Computer Vision for Autonomous Vehicles

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Introduction

- Processing of digital cameras is the main goal of computer vision.
- Aim of my TKP project: extension of point-based vision methods
  - **with the utilization of affine transformations.**
- Principal application: visual system(s) for autonomous devices.
  - Our car are equipped with several sensors, including digital cameras and LiDAR.
  - Key goals at ELTE: *research*, *development* and *education*.
- Industrial applicability is also very important:
  - Demonstrations based on research results.
  - Collaboration with Robert Bosch GmbH.

Progress Report

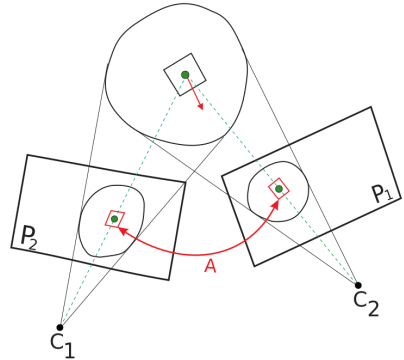
- ELTECar
  - Constructed as a joint EFOP - TKP project
  - Sensor Kit (with *Bandó Kovács*)
  - Databases (with *János Szalai-Gindl*)
- Affine transformations in computer vision
  - Optimal surface normal estimation (with *Lóczi Lajos*)
  - Visual odometry using ELTECar
  - Validation: multiple-chessboards
  - Visual Debugger
- Camera-LiDAR calibration
  - Fully automatic methods proposed
  - Chessboard and sphere-based algorithms proposed.
- Cooperation with an industrial partner (Robert Bosch GmbH)
  - Competition for Parking Car detection
- Other
  - Reading group /seminars

ELTECar with Sensor-Kit

→ Collaboration with *Bandó Kovács*

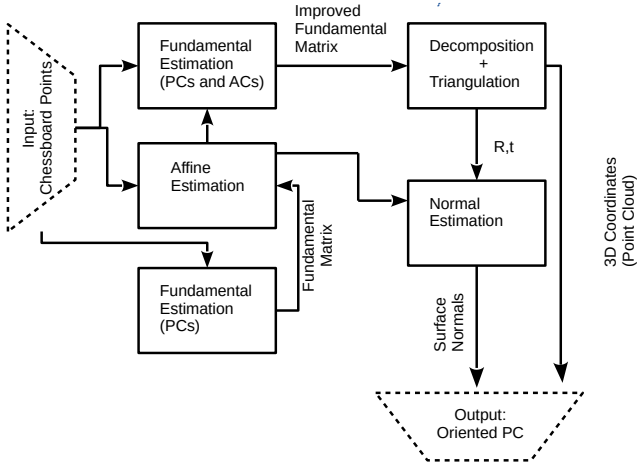
- Sensor-set with several sensors
  - LiDAR (top)
  - Six digital camera (top)
  - Standard GPS
  - IMU
- Coming soon...
  - Ultrasound
  - Radar
  - One-beam LiDARs
- Real-time processing (speed: 1-4 FPS)
- Big-data collection
  - Joint project with *János Szalai-Gindl*: database construction

Affine Transformations in Stereo Vision



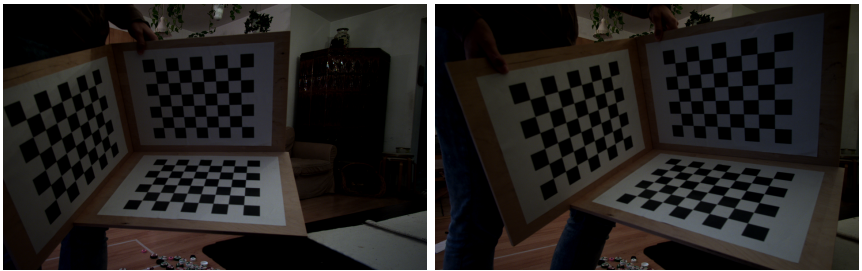
- **Affine transformations, camera parameters and point correspondences relate to each other.**
  - Basic equation proposed by Jozsef Molnar in 2013.
  - We have extended this work to generalize epipolar geometry.
    - Homography, Fundamental/Essential matrix estimation, Plane segmentation, ...

Reconstruction Pipeline



Validation Using Special Calibration Object

- A special calibration object constructed to validate the reconstruction method.
- Known geometry: three perpendicular planes.
- Special pattern to support estimation of affine transformations.

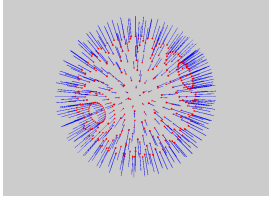


Rapid optimal surface normal estimation

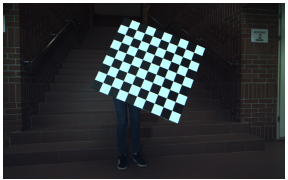
- The task is an argument-minimization one:

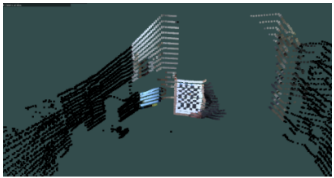
$$\arg_{\mathbf{n}} \min \sum_{i=1}^{4} \left\| a_i - \frac{\mathbf{w}_i^T \mathbf{n}}{\mathbf{w}_5^T \mathbf{n}} \right\|^2 \tag{1}$$

  - $\mathbf{A} = \begin{bmatrix} a_1 & a_2 \\ a_3 & a_4 \end{bmatrix}$ is the known affine transformation
  - $\mathbf{w}_i$ depends on camera parameters and point locations.
  - $\mathbf{n}$: normal vector to be estimated.
- Our novel solution given via a linear equation
  - Multiple addition and multiplication + one division



LiDAR-camera calibration

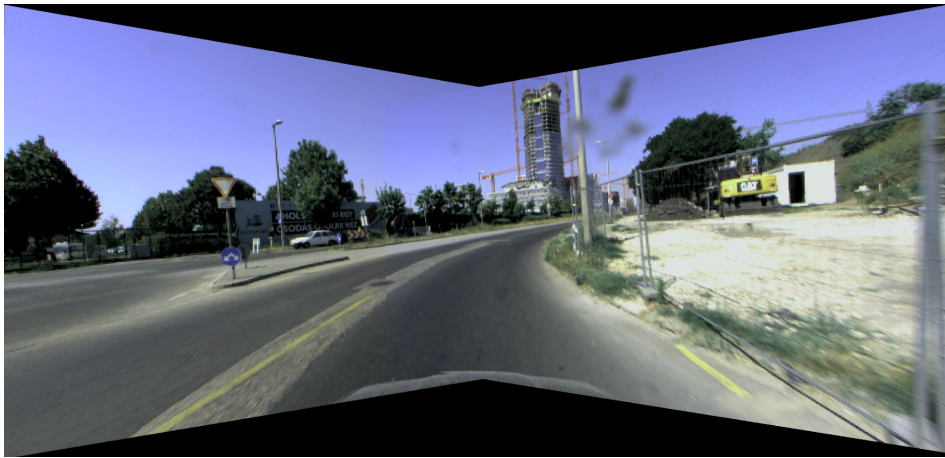




- Joint calibration of different sensors/modalities are very challenging
- In this research, we focus on
  - LiDARs $\rightarrow$ Point clouds
  - Digital cameras $\rightarrow$ RGB images
- Novel methods proposed
  1. Chessboard-based method with a special fixation
  2. Spherical object-based calibration

Camera (Image) Processing

- Merging images with different orientations
  - Field of View (FoV) enlarged.



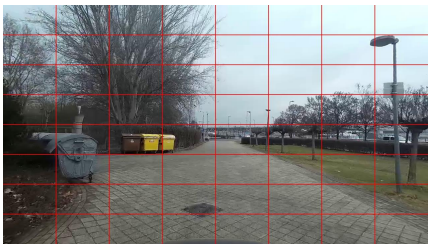
Real-time Plane Detection

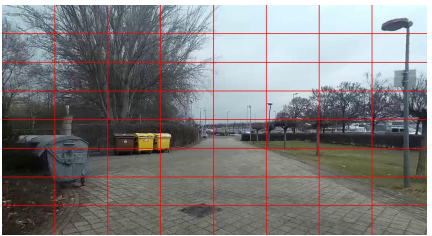
- Road surface detection
  - RANSAC-type algorithm using GPU.

$\rightarrow$ Joint work with *Bandó Kovács*

Camera (Image) Processing

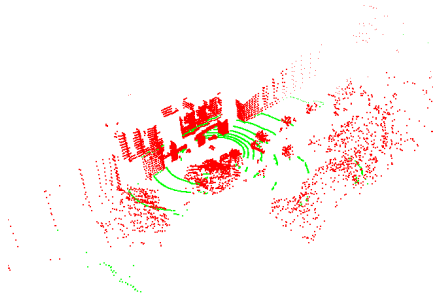
- Planar motion has several advantages
  - For example, DoF of external calibration reduced from five to two.
- For planar motion,
  - Camera image must be perpendicular to the road space.
  - Vertical image direction must be parallel to the gravity vector.
- Correction can be carried out by algorithm. We have developed two methods
  - By detecting the road or
  - the horizon.





ELTE-Bosch Competition for Parking Car Detection

- (Joint work with János Szalai-Gindl and his colleagues.)
- **Goal**: Detection of parking devices
- ELTECar with multiple sensors
  - Digital cameras (3)
  - Velodyne VLP-16 LiDAR LiDAR (1) (20 RPM/sec)
- Students should produce results in LiDAR and/or camera images
- Manual annotation
- Fully automatic quantitative evaluation
  - Using Sutherland-Hodgeman polygon cutting



Publications

- **Published**
  - A Q2 journal article
  - A Springer selected paper (CCIS series)
  - A CVPR tutorial (A*)
  - Four ICRA papers (A)
  - Four VISAPP papers (B-C)
  - Several papers in local conferences (CVWW, KEPAF)
- **Under Review**
  - A D1 journal article (major revision)
  - An ECCV paper (A)

Thank you for your attention

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