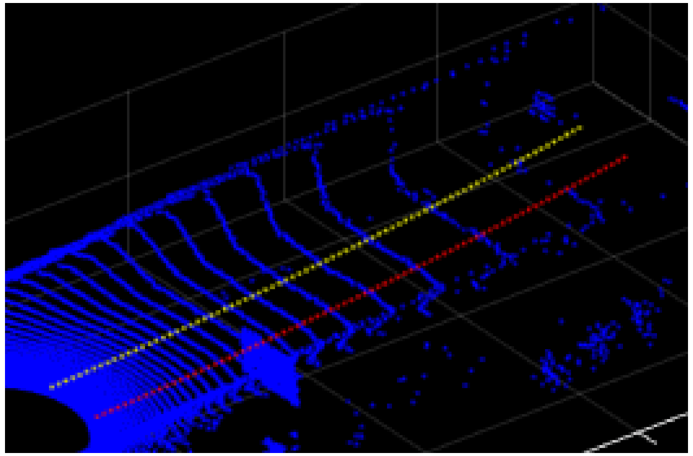
Inerciálna fúzia



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

Nové príklady detekcie s lidarom

Čiary

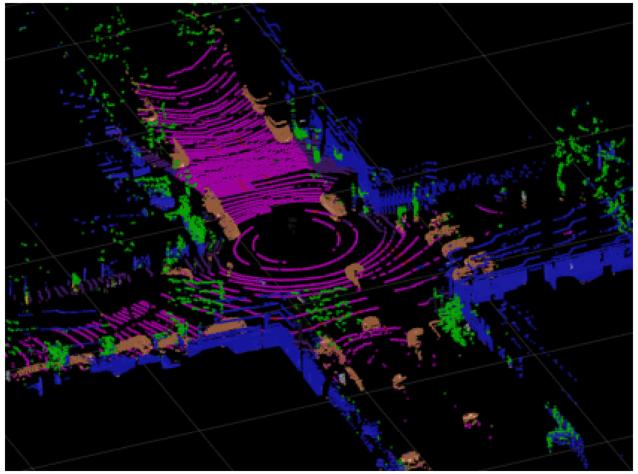


[Lane Detection in 3-D Lidar Point Cloud]

Lidar Toolbox™

R2021a

Sémantická segmentácia

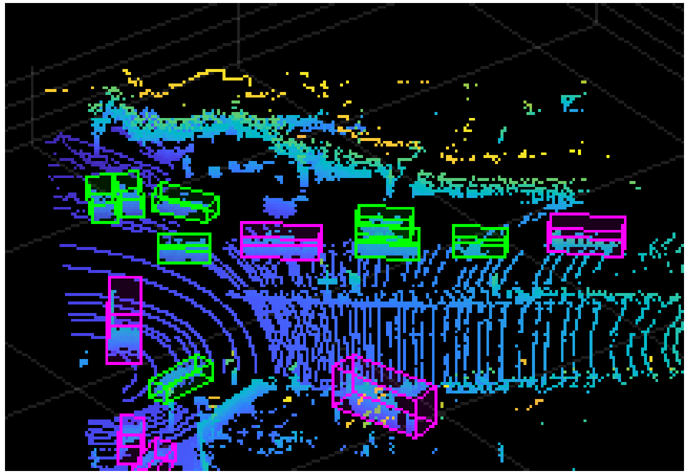


[Lidar Point Cloud Semantic Segmentation Using SqueezeSegV2 Deep Learning Network]

Lidar Toolbox™,
Deep Learning Toolbox™

Updated R2021a

PointPillars



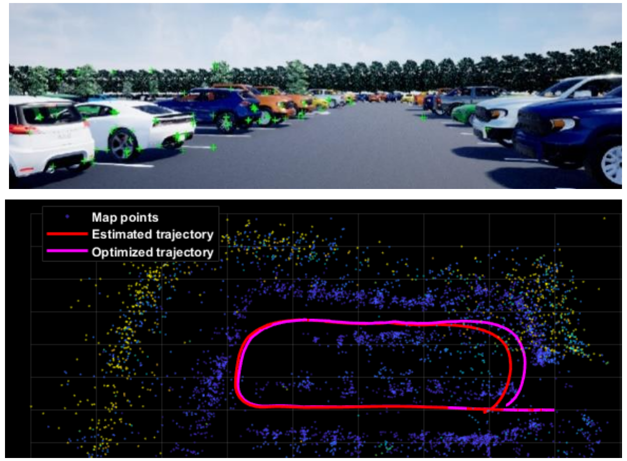
[Lidar 3-D Object Detection Using PointPillars Deep Learning]

Lidar Toolbox™,
Deep Learning Toolbox™

Updated R2021a

Nové príklady pre SLAM algoritmus

Monokulárna kamera

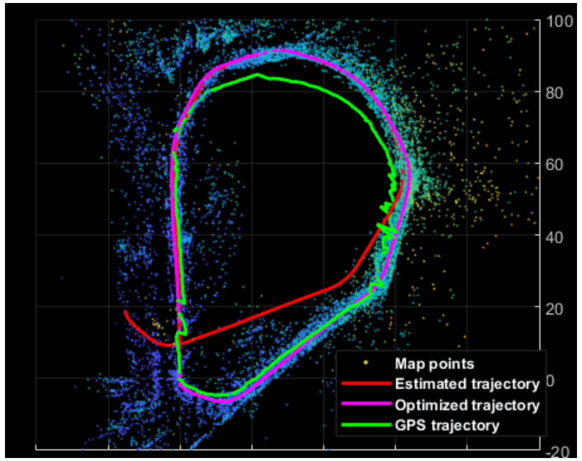


[Develop Visual SLAM Algorithm Using Unreal Engine Simulation]

Automated Driving Toolbox™
Computer Vision Toolbox™
Navigation Toolbox™

R2020b

Stereo kamera

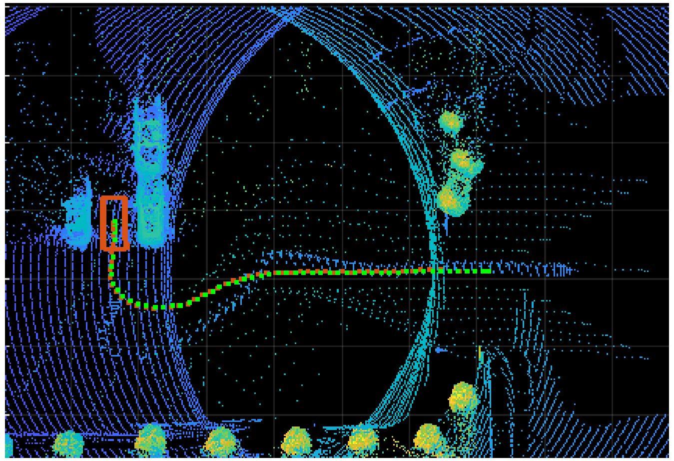


[Stereo Visual Simultaneous Localization and Mapping]

Computer Vision Toolbox™

R2021a

Lidar

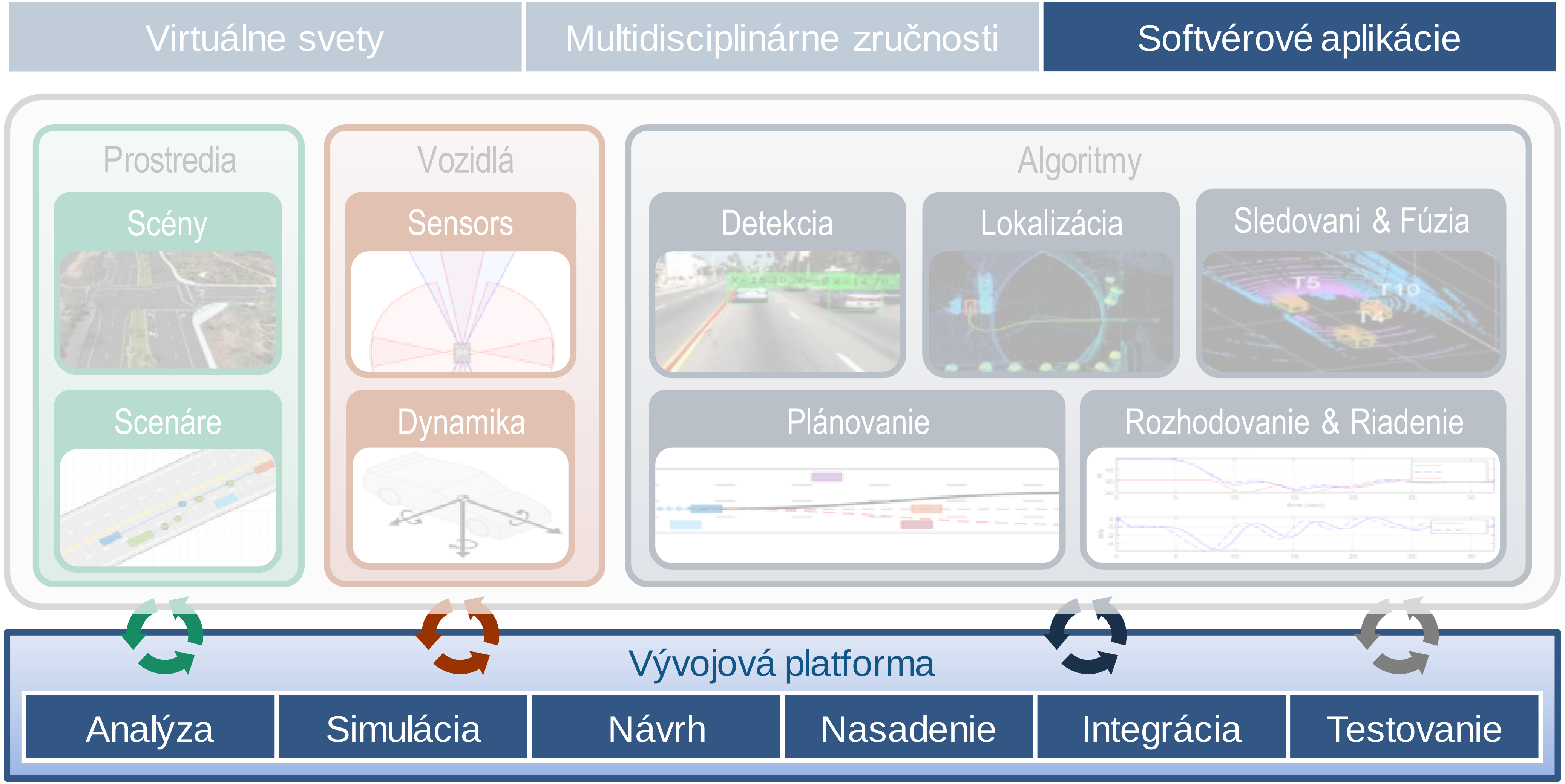


[Design Lidar SLAM Algorithm using 3D Simulation Environment]

Automated Driving Toolbox™
Computer Vision Toolbox™
Navigation Toolbox™

R2020b

Výuoj systémov autonómneho riadenia

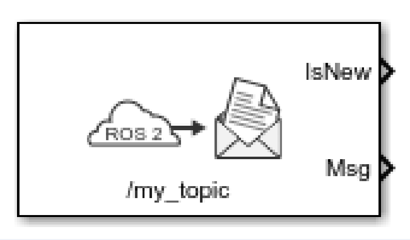


Vývoj softvérových aplikácií

Kód

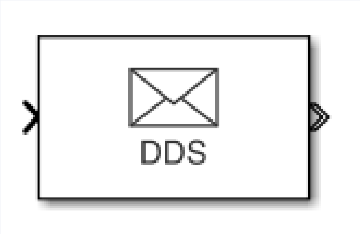
C | C++ | GPU | HDL

ROS / ROS 2.0

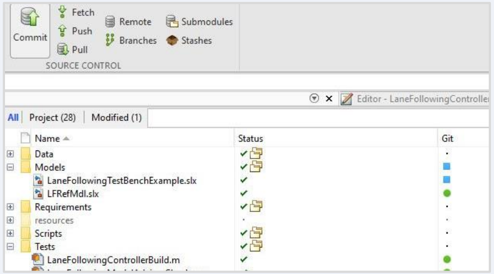


AUTOSAR

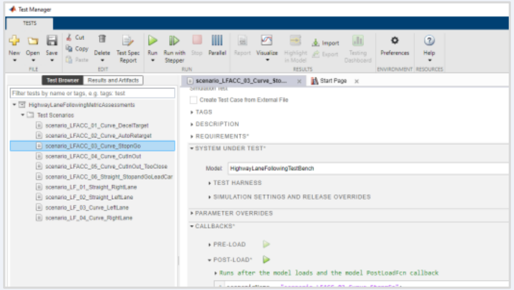
DDS



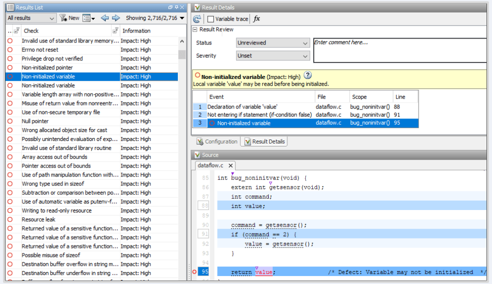
Continuous Integration



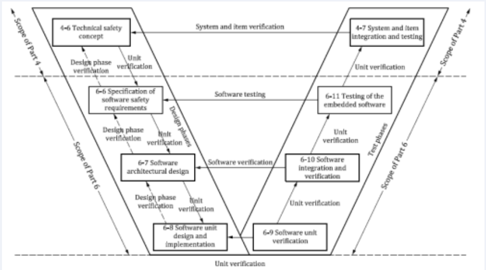
Automatické testovanie



Analýza kódu

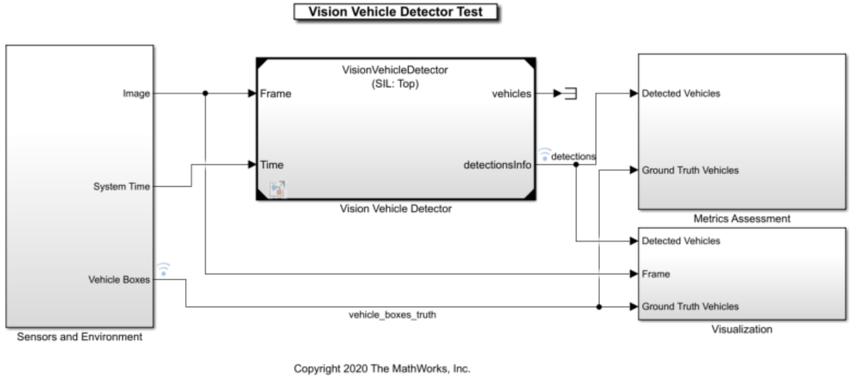


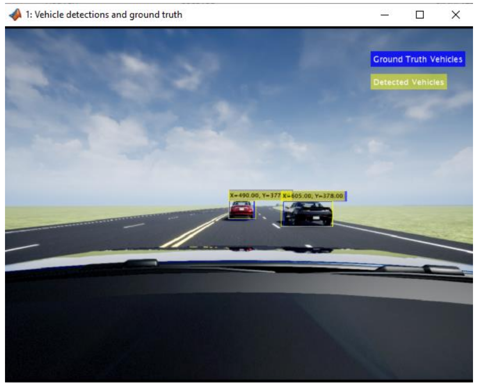
ISO 26262



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,

Generovanie C/C++ a GPU kódu v Simulinku

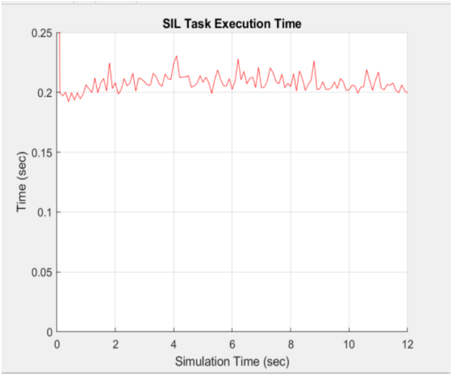


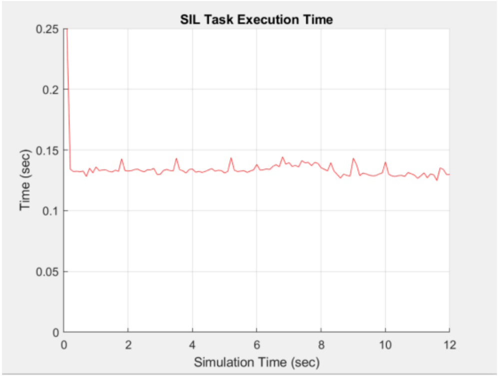


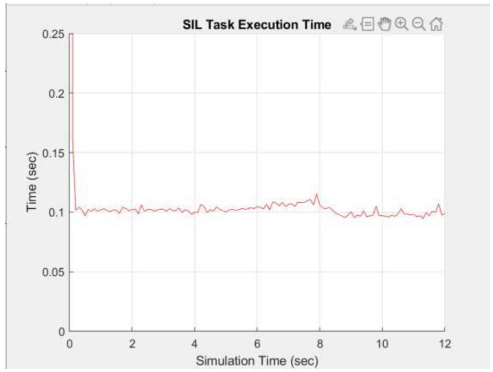
- Generovanie kódu, verifikácia funkcii a meranie času vykonávania pomocou Software-In-the Loop (SIL)

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

YOLOv2 CPU - MKLDNN	YOLOv2 GPU - cuDNN	YOLOv2 GPU - tensorRT







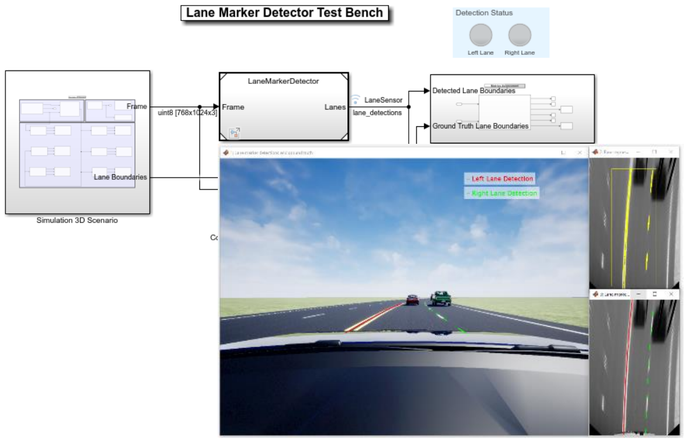
[Generate Code for Vision Vehicle Detector]

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

R2021a

Nové príklady generovania C/C++ kódu

Nasadenie sledovania čiary do C/C++

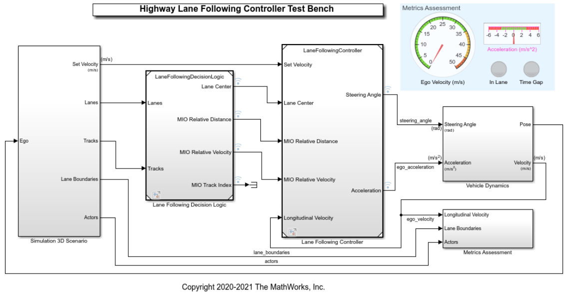


[Generate Code for Lane Marker Detector]

Automated Driving Toolbox™
Embedded Coder

R2020b

Nasadenie riadenia do C/C++



Summary

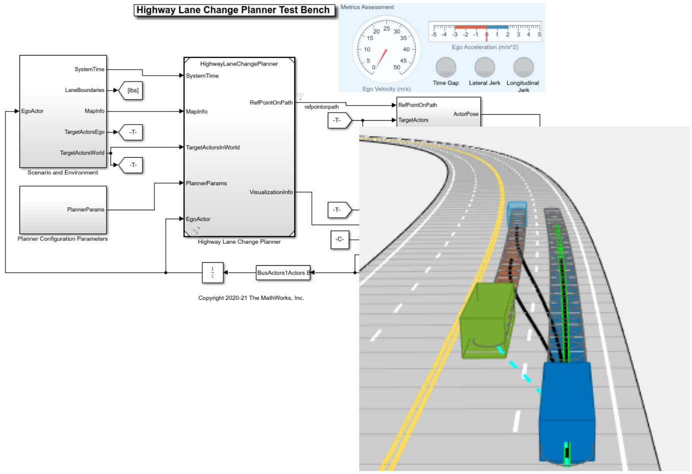
File/Complexity		Test 1 Decision	Statement	Function	Function call	Relational Boundary
TOTAL COVERAGE	200	81%	90%	85%	94%	11%
1. . . . LaneFollowingController.cpp	43	41%	54%	75%	67%	4%
2. . . . LaneFollowingControllerAPV_PathFollowingControlSystem.cpp	152	90%	96%	100%	98%	21%
3. . . . LaneFollowingController_capi.cpp	5	--	95%	80%	100%	--

[Generate Code for Highway Lane Following Controller]

Automated Driving Toolbox™
Model Predictive Control Toolbox™
Embedded Coder

R2021a

Nasadenie plánovania do C/C++

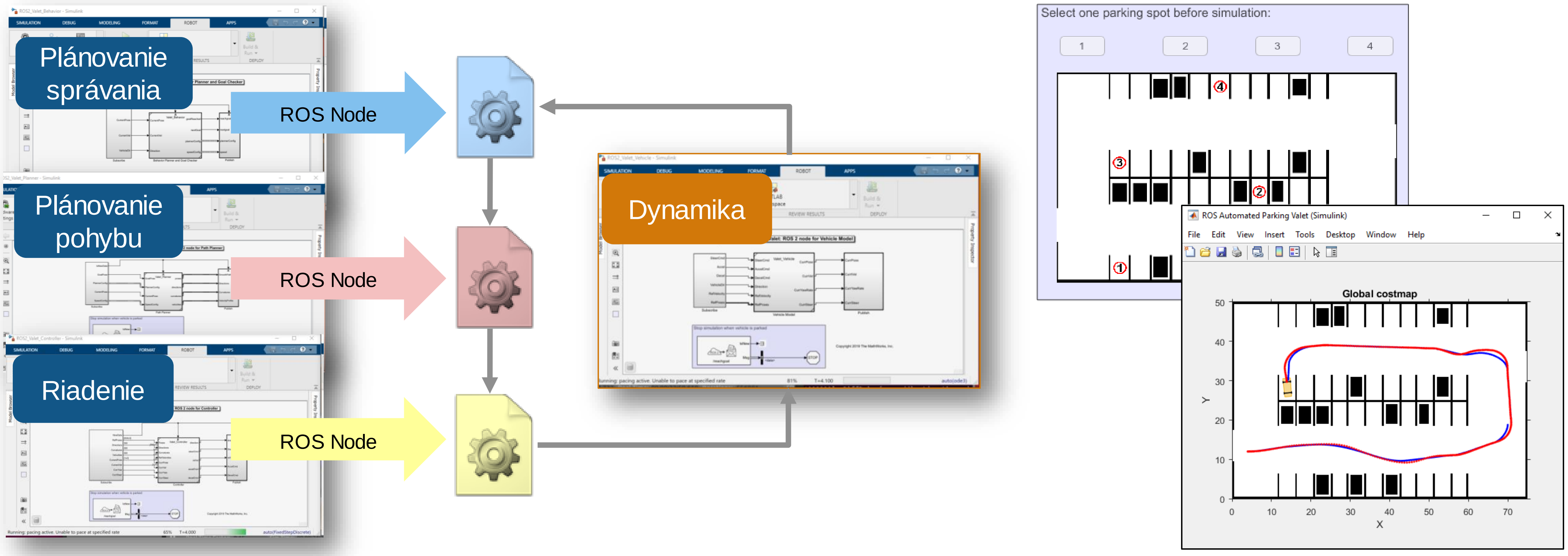


[Generate Code for Highway Lane Change Planner]

Automated Driving Toolbox™
Navigation Toolbox™
Embedded Coder

R2021a

Nasadenie plánovania a riadenia do ROS / ROS 2.0



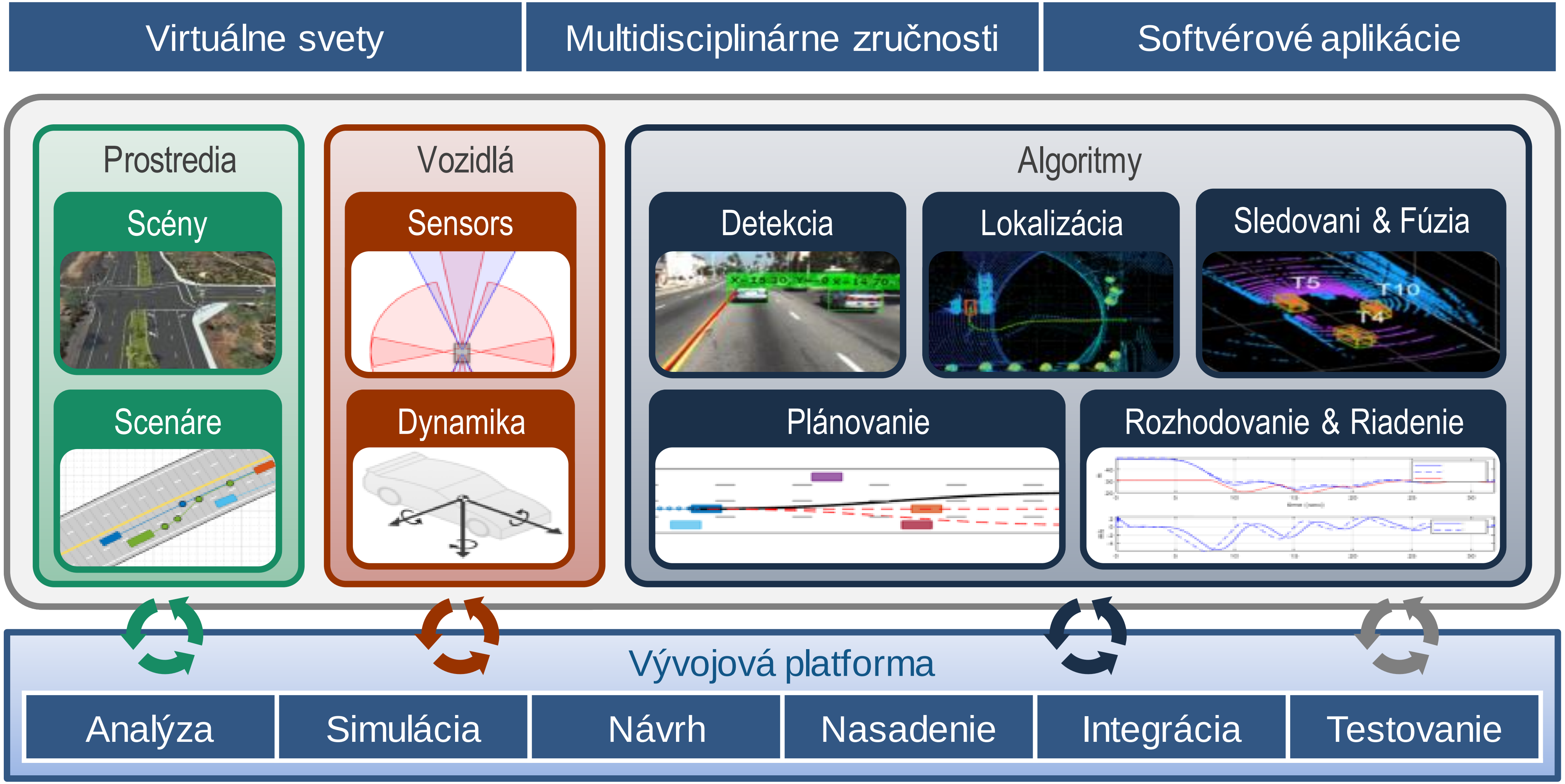
[Automated Parking Valet with ROS in Simulink](#)

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

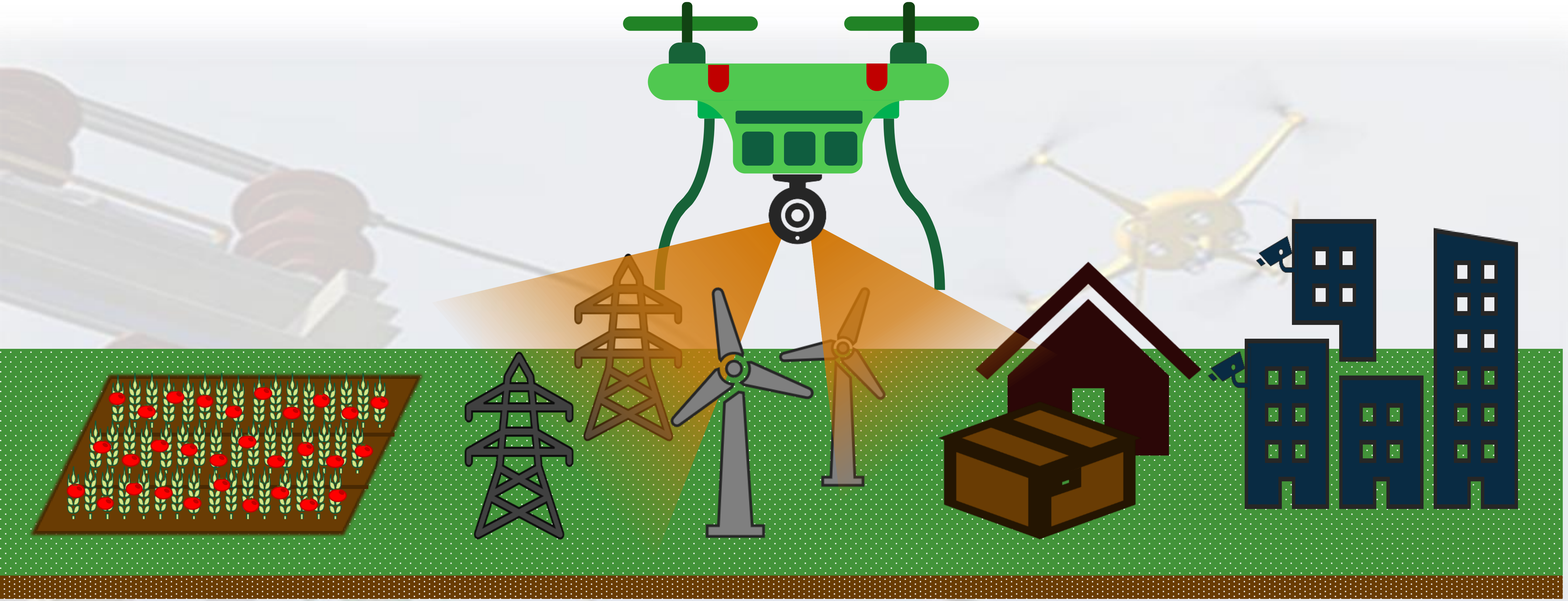
ROS Toolbox, Embedded Coder®, Automated Driving Toolbox™, Model Predictive Control Toolbox™

R2020b

Vývoj systémov autonómneho riadenia



Autonómne UAV



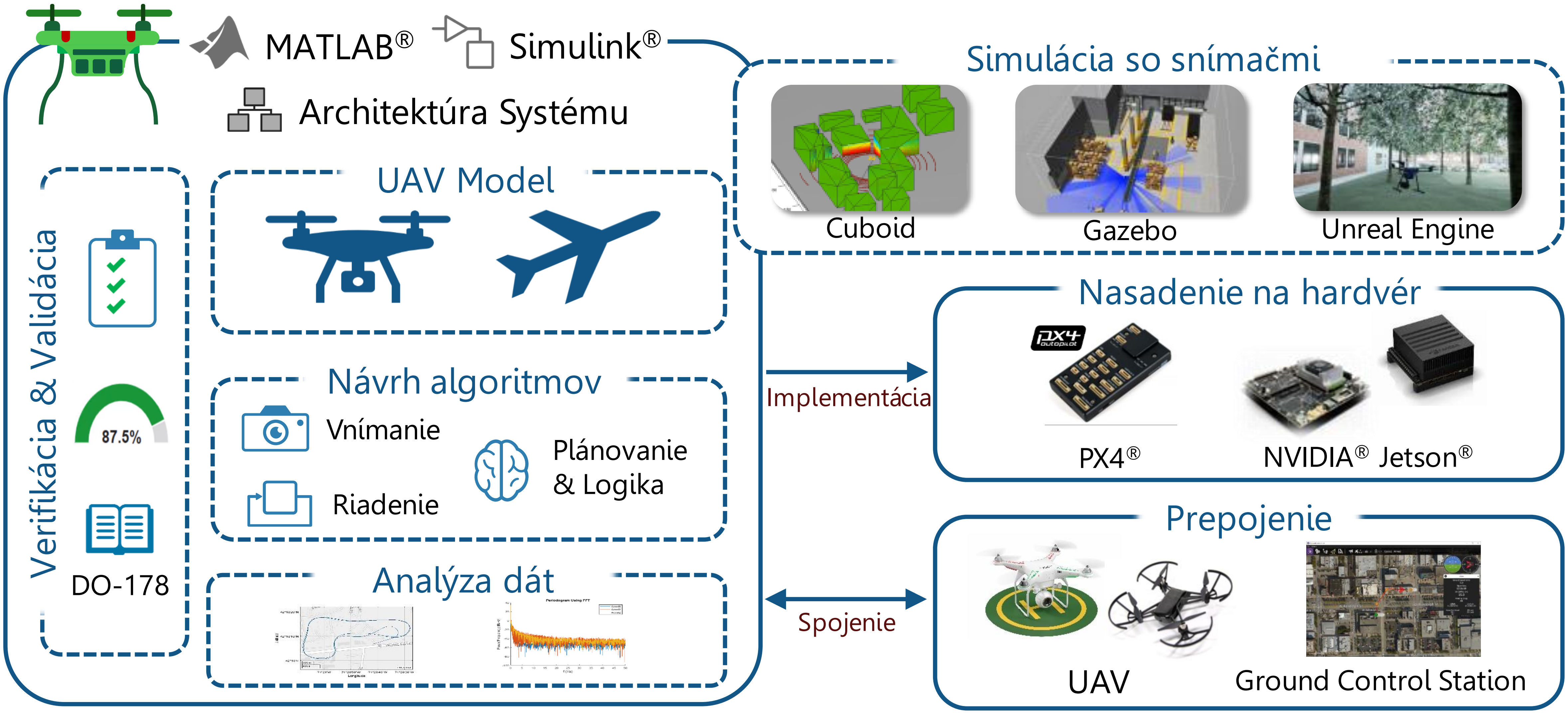
Mapovanie a prieskum

Inšpekcie a monitorovanie

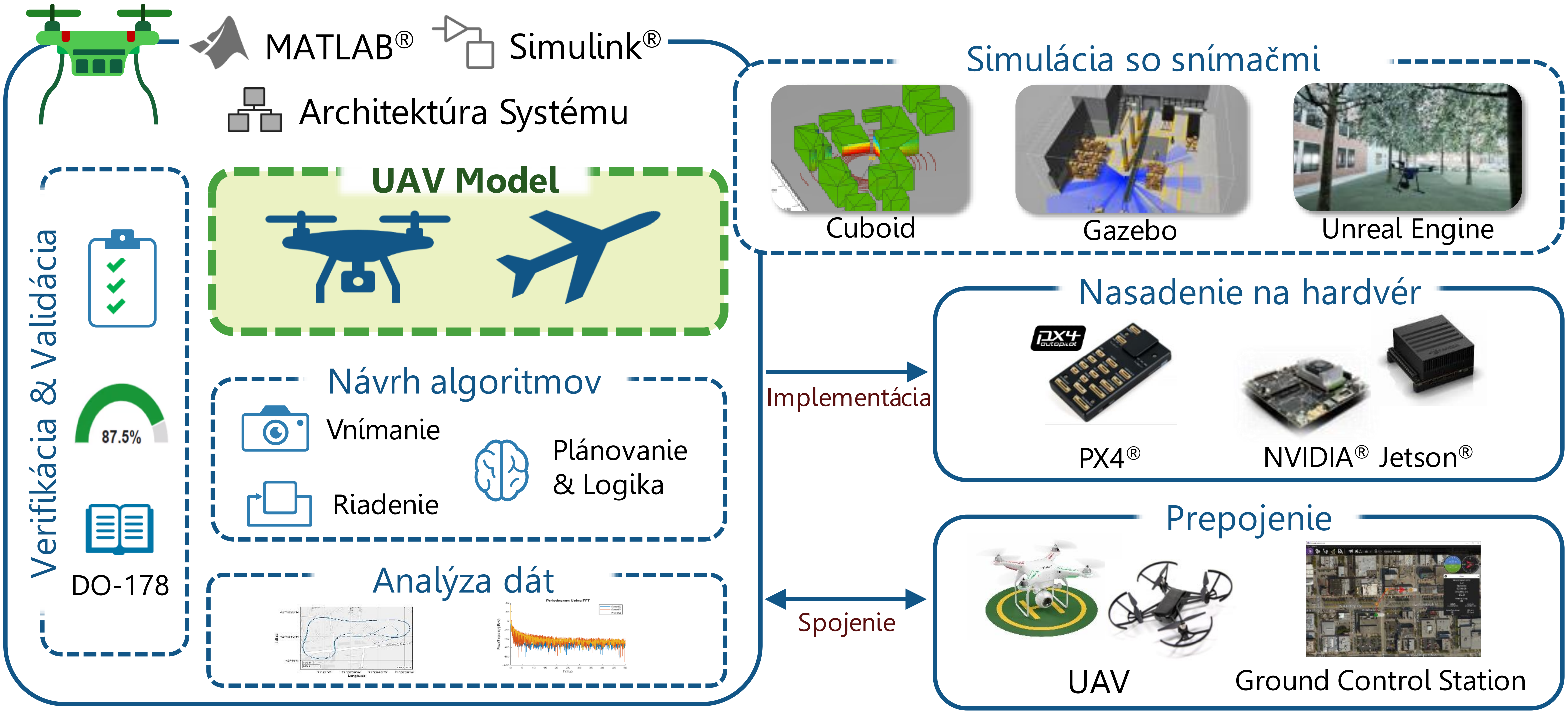
Doručovanie a doprava

Bezpečnosť a obrana

Vývoj UAV aplikácií



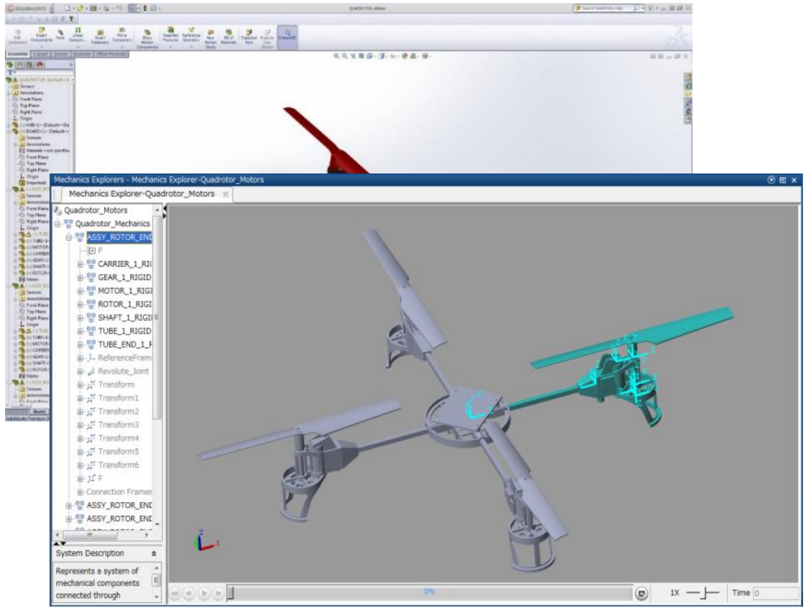
Výjvoj UAV aplikácií



UAV Model: Výbeh vhodnej zložitosti

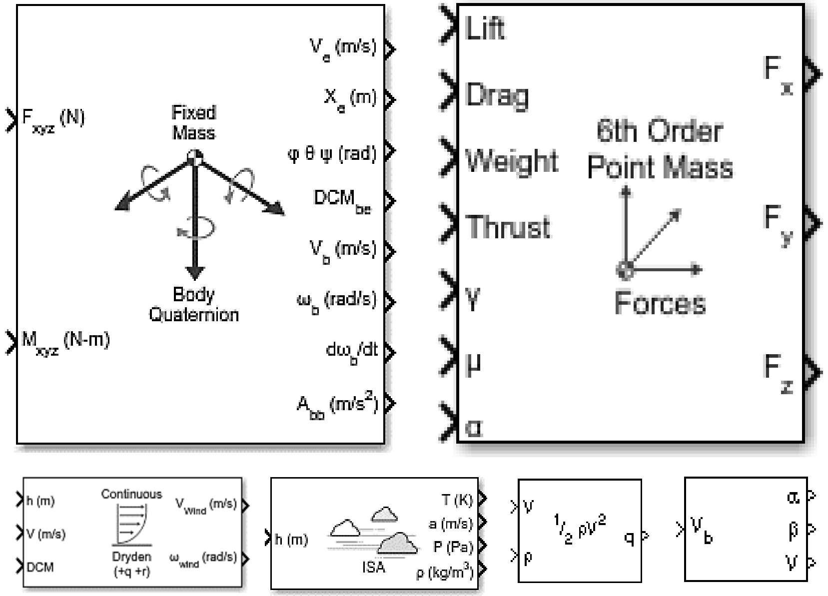
Vysoká presnosť
Stavba UAV

Aproximácia
Programvanie UAV



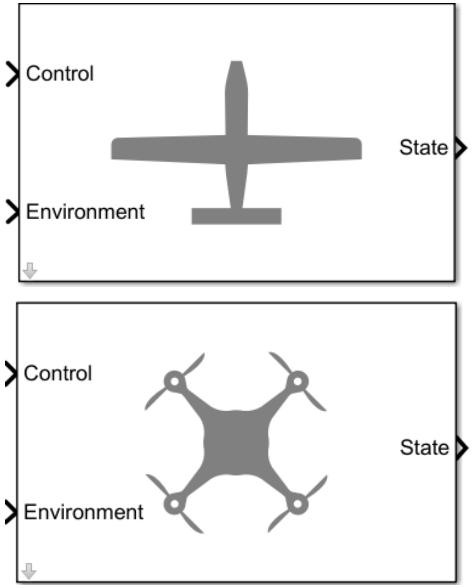
Physical Modeling Link

Model construction techniques and best practices, domain-specific modeling, physical units



Vehicle Dynamics Link

Model aerodynamics, propulsion, and motion of aircraft and spacecraft

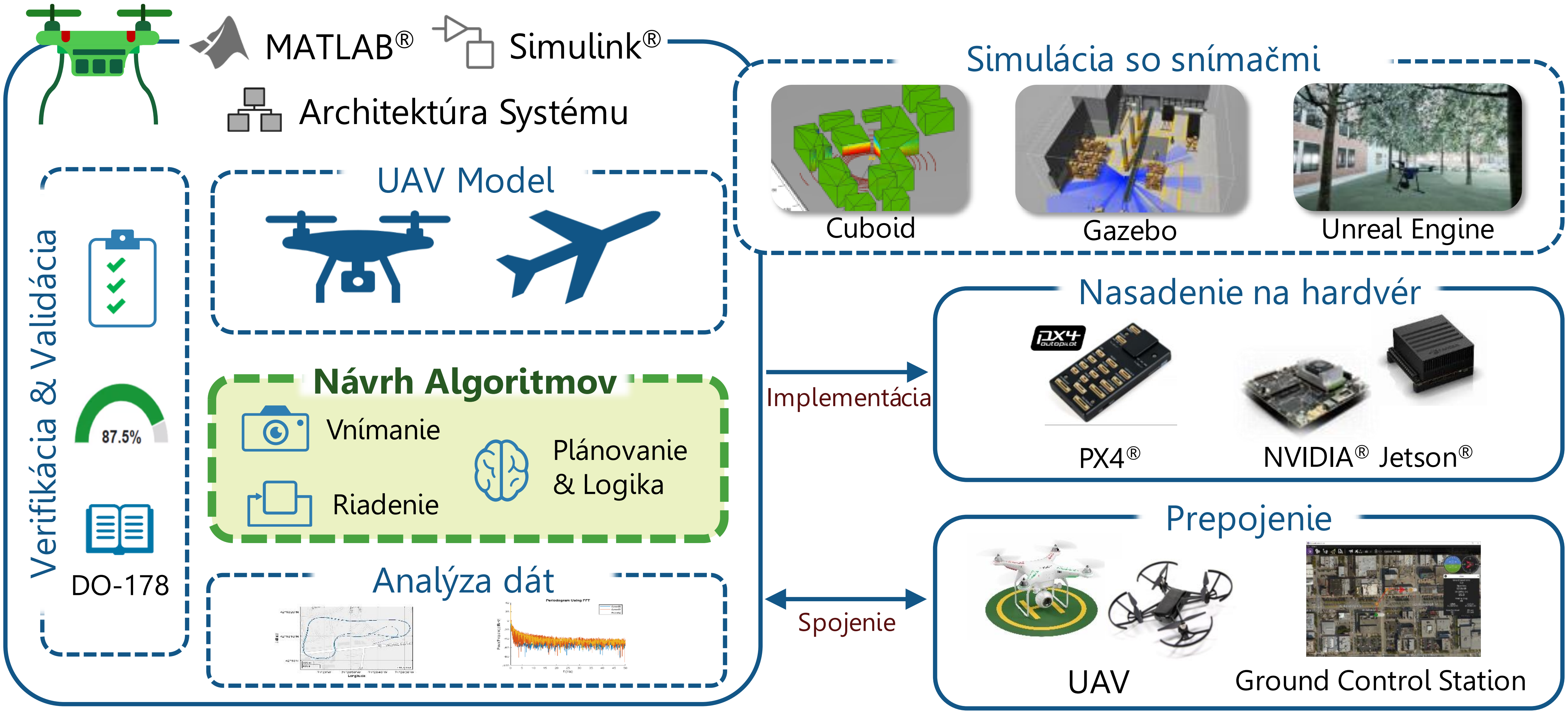


Guidance Model Link

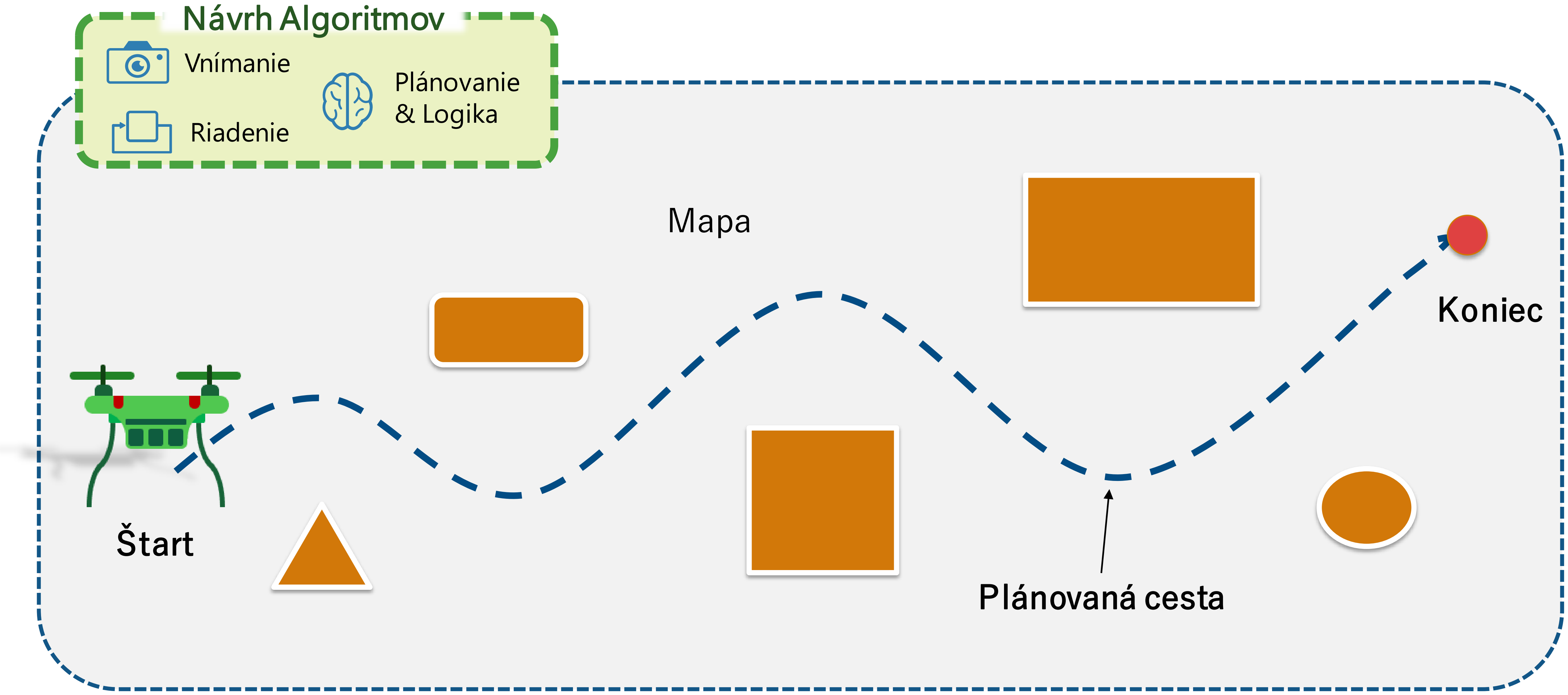
Reduced-order model for UAV

 Simscape Multibody, Aerospace Blockset, UAV Toolbox

Vývoj UAV aplikácií



Vývoj autonómnych UAV algoritmov



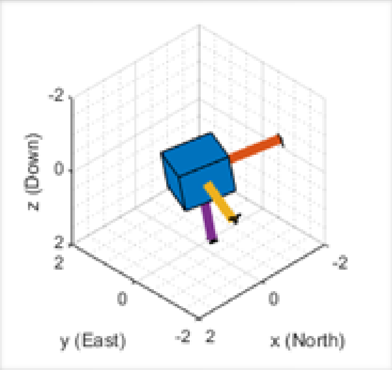
Vývoj autonómnych UAV algoritmov

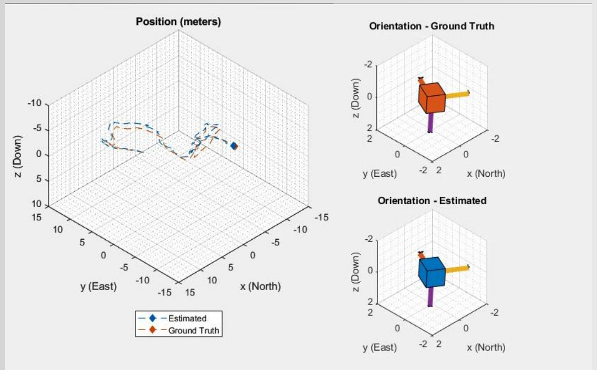
Vnímanie

Plánovanie & Logika

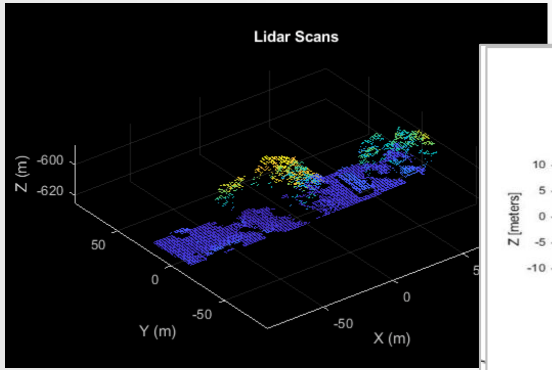
Riadeine

Vlastné vnímanie

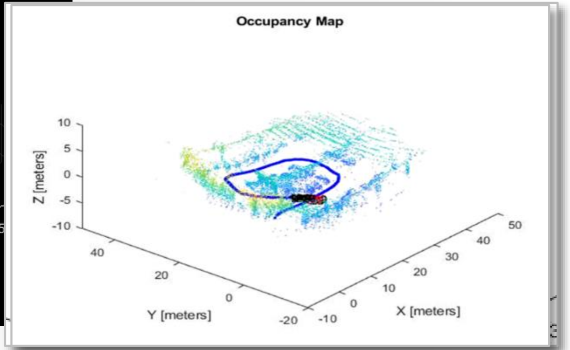




Link

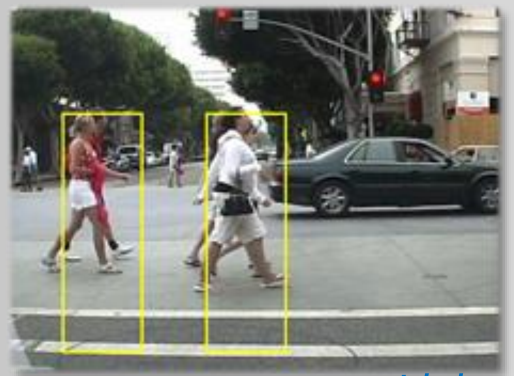


Link

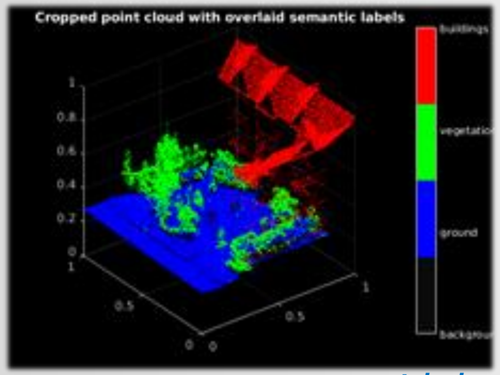


Link

Situačné vnímanie

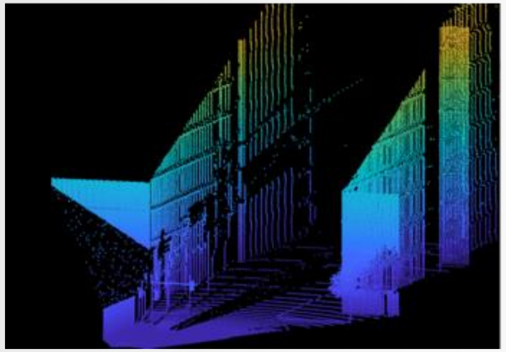


Link

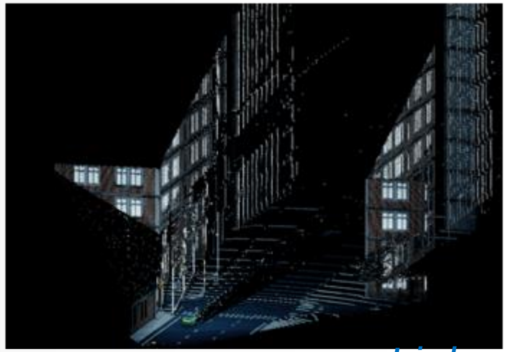


Link

Lidar point cloud data



Fused lidar and camera data



Link

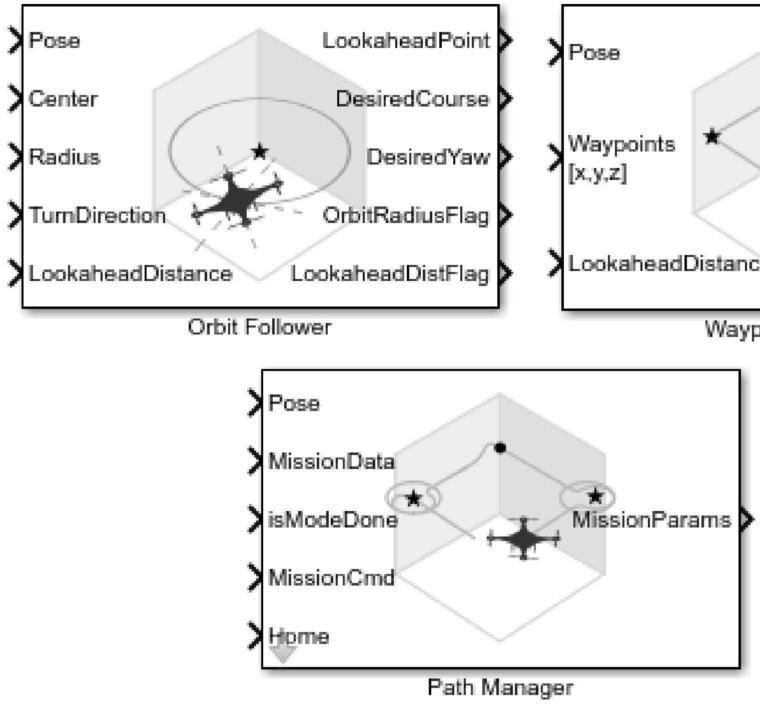
 Sensor Fusion and Tracking Toolbox, Lidar Toolbox, Navigation Toolbox, Computer Vision Toolbox, Deep Learning Toolbox

Vývoj autonómnych UAV algoritmov

Vnímanie

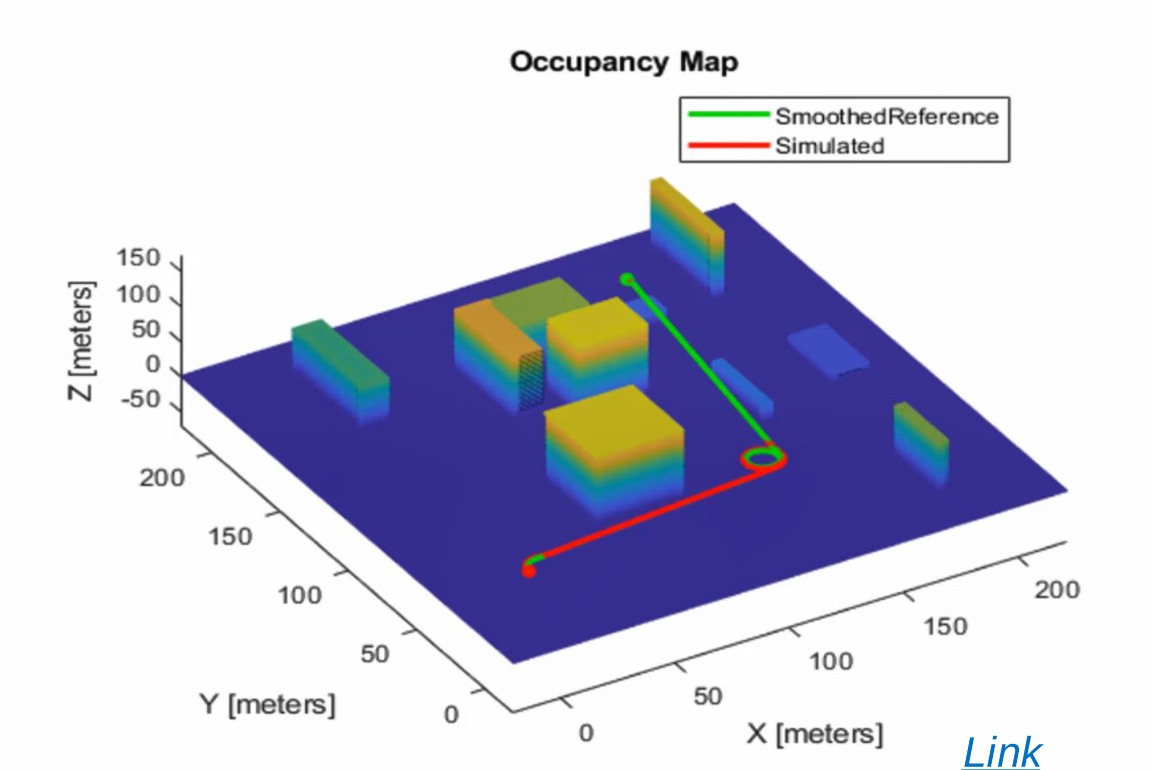
Plánovanie & Logika

Riadenie



Link

Definícia UAV misie s bodmi a algoritmami sledovania trajektórie



Link

Plánovanie UAV pohybu s s pokročilými plánovačmi

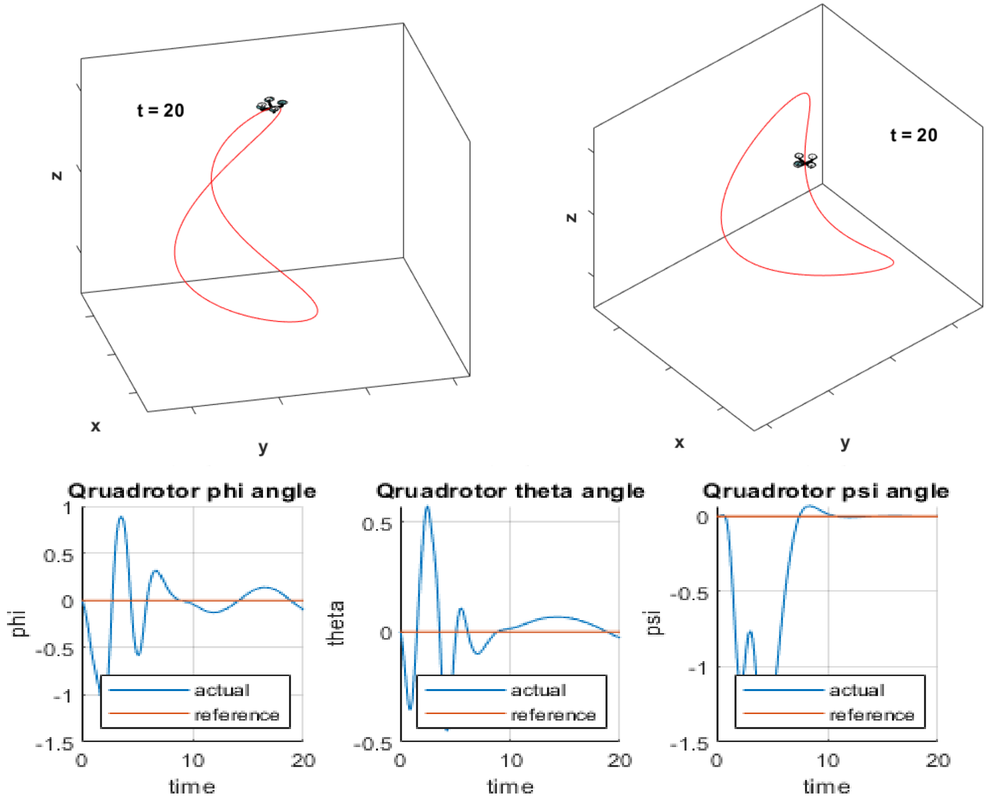
 UAV Toolbox, Navigation Toolbox

Výyvoj autonómnych UAV algoritmov

Vnímanie

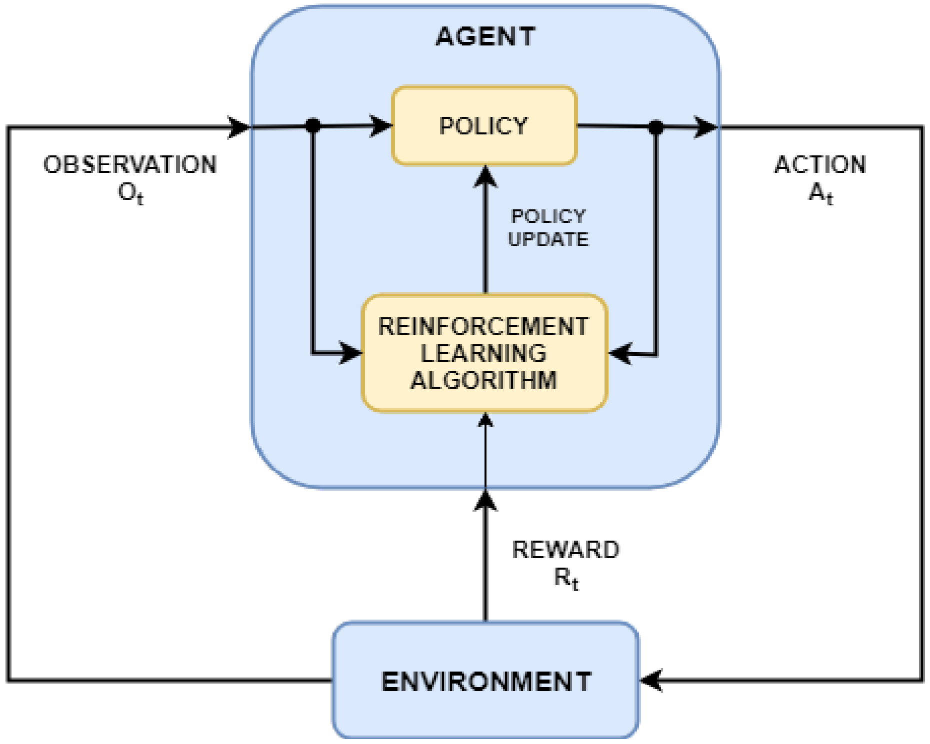
Plánovanie & Logika

Riadenie



Link

Regulátor sledovania trajektórie s nelineárnym MPC



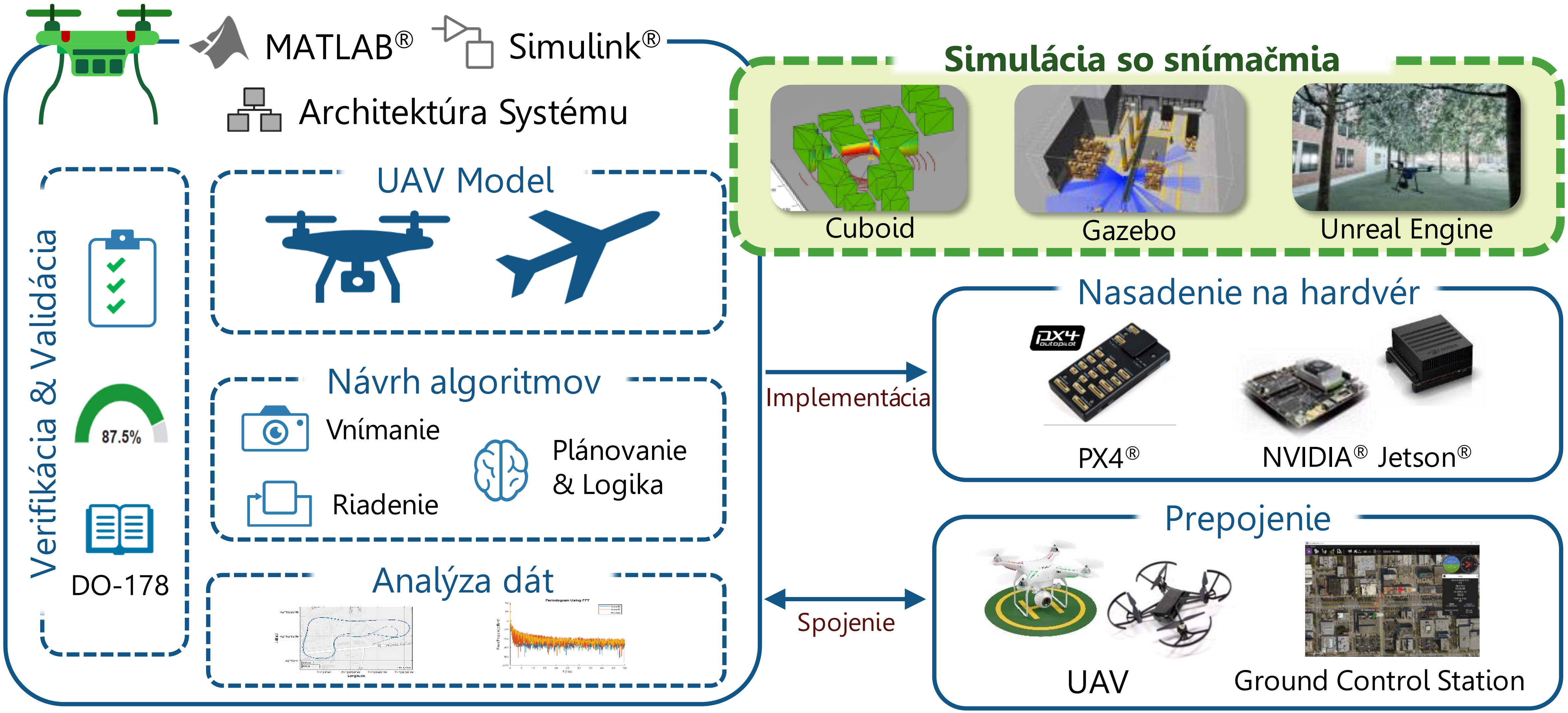
Link

Trénovanie policy pre generovanie trajektórie s využitím reinforcement learning

 Model Predictive Control Toolbox, Reinforcement Learning Toolbox

HUMUSOFT

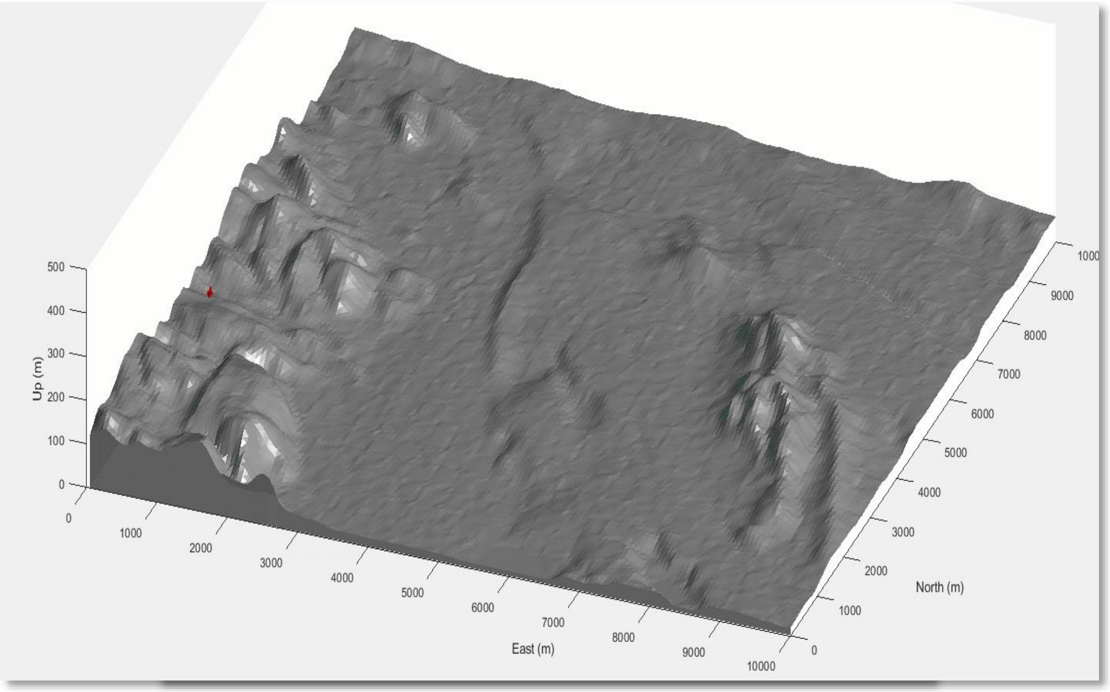
Vývoj UAV aplikácií



Simulácia s modelom snímačov

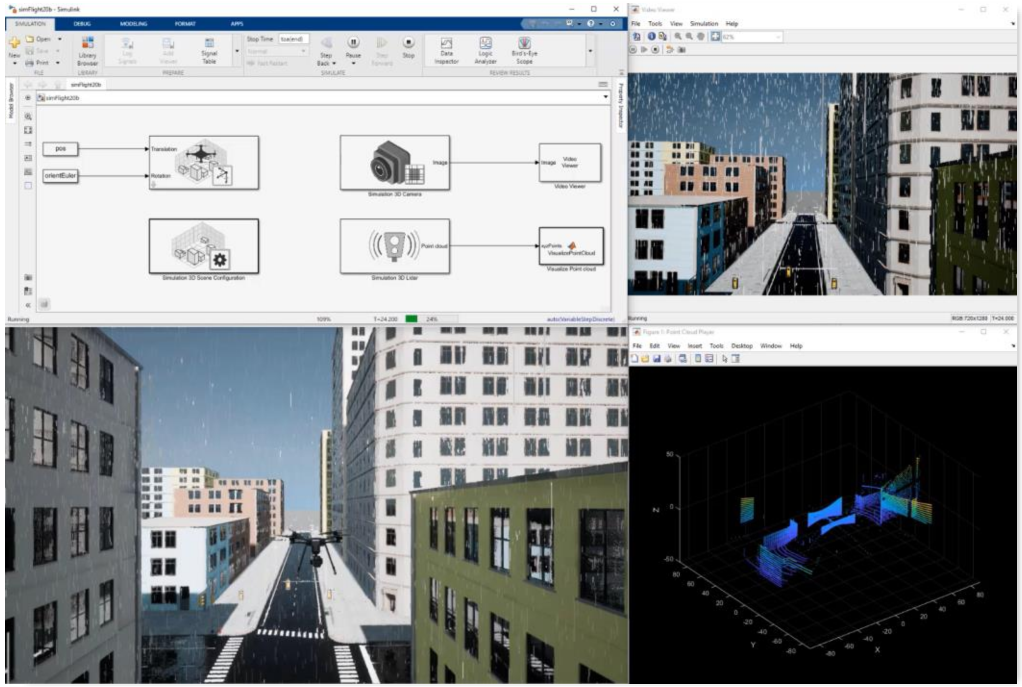
Cuboid
Výkon

Unreal Engine®
Realistické



Rýchla tvorba scenárov a generovanie dát zo snímačov

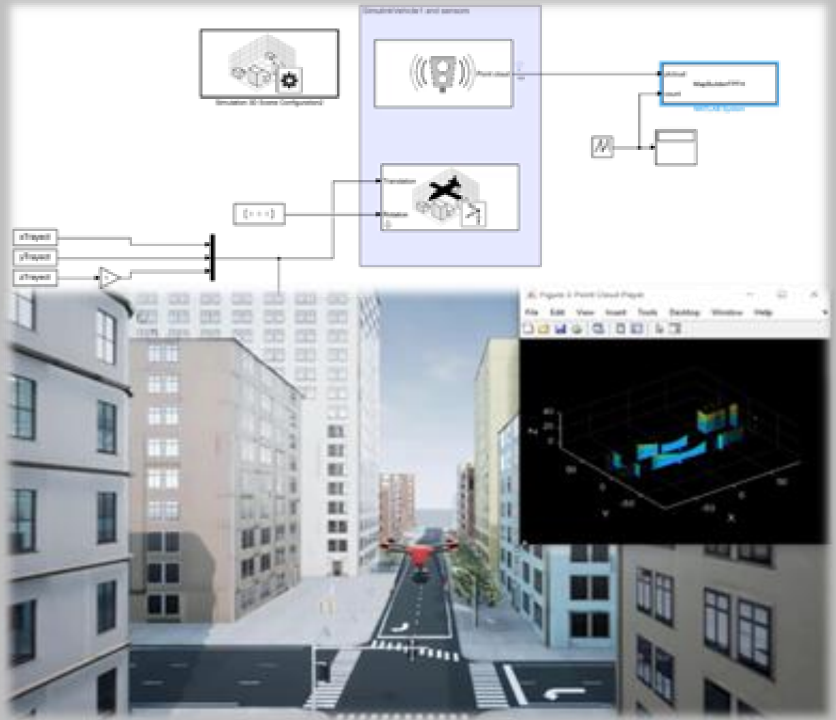
Link

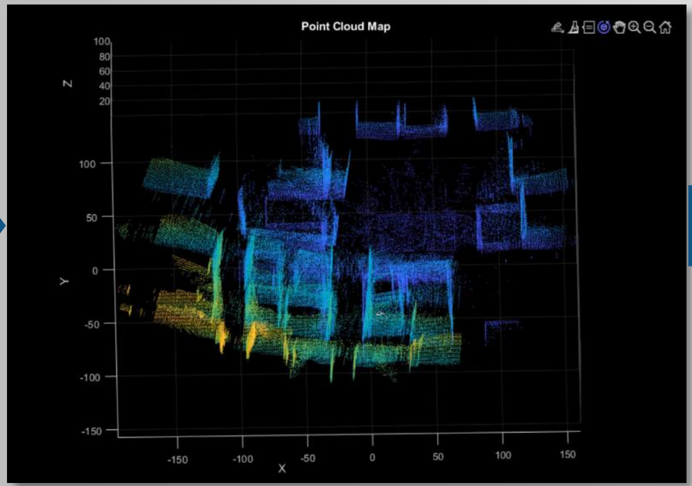


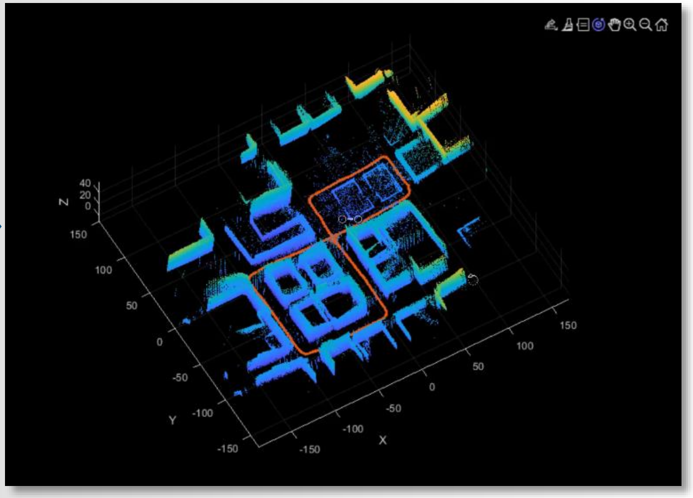
Realistická grafika na testovanie autonómnych algoritmov

Link

Príklad: Tvorba 3D mapy s Lidarom







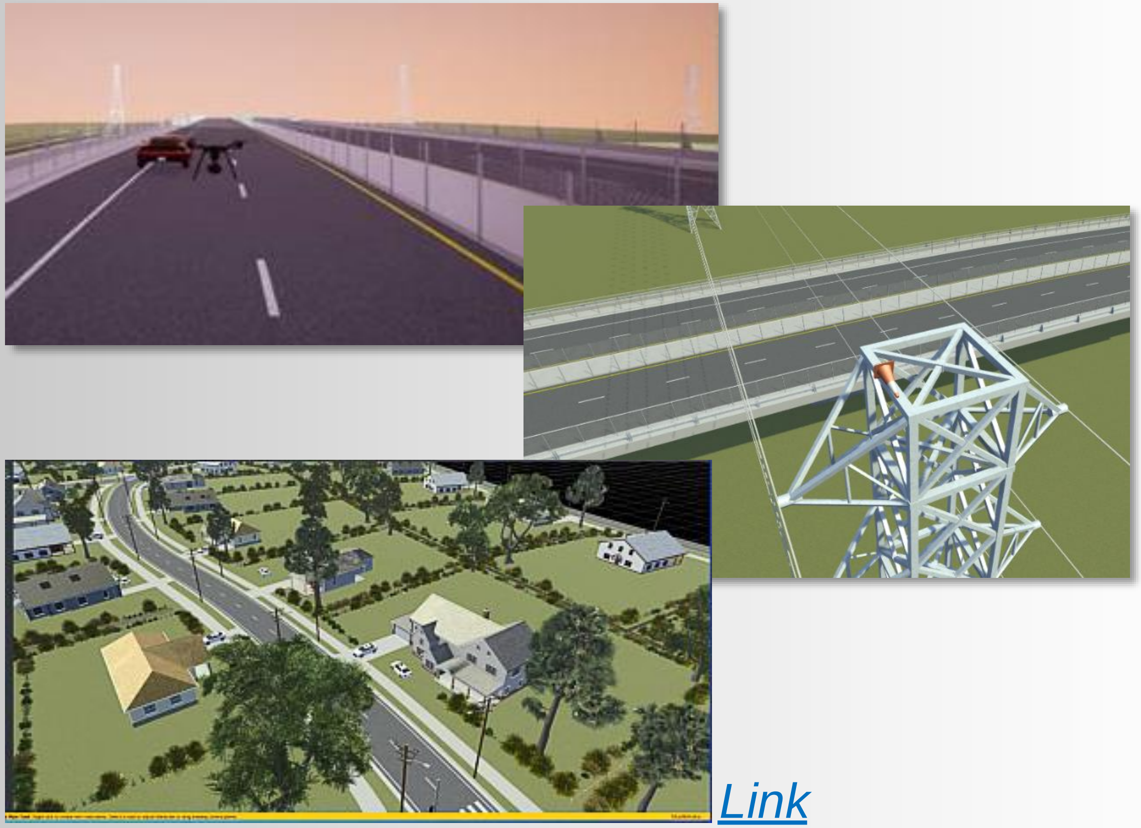
Simulácia
Dáta zo snímačov

Výber a porovnanie
Registrácia a zarovnanie

Detekcia slučiek
Tvorba mapy
Optimalizácia

Tvorba 3D scén pre UAV simulácie

Link

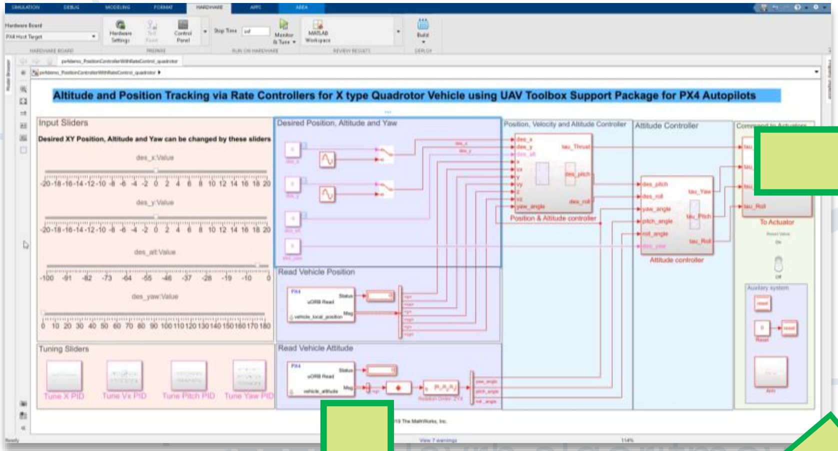


Link

Návrh 3D scén pre simuláciu a testovanie autonómnych algoritmov

 RoadRunner, RoadRunner Asset Library, UAV Toolbox Interface for Unreal Engine Projects

Automatické generovanie kódu



Nasadenie riadenia na hardvér autopilota

Link

Nasadenie algoritmov na embedded zariadenia

Link

Nasadenie na hardvér

PX4®

NVIDIA® Jetson®

CPU

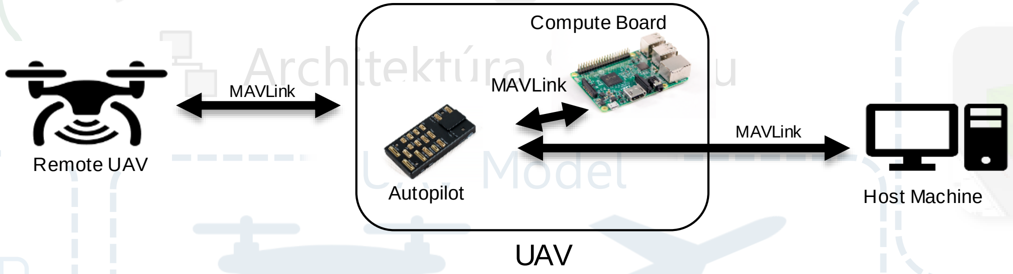
FPGA

GPU

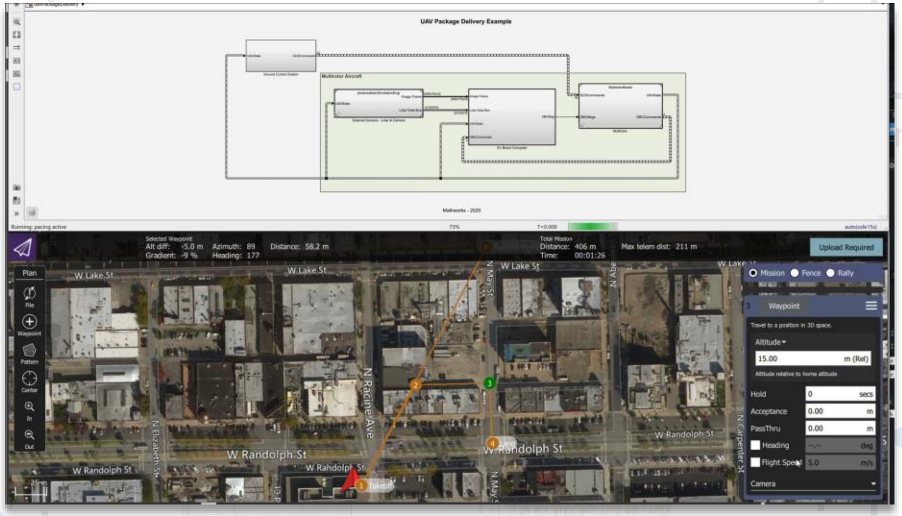
ROS

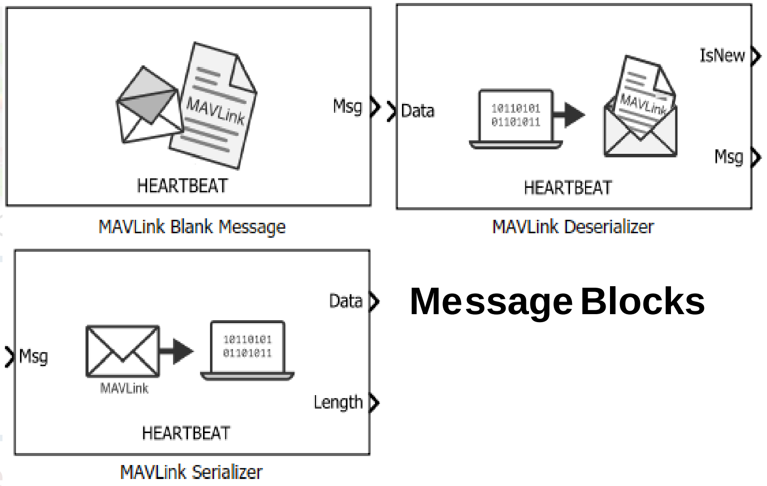
 UAV Toolbox, Simulink Coder, Embedded Coder, GPU Coder

Pripojenie k UAV pomocou MAVLink protokolu



MAVLink spojenie

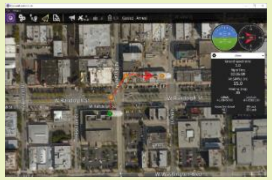




Message Blocks

[Link](#)

Pripojenie

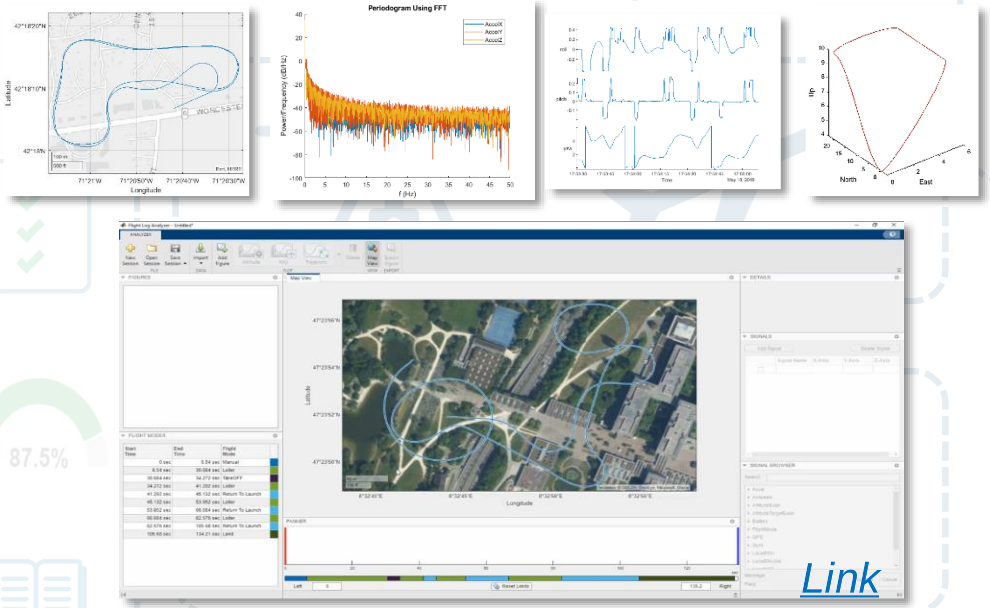


UAV | Ground Control Station

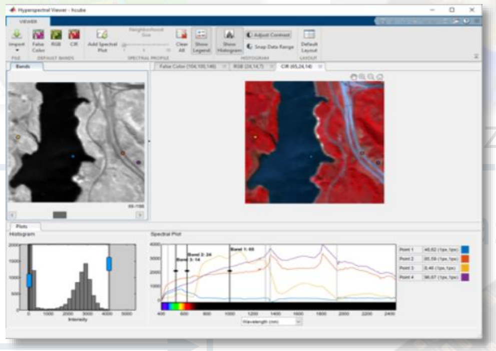
Analýza letových dát

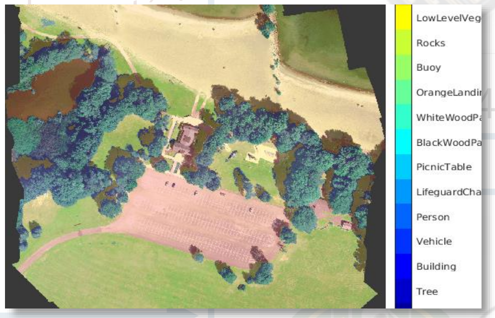
Analýza letových logov

Analýza ďalších dát



Link

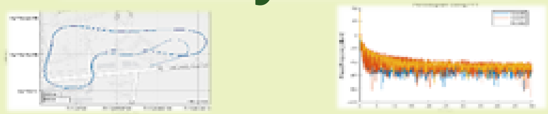




Link

Link

Analýza Dát



 UAV Toolbox, Computer Vision Toolbox, Deep Learning Toolbox

Vývoj UAV aplikácií

MATLAB® Simulink®

Architektúra Systému

Verifikácia & Validácia

87.5%

DO-178

UAV Model

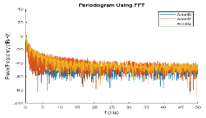
Návrh algoritmov

Vnímanie

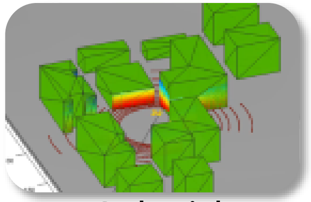
Riadenie

Plánovanie & Logika

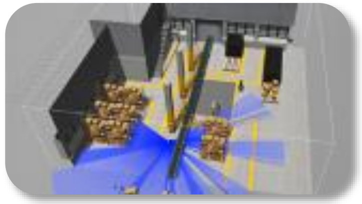
Analýza dát



Simulácia so snímačmi



Cuboid



Gazebo

Unreal Engine

Implementácia

Nasadenie na hardvér

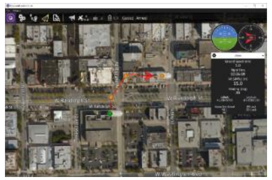
PX4®

NVIDIA® Jetson®

Spojenie

Prepojenie

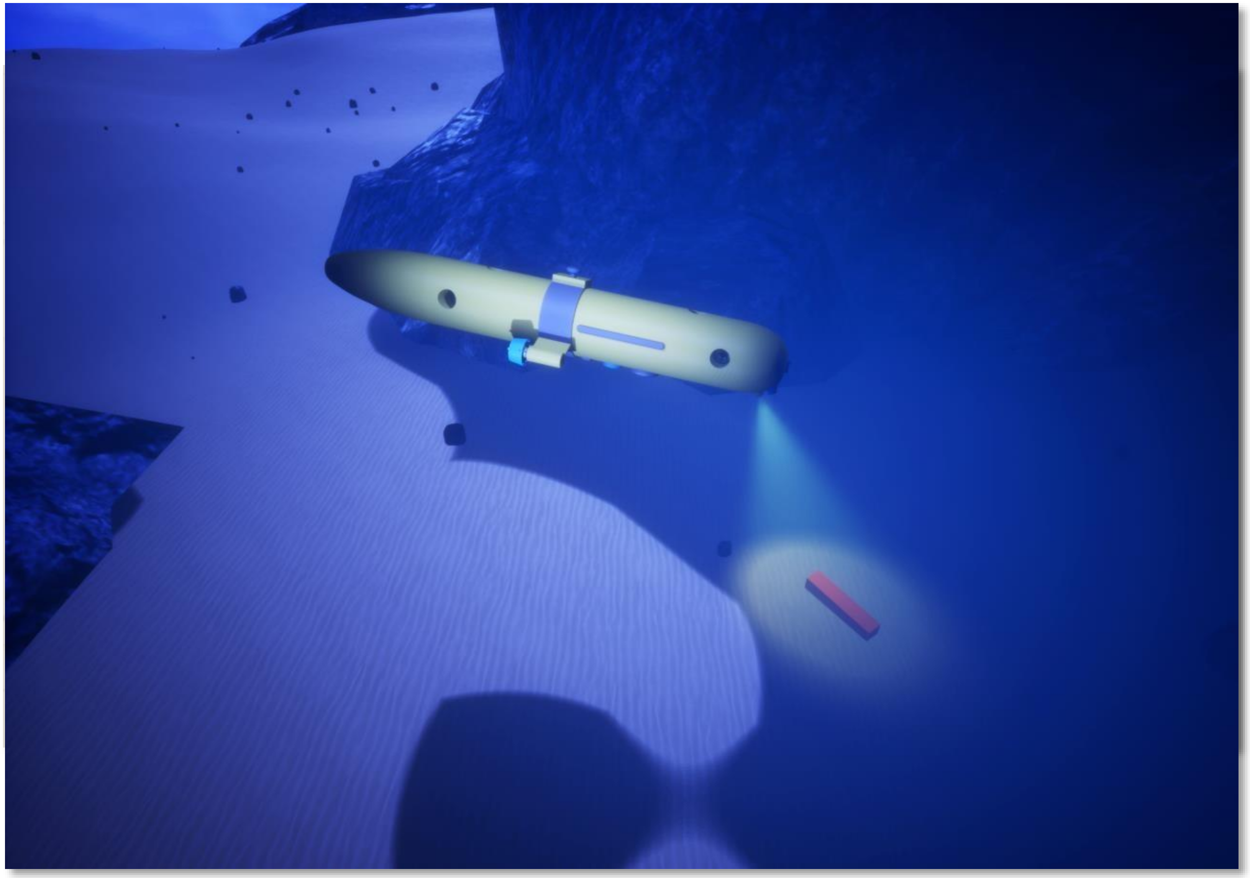
UAV



Ground Control Station

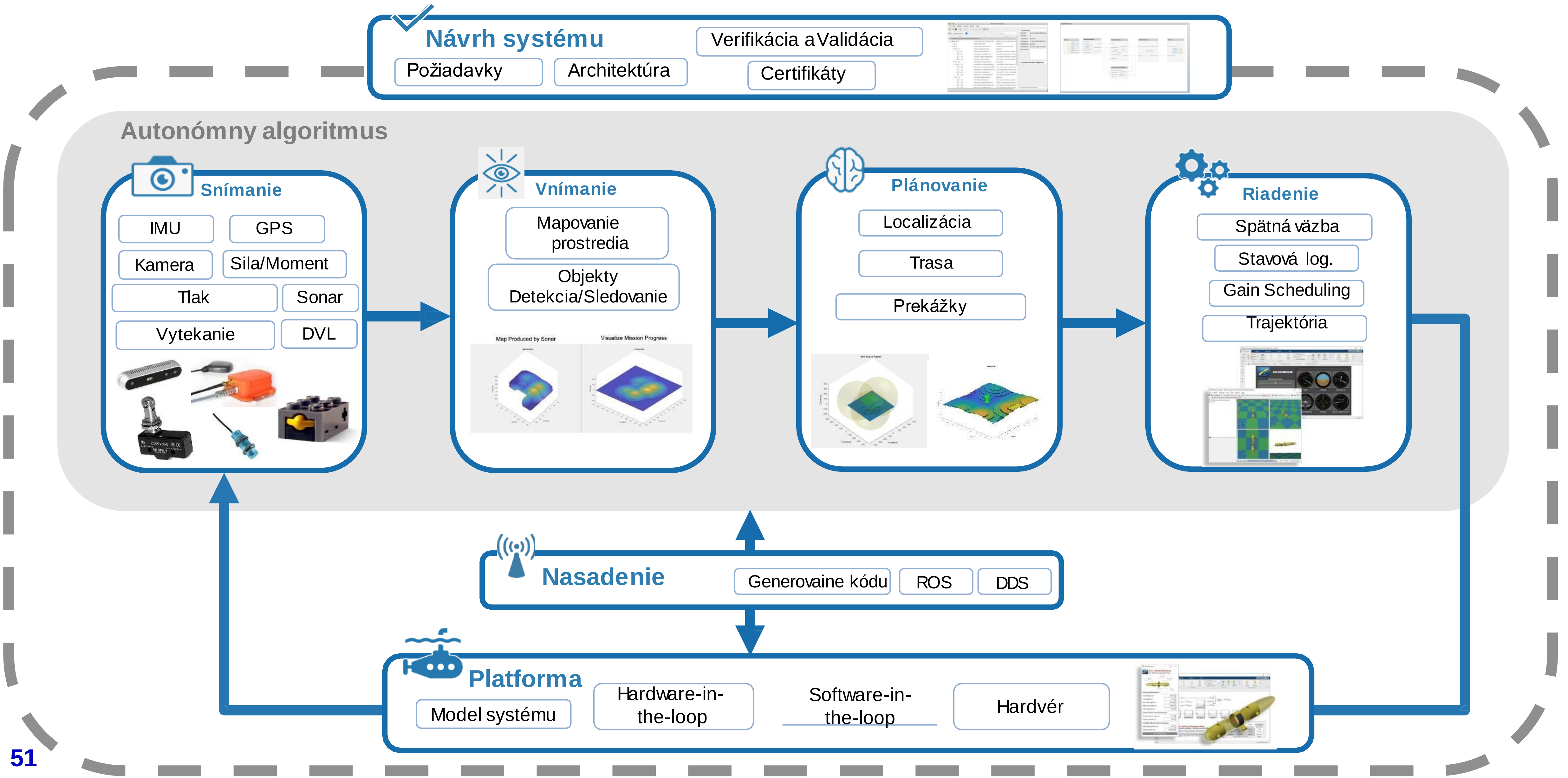
Vývoj AUV aplikácií

- **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

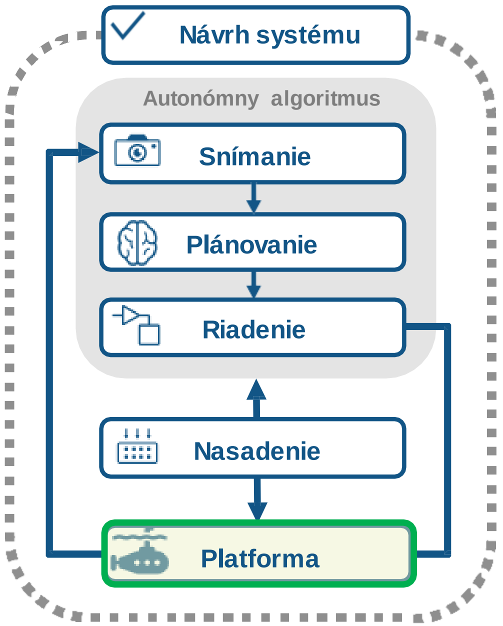
Vývoj AUV

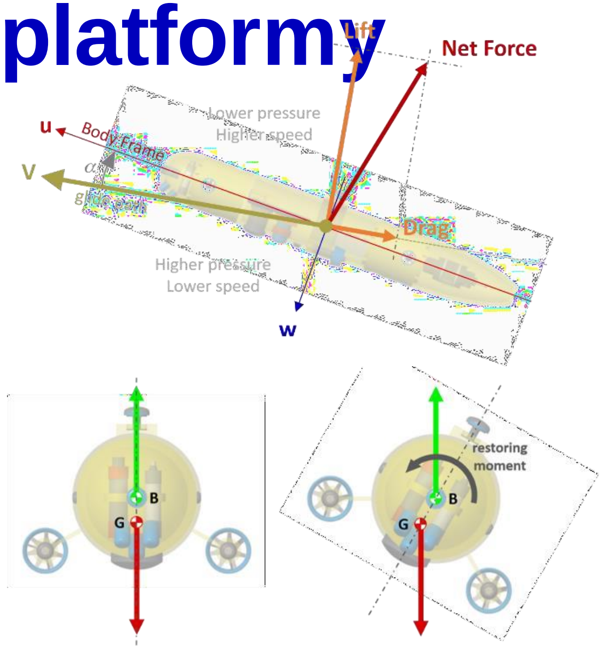


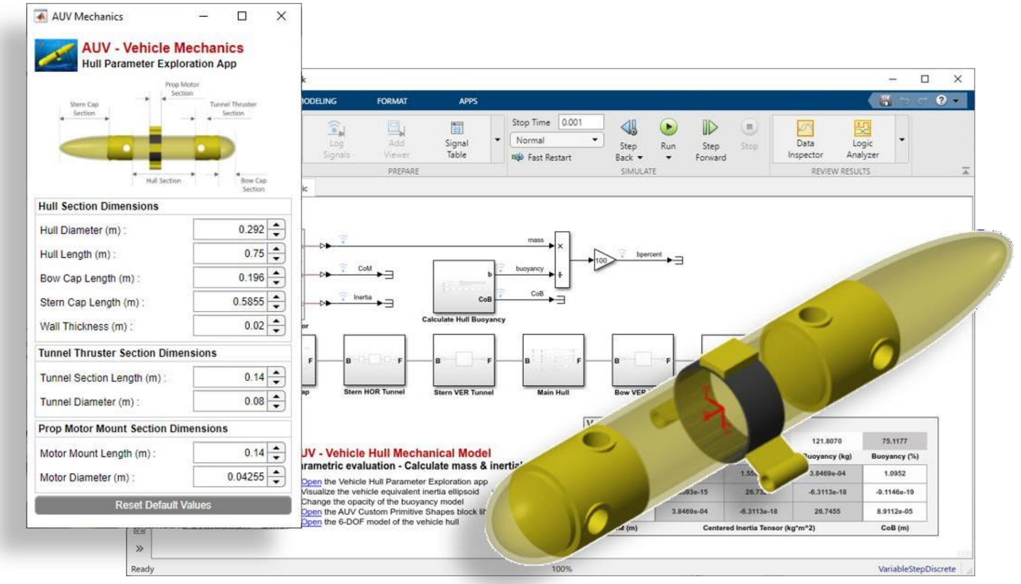
Návrh systému
Požiadavky
Architektúra
Verifikácia a Validácia
Certifikáty
Autonómny algoritmus
Snímanie
IMU
GPS
Kamera
Sila/Moment
Tlak
Sonar
Vytekanie
DVL
Vnímanie
Mapovanie prostredia
Objekty Detekcia/Sledovanie
Map Produced by Sonar
Visualize Mission Progress
Plánovanie
Localizácia
Trasa
Prekážky
Riadenie
Spätná väzba
Stavová log.
Gain Scheduling
Trajektória
Nasadenie
Generovaine kódu
ROS
DDS
Platforma
Model systému
Hardware-in-the-loop
Software-in-the-loop
Hardvér

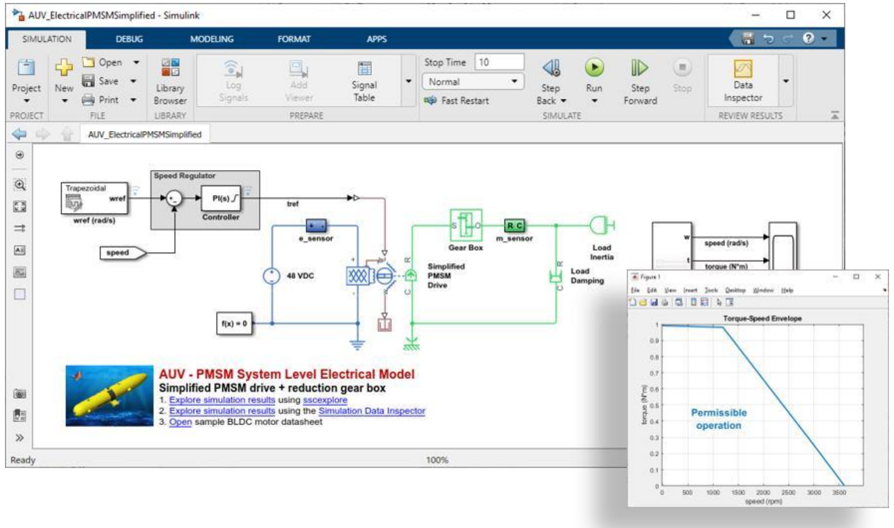
HUMUSOFT

Modelovanie platformy



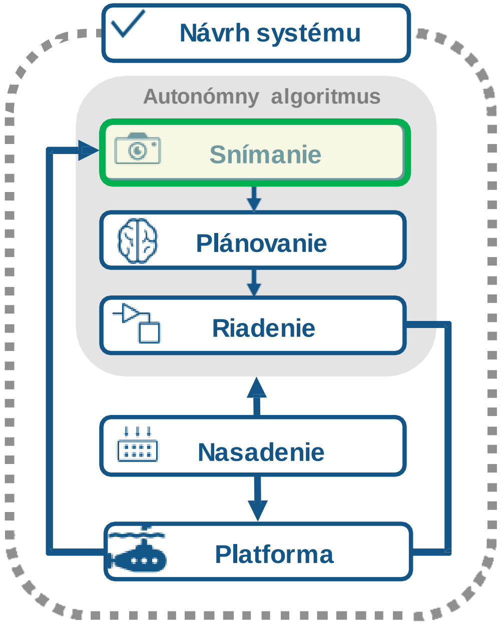


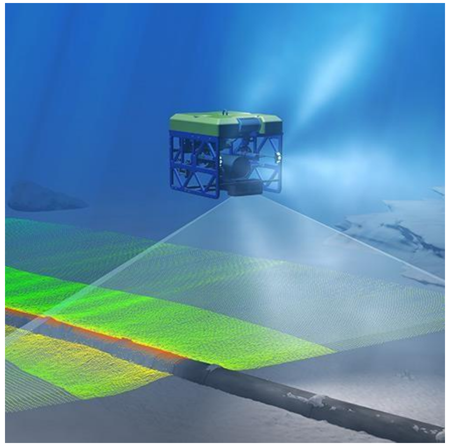




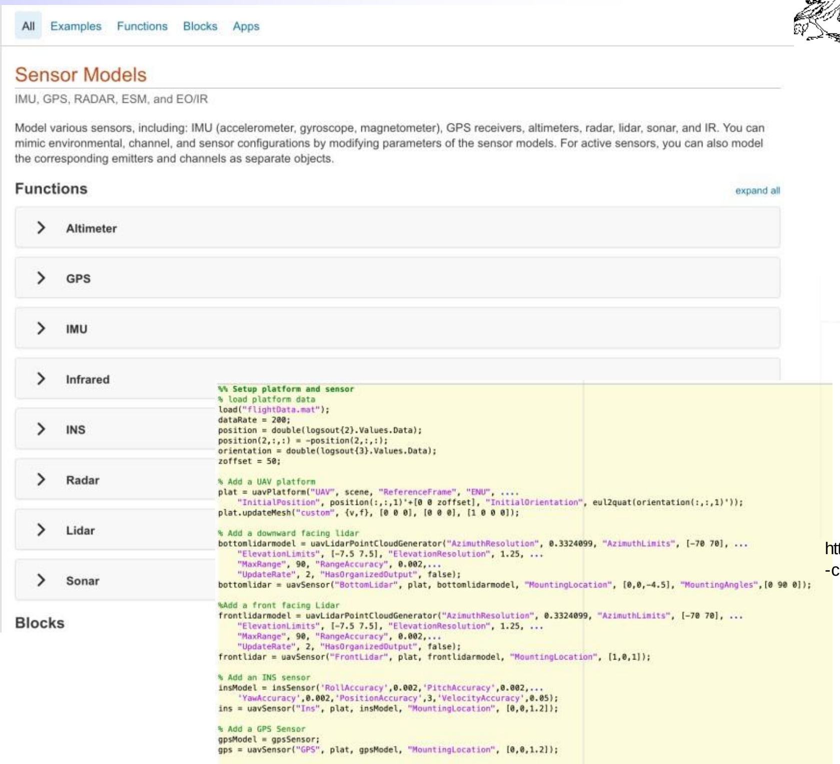
[Physical Modeling with Simscape](#)
[System Modeling and Simulation with Simulink](#)

Snímanie a vnímanie





http://www.teledynemarine.com/multibeam-echosounders




```
%% Setup platform and sensor
% load platform data
load("flightData.mat");
dataRate = 200;
position = double(logsout{2}.Values.Data);
position(2,:,:) = -position(2,:,:);
orientation = double(logsout{3}.Values.Data);
zoffset = 50;

% Add a UAV platform
plat = uavPlatform("UAV", scene, "ReferenceFrame", "ENU", ....
    "InitialPosition", position(:,:,1)'+[0 0 zoffset], "InitialOrientation", eul2quat(orientation(:,:,1)'));
plat.updateMesh("custom", {v,f}, [0 0 0], [0 0 0], [1 0 0 0]);

% Add a downward facing lidar
bottomlidarmodel = uavLidarPointCloudGenerator("AzimuthResolution", 0.3324099, "AzimuthLimits", [-70 70], ...
    "ElevationLimits", [-7.5 7.5], "ElevationResolution", 1.25, ...
    "MaxRange", 90, "RangeAccuracy", 0.002,...
    "UpdateRate", 2, "HasOrganizedOutput", false);
bottomlidar = uavSensor("BottomLidar", plat, bottomlidarmodel, "MountingLocation", [0,0,-4.5], "MountingAngles",[0 90 0]);

%Add a front facing Lidar
frontlidarmodel = uavLidarPointCloudGenerator("AzimuthResolution", 0.3324099, "AzimuthLimits", [-70 70], ...
    "ElevationLimits", [-7.5 7.5], "ElevationResolution", 1.25, ...
    "MaxRange", 90, "RangeAccuracy", 0.002,...
    "UpdateRate", 2, "HasOrganizedOutput", false);
frontlidar = uavSensor("FrontLidar", plat, frontlidarmodel, "MountingLocation", [1,0,1]);

% Add an INS sensor
insModel = insSensor('RollAccuracy',0.002,'PitchAccuracy',0.002,...
    'YawAccuracy',0.002,'PositionAccuracy',3,'VelocityAccuracy',0.05);
ins = uavSensor("Ins", plat, insModel, "MountingLocation", [0,0,1.2]);

% Add a GPS Sensor
gpsModel = gpsSensor;
gps = uavSensor("GPS", plat, gpsModel, "MountingLocation", [0,0,1.2]);
```

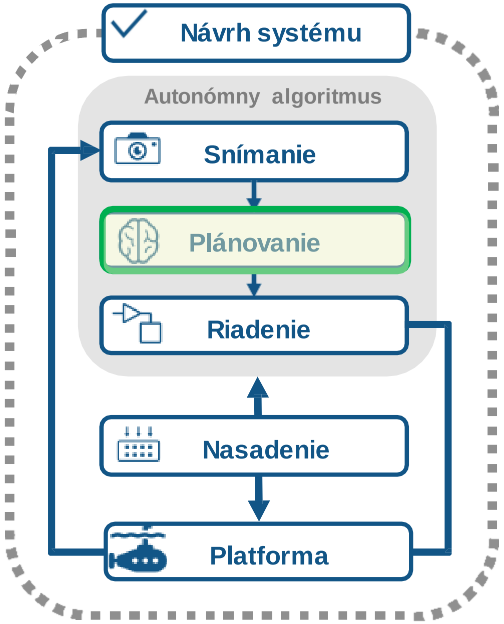
https://www.ixblue.com/products/phins-compact-series

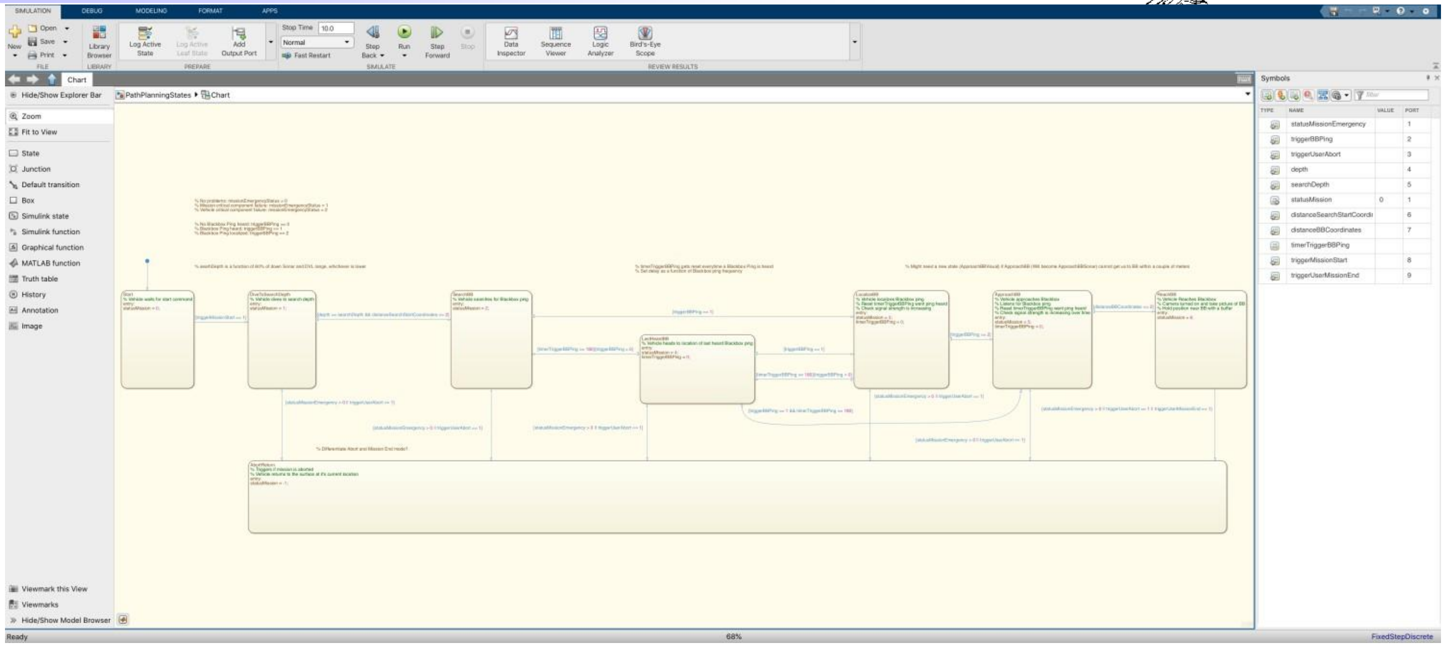
Map Produced by Sonar

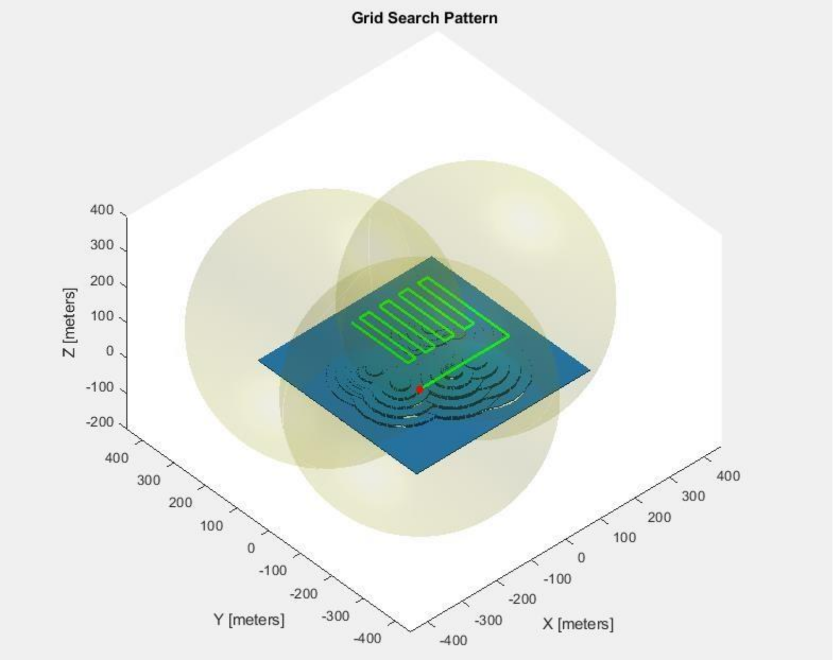
Visualize Mission Progress

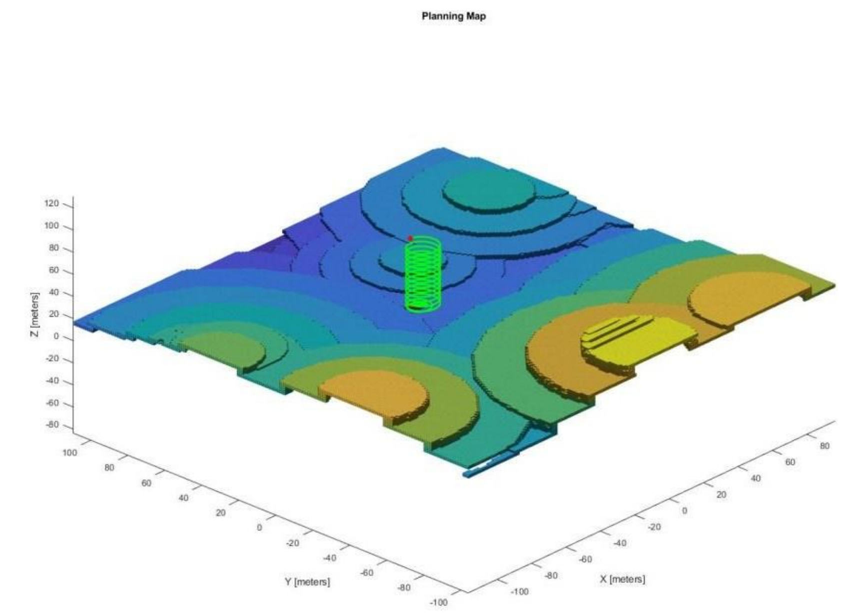
Sensor Fusion and Tracking Toolbox
Lidar Toolbox
Computer Vision Toolbox
Deep Learning Toolbox
Scenario Simulation

Plánovanie a rozhodovanie



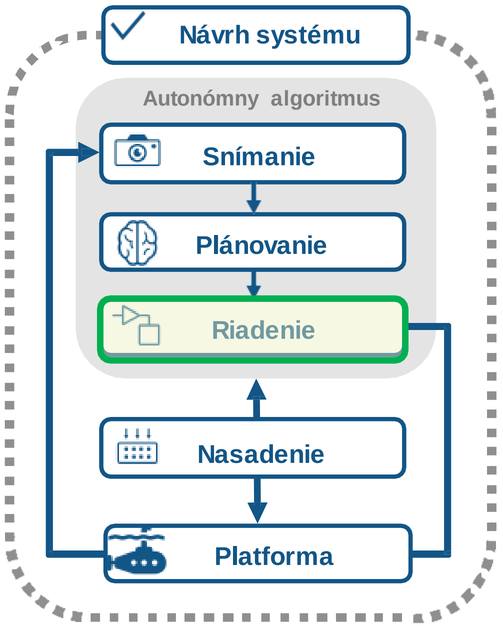


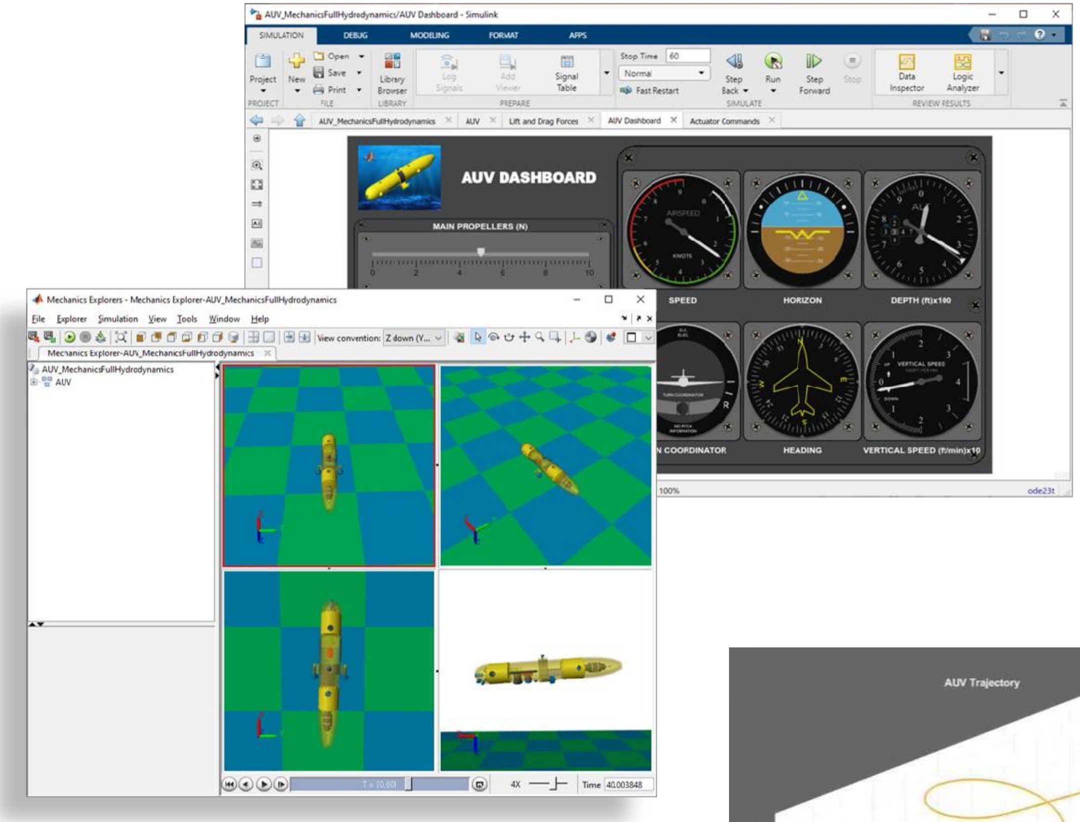


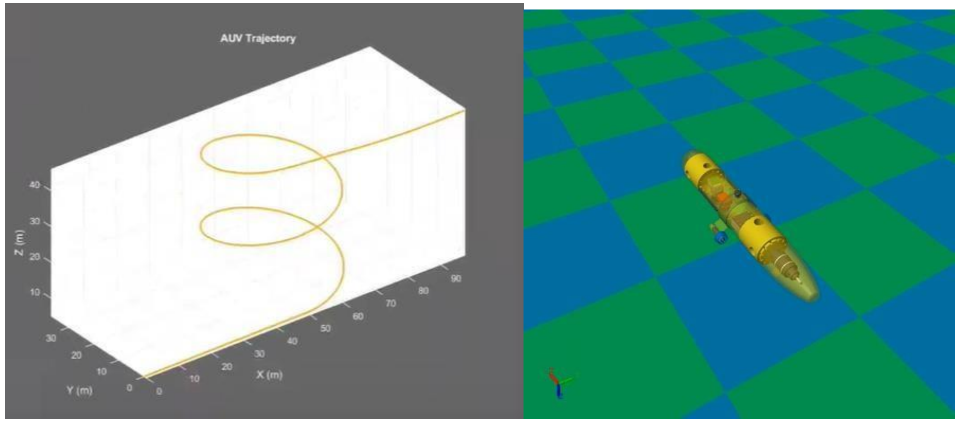


[Navigation Toolbox](#)
[Stateflow](#)
[Reinforcement Learning Toolbox](#)

Riadenie


Návrh systému
Autonómny algoritmus
Snímanie
Plánovanie
Riadenie
Nasadenie
Platforma


AUV DASHBOARD
MAIN PROPELLERS (N)
SPEED
HORIZON
DEPTH (ft)x100
HEADING
VERTICAL SPEED (ft/min)x10


AUV Trajectory
Z (m)
Y (m)
X (m)

Zdroje informácií

- **MATLAB and Simulink for Autonomous Underwater Vehicles – solutions page**
  - https://www.mathworks.com/solutions/aerospace-defense/auv.html
- **Design, Modeling and Simulation of Autonomous Underwater Vehicles – webinár**
  - https://www.mathworks.com/videos/design-modeling-and-simulation-of-autonomous-underwater-vehicles-1619636864529.html
- **AUV Deep Dive video séria**
  - https://www.mathworks.com/videos/series/auv-deep-dive.html
- **AUV Demo – ukážkové modely**
  - https://github.com/mathworks-robotics/modeling-and-simulation-of-an-AUV-in-Simulink

Ďakujem za pozornosť