Autonomous Systems

Lajos Lóczi, János Szalai-Gindl, László Zsolt Varga,
Bandó Kovács, Levente Hajder

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Introduction

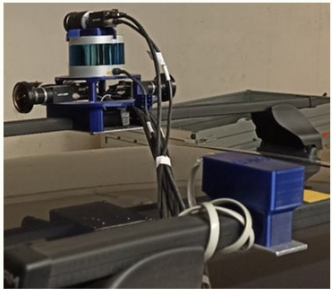
- The topics in autonomous systems are intensively researched.
- Autonomous systems are in focus of our university due to
  - Hungarian and European Union-financed projects,
  - industrial collaboration,
  - Computer Science for Autonomous System MSc major.
- The area is important for both theoretical and practical reasons.
- Popular topics for students.

Group Members

- László Zsolt Varga
  - Autonomous agents and multi-agent systems.
- János Szalay-Gindl
  - LiDAR point cloud processing.
- Lajos Lóczi
  - Mathematical aspects: numerical methods for systems of differential equations; analytical and numerical optimization.
- Bandó Kovács
  - Hardware and software development; sensor integration.
- Levente Hajder
  - 3D Computer Vision.
- Last but not least: **many talented students**.

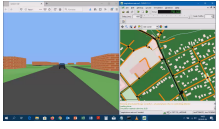
Sensor-Kit

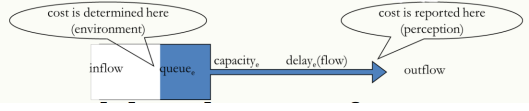
- Skoda Fabia
  - without CAN-bus. :-(
- Modern Sensors
  - LiDAR
  - RGB Digital Cameras
  - GPS
  - IMU



Trustworthy Algorithmic Routing of Autonomous Vehicles

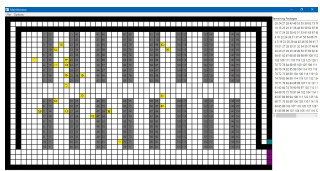
- Development of the intention-aware online routing game model for trustworthy routing
- Development of the routing model evaluator software to evaluate the routing model in a simulation environment
- Multi-agent paradigm in software engineering and trustworthiness: comparison of the online routing model and other routing models

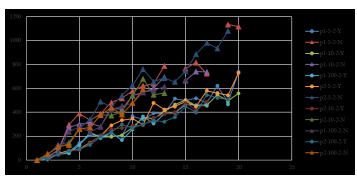


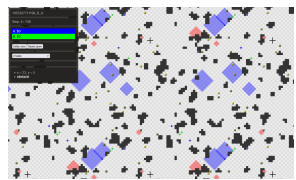


Multi-agent Optimizations to Increase Trustworthiness

- Agents in a grid world, simulation software for a warehouse
- Enhancement of multi-agent algorithms to improve warehouse operation
- Development of agent architecture for a grid world multi-agent system

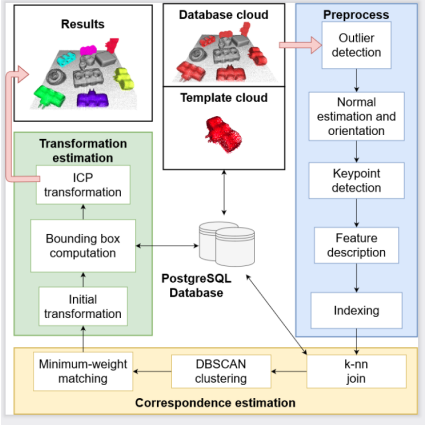






Pattern Matching in Large-scale Point Clouds

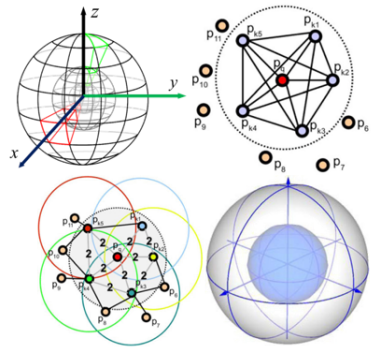
- Modern LiDAR sensors $\Longrightarrow$ large-scale 3D point clouds, challenges in data-storage and analysis.
- Point cloud registration, point-cloud based matching.
- Refinement of previous results.



Feature Descriptors

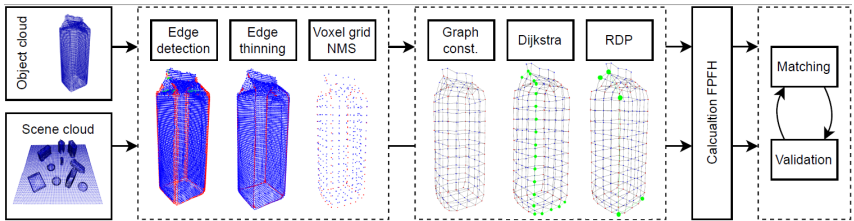
- Collection of Closest Points.
- Reduction of feature descriptors:
  - Application of Principal Component Analysis;
  - Novel binarization method.

→ Image source: Guo, Y., Bennamoun, M., Sohel, F., Lu, M., Wan, J., Kwok, N. M. (2016). A comprehensive performance evaluation of 3D local feature descriptors. International Journal of Computer Vision, 116(1), 66-89. 69. old.: Figure 1



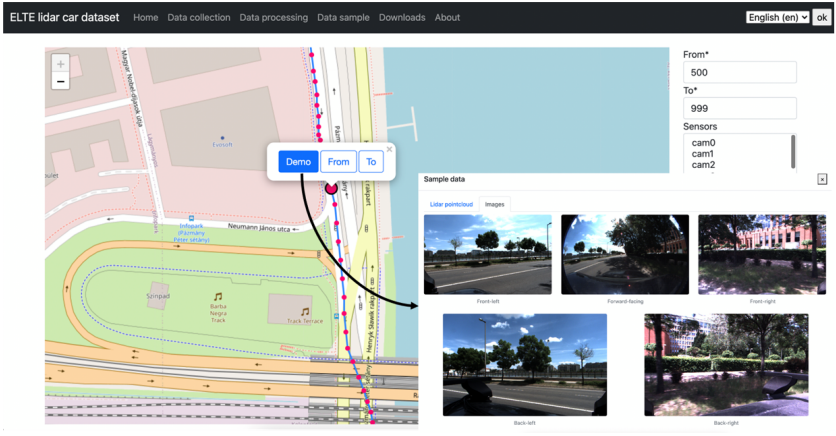
Detection of Correspondences

- DBSCAN-based classification is obsolete.
  - Time demand is very high
- Novel method: chain-based approach



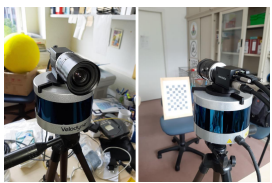
Database Building

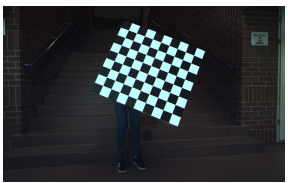
- Synchronized LiDAR-Camera database
- Web-interface

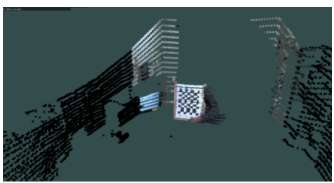


LiDAR-Camera Calibration

- Very challenging task to calibrate different sensors.
- Calibration:
  - extrinsic parameters (location, orientation).
- We have developed two approaches:
  1. chessboard-based, semi-automatic;
  2. spherical object-based, fully automatic.







Numerical Methods for Differential Equations

- Extrapolation methods
- Linear multi-step methods combined with Richardson extrapolation
  - active / local
  - passive / global
- Experiments
  - Consistency stability, convergence and absolute stability
  - Important due to both theoretical and practical reasons

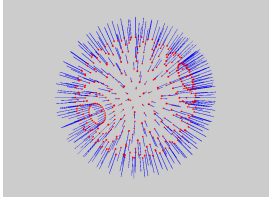
$\rightarrow$ Joint work with Ágnes Havasi, Imre Fekete Imre and Lajos Lóczi

Rapid Optimal Normal Estimation

- Mathematical formula for the problem:

$$\arg_{\mathbf{n}} \min \sum_{i=1}^{4} \left\| a_i - \frac{\mathbf{w}_i^T \mathbf{n}}{\mathbf{w}_5^T \mathbf{n}} \right\|^2, \tag{1}$$

  - where $\mathbf{A} = \begin{bmatrix} a_1 & a_2 \\ a_3 & a_4 \end{bmatrix}$ is the affine transformation;
  - $\mathbf{w}_i$ depends on camera parameters and spatial location;
  - $\mathbf{n}$: normal to be estimated.
- We proved that the optimal normal estimation can be obtained via a linear formula.
  - It is very rapid.

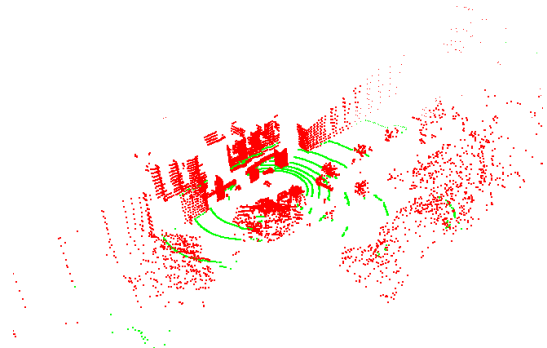


Collaboration outside the group

- Gábor Baranyi - András Lőrincz (NIPG) : Conversion between real and weak perspective projection.
  - Distortion is lower for weak-perspective camera model.
  - For machine learning, images with low distortions are usually applied.

Industrial Collaboration: Robert Bosch GmbH

- Common Topics
  - Similar Sensor-Kits
  - 3D Vision
  - Sensor Fusion
- ELTE-Bosch Competition for Parking Car Detection
- Projects for MSc students
  - Tamás Tófalvi (sensor fusion)
  - Botond Nás (IMU filtering - IMU - camera fusion)



Publications

	Accepted	Submitted
Journal papers	7	4
Conferences	14	1
TDK papers	8	
Total	29	5

Summary

- Research group deals with three important research areas:
  - Autonomous agents and multi-agent systems;
  - 3D vision for autonomous vehicles; real-time sensing of the environment;
  - Numerical methods for differential equations.
- Theoretical results; many applications.
- We have many accepted publications in top conferences/journals.
- Research results are utilized in education.
- Industrial collaboration with Bosch.

Thank you for your attention.