Photogrammetry & Robotics Lab

Introduction to Photogrammetry

Cyrill Stachniss

The slides have been created by Cyrill Stachniss.

What is Photogrammetry?

- “photos” = light
- “gramma” = to drawn
- “metron” = to measure
- Photogrammetry = measuring with light (photographs)

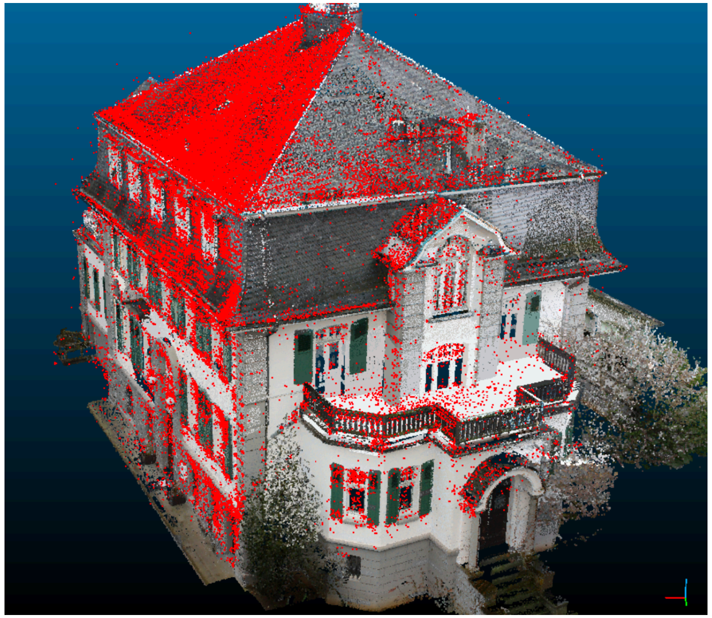
[Courtesy: ImagingSource]

What is Photogrammetry?

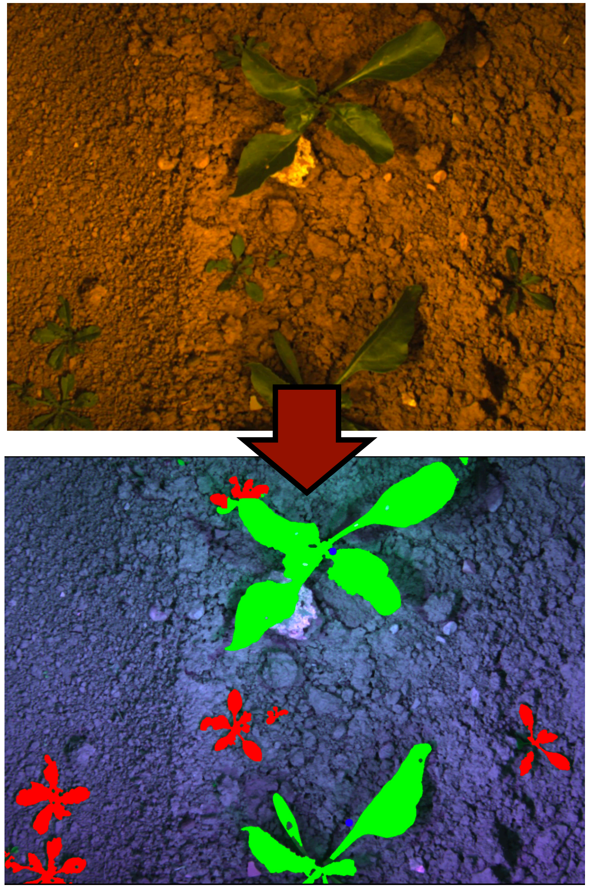
“Estimation of the geometric and semantic properties of objects based on images or observations from similar sensors.”

What are “similar sensors”?

Two Key Problems in Photogrammetry



Estimating geometry



Estimating semantics

What Do We Measure?

- Camera localization
- Determine the location of objects
- 3D reconstruction
- Similarities & data association
- Object detection
- Semantic interpretation
- …

Involved Disciplines

At the intersection of 4 disciplines

- Traditional photogrammetry
- Computer vision
- Machine learning
- Robotics

Photogrammetry Connections

- Developed for surveying purposes and is a part of the **geodetic sciences**
- A form of optical **remote sensing**
- Digital photogrammetry has strong connections to **image processing** and **computer vision**
- Strong links between photogrammetry and **state estimation** and **robotics**
- Uses **machine learning** approaches

Advantages (1)

- Contact-free sensing

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Why is contact-free sensing relevant?

Advantages (1)

- Contact-free sensing is important for
  - inaccessible (but visible) areas
  - sensitive material
  - hot/cold material
  - toxic material

Advantages (1)

- Contact-free sensing
- Relatively easy to acquire a large number of measurements
- Dense coverage of comparably large areas
- Flexible resolution (small but accurate or large but coarse models)
- 2D sensing and 3D sensing

Advantages (2)

- Ability to record dynamic scenes
- More than just geometry (image interpretation, inferring semantics, classification, …)
- Data can be interpreted by humans
- Recorded images document the measuring process
- Automatic data processing
- Possibility for real-time processing

There is no free lunch!

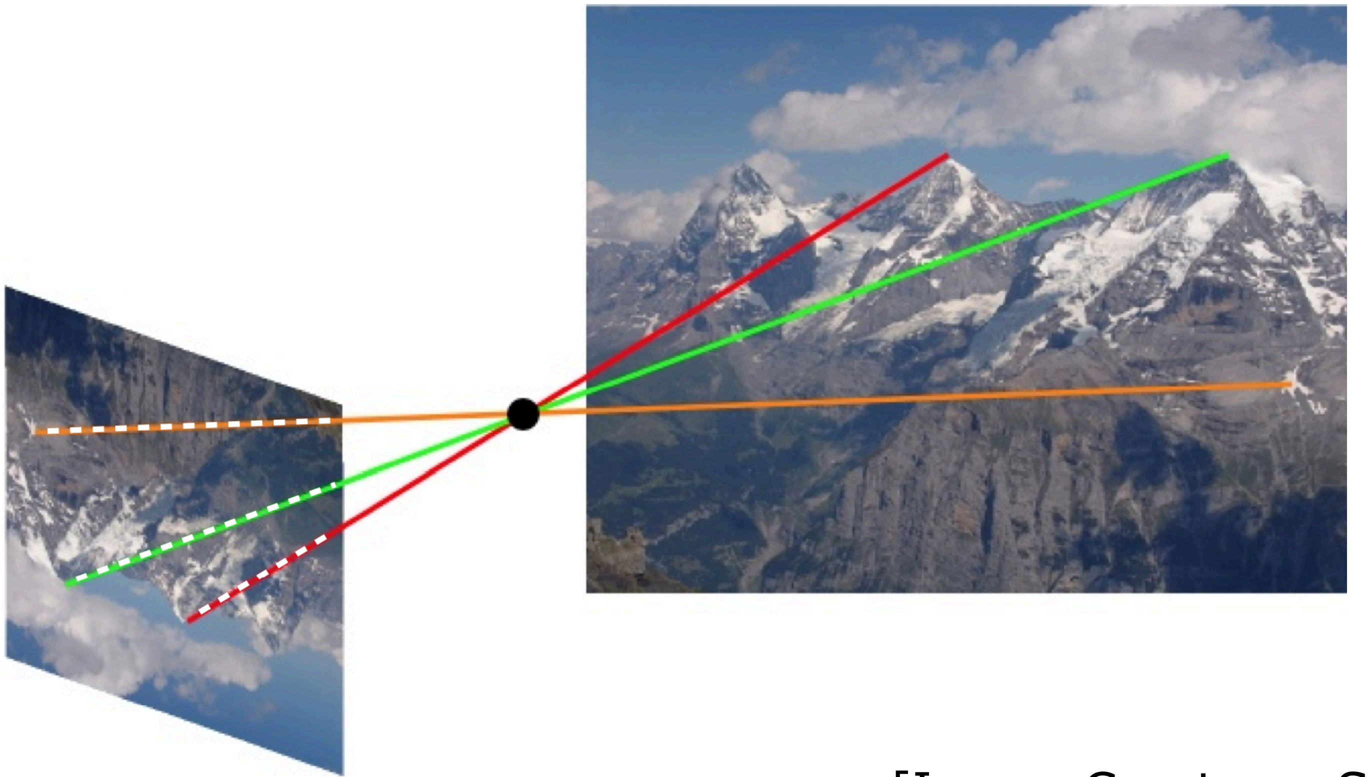
What are the disadvantages of using cameras?

Disadvantages

- Light source is needed
- Cameras only measures intensities from certain directions
- Occlusions and visibility constraints
- One image is a projection of the 3D world onto a 2D image plane
- Other techniques may achieve a higher measurement accuracy

Cameras to Measure Directions

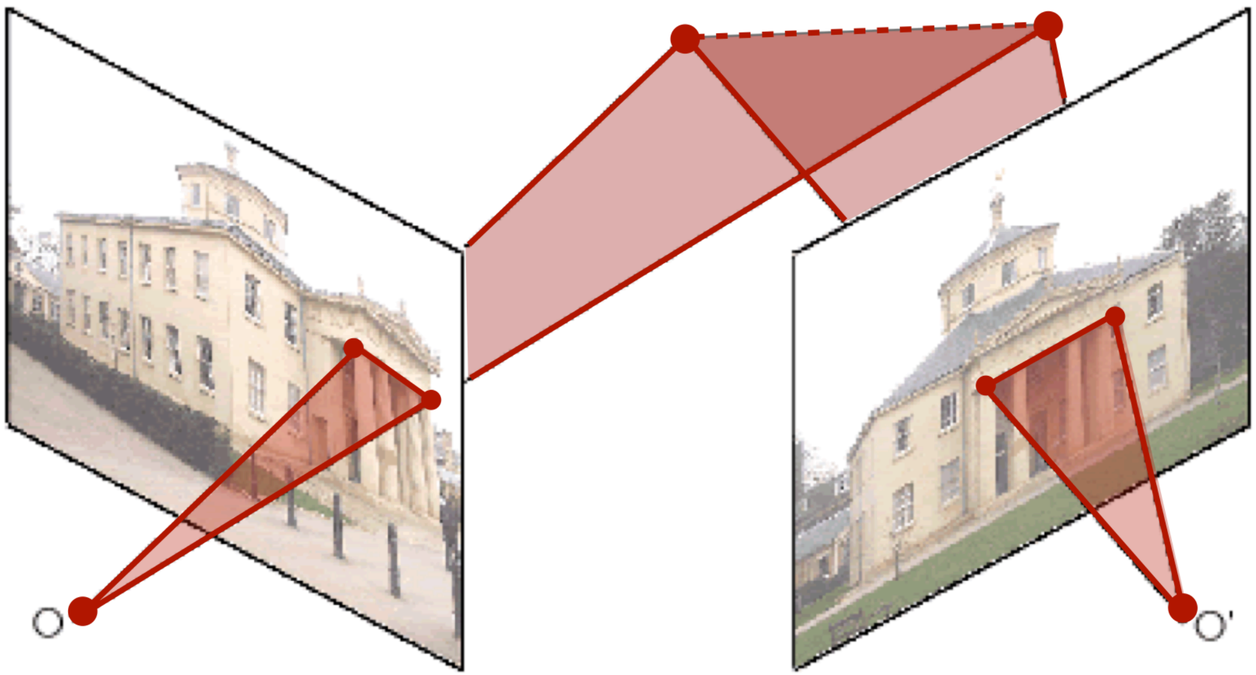
An image point in a camera image defines a ray to the object point



[Image Courtesy: Schindler]

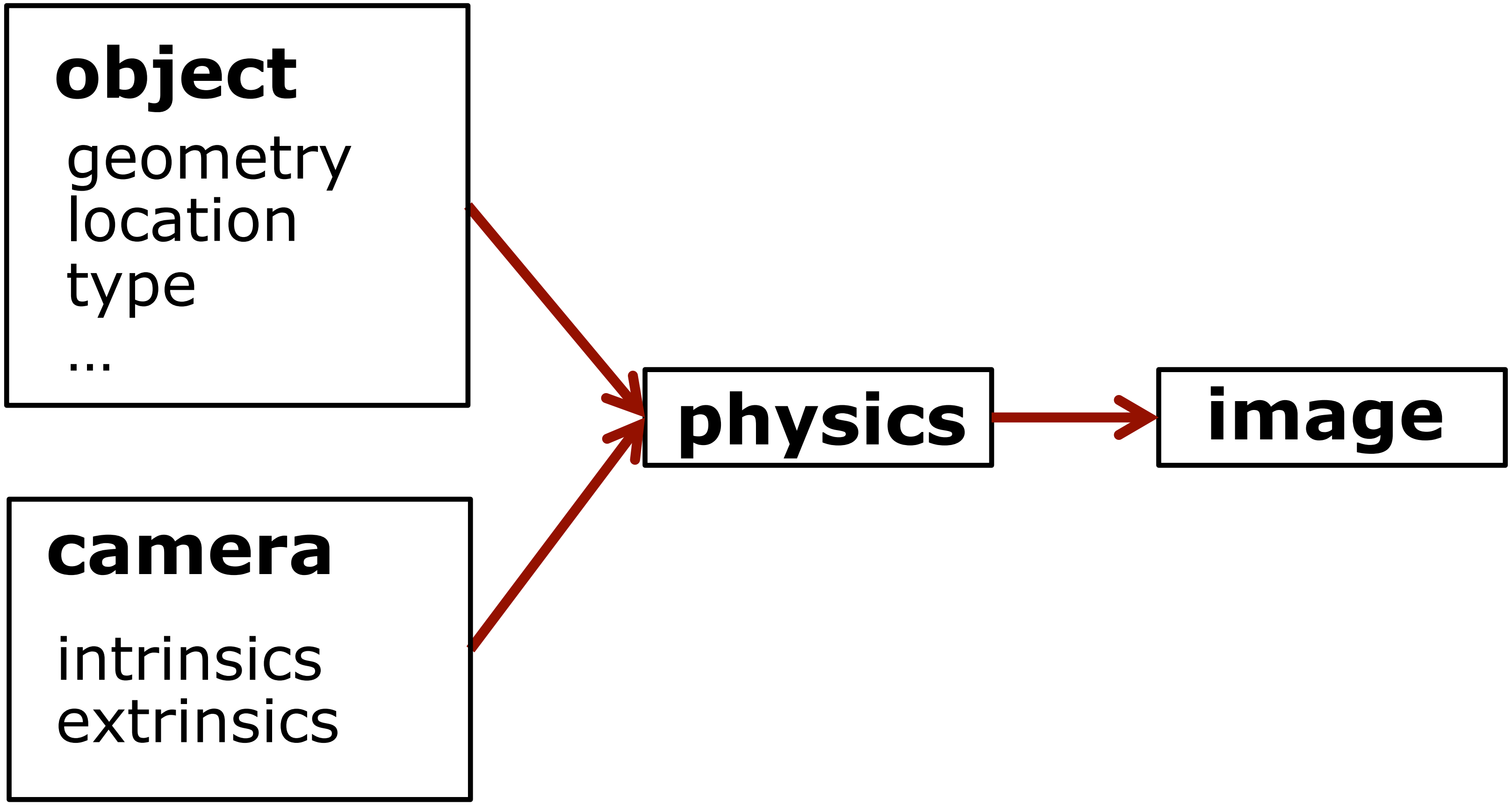
3D Perception (see Photo II)

Multiple observations from different directions allows for estimating the 3D location of points via triangulation

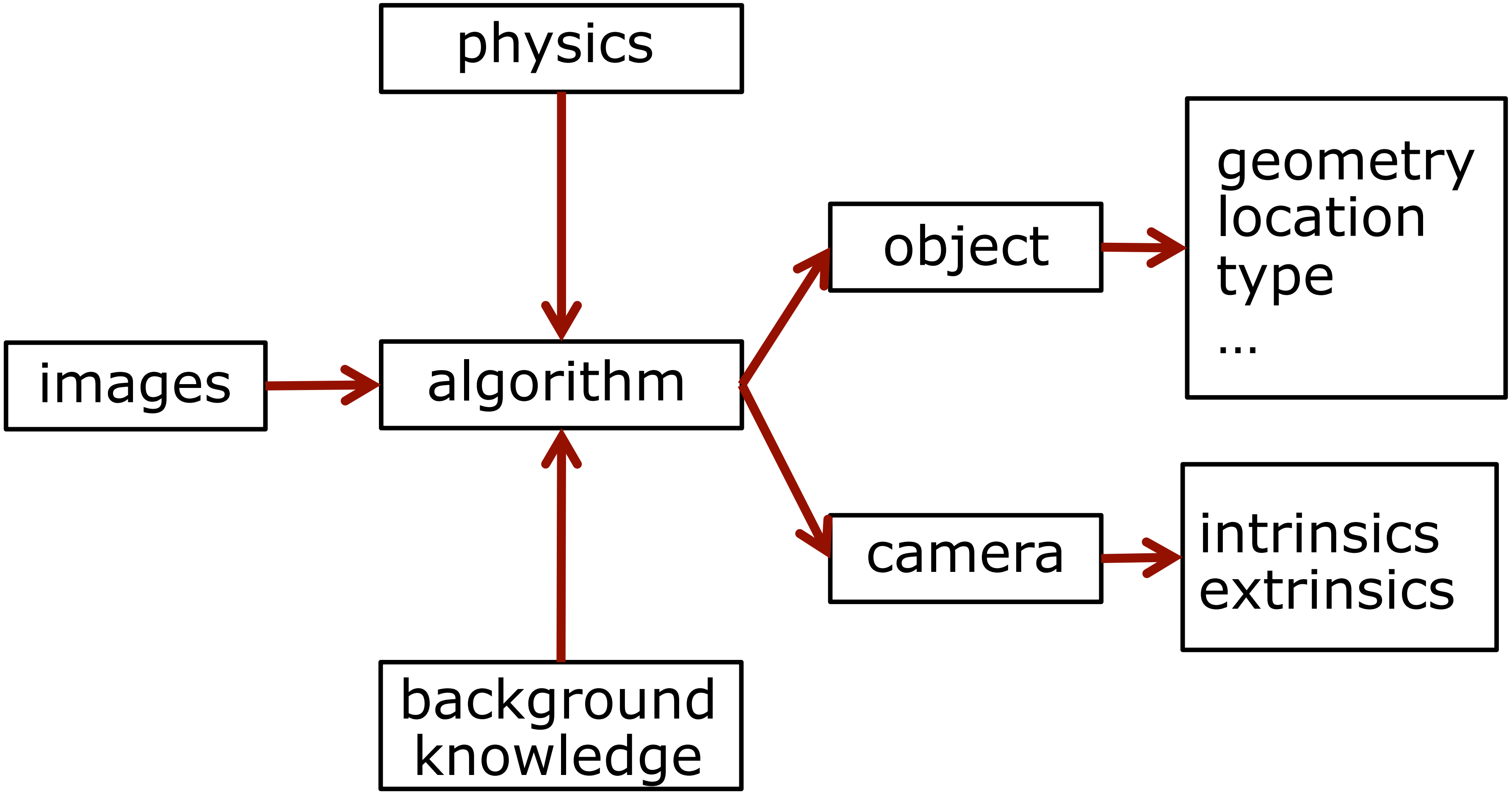


[Image Courtesy: Schindler]

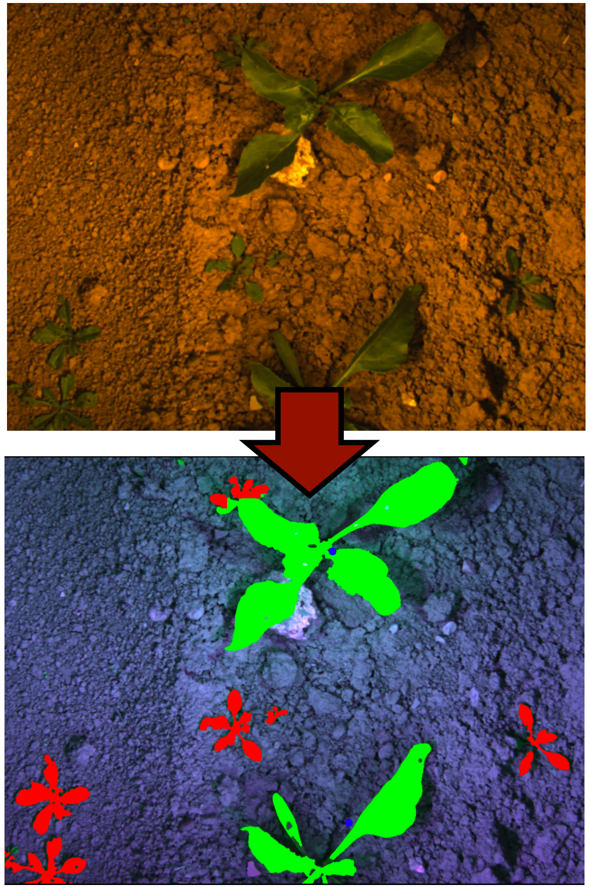
From the Object to the Image

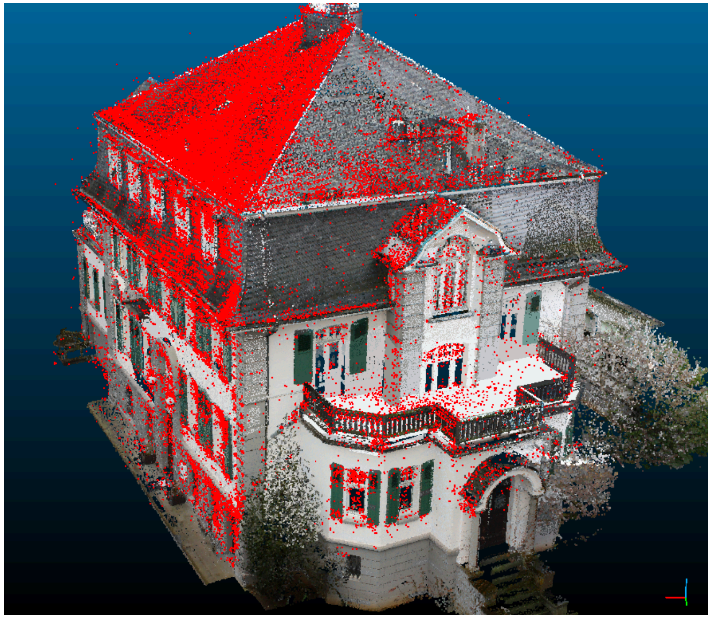


The Inverted Mapping



Two Key Problems in Photogrammetry





Estimating semantics   Estimating geometry

Human Perception

Queue of human perception

object ➡ eye ➡ brain ➡ interpretation

Who does most of the work, eye or brain?

Experiment

- Person, who is blind from birth on
- Camera records a scene
- Image “printed” on the persons skin using a pin for each pixel

Can this person see?

Experiment

- Person, who is blind from birth on
- Camera records a scene
- Image “printed” on the persons skin using a pin for each pixel
- Yes, the person can recognize different objects and interpret the scene

Conclusion: the brain does most of the work, so algorithms are central!

Algorithms are Central

- Estimating geometry and semantics from images requires brain power
- Algorithms are the central element and play a major role in this course
- Implementing solutions is key understanding the approaches
- Programming is a tool you must learn

Typical Sensors

Typical Sensors

- Industrial cameras


[Courtesy: Stingray, ImagingSource, UniQ]

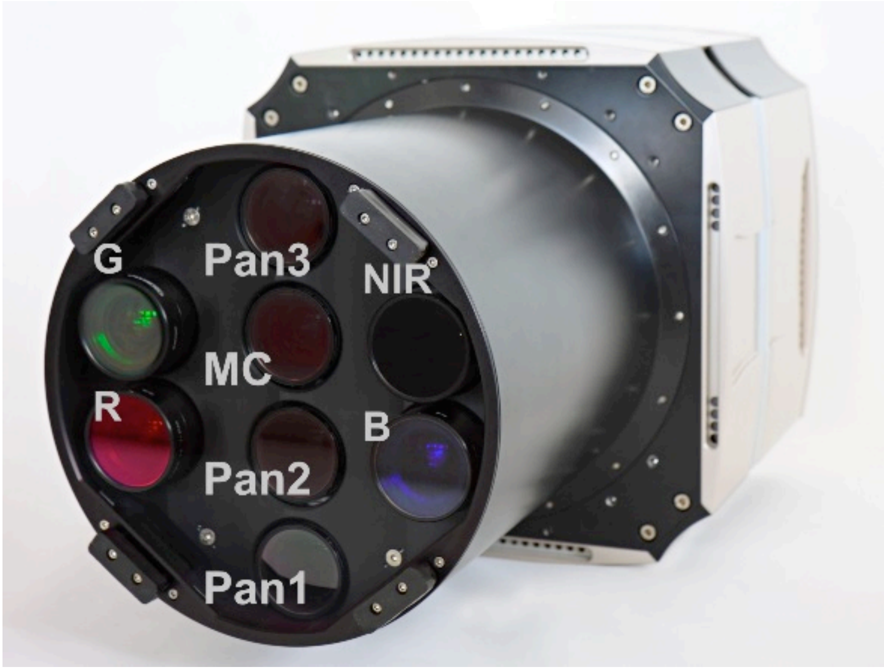
Typical Sensors

- Consumer cameras

[Courtesy: Nikon, Sony, Fuji]

Typical Sensors

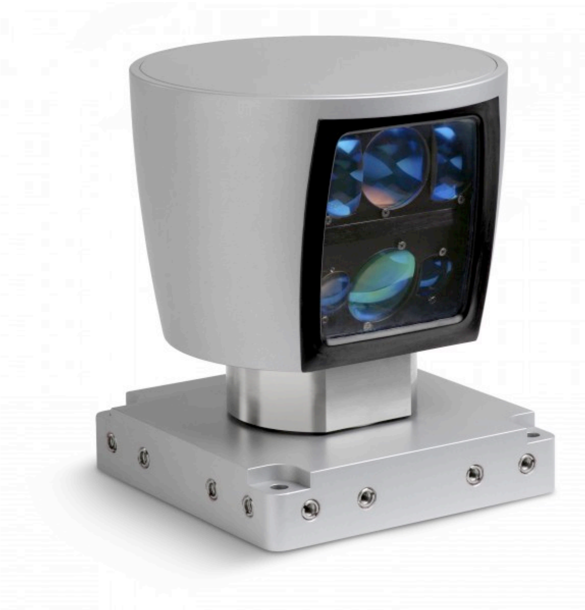
- Microsoft Ultracam (Bing Maps)



[Courtesy: Microsoft]

Typical Sensors

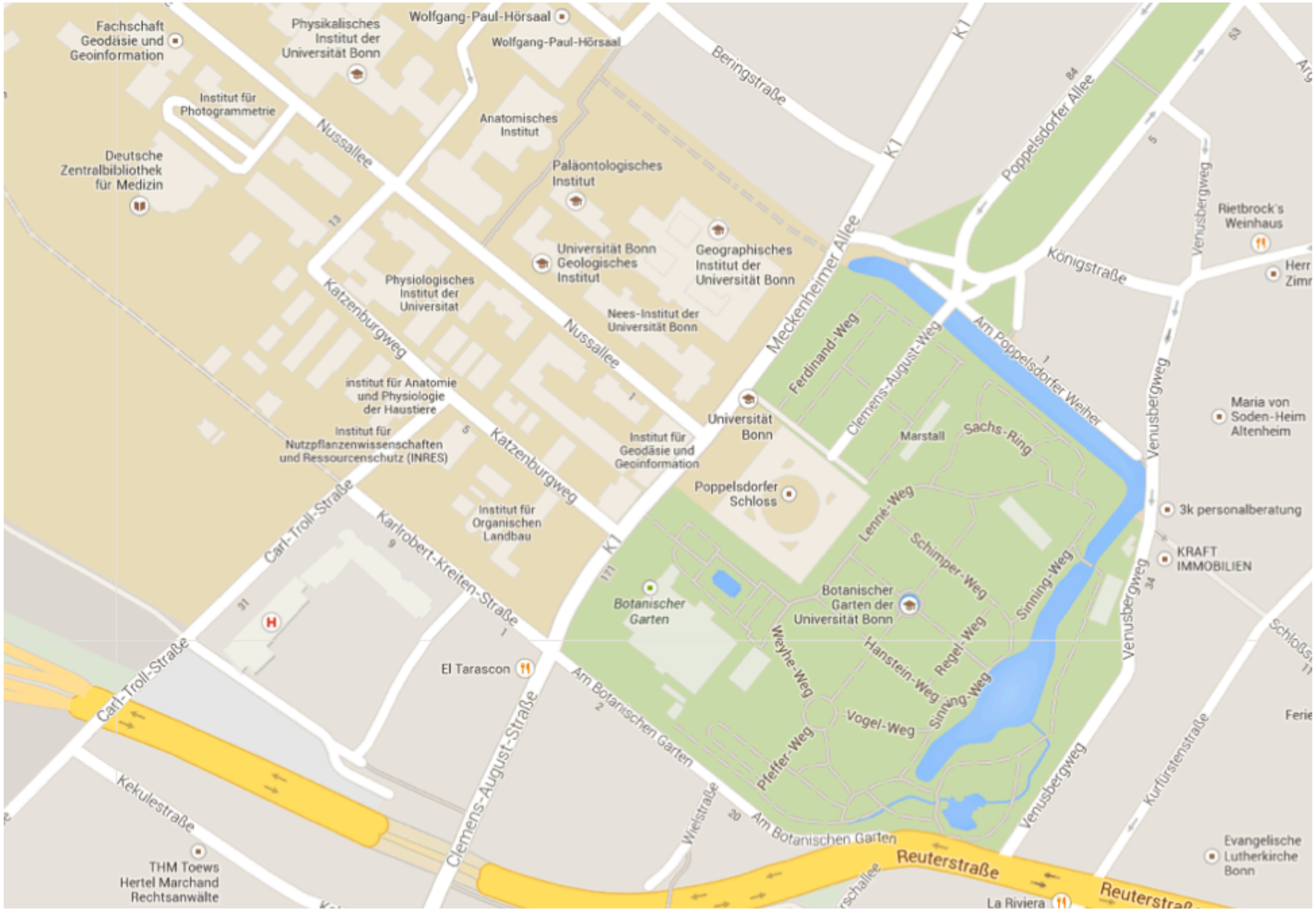
- Laser range finders



[Courtesy: Velodyne, Sick, Faro]

Applications

Application: Maps

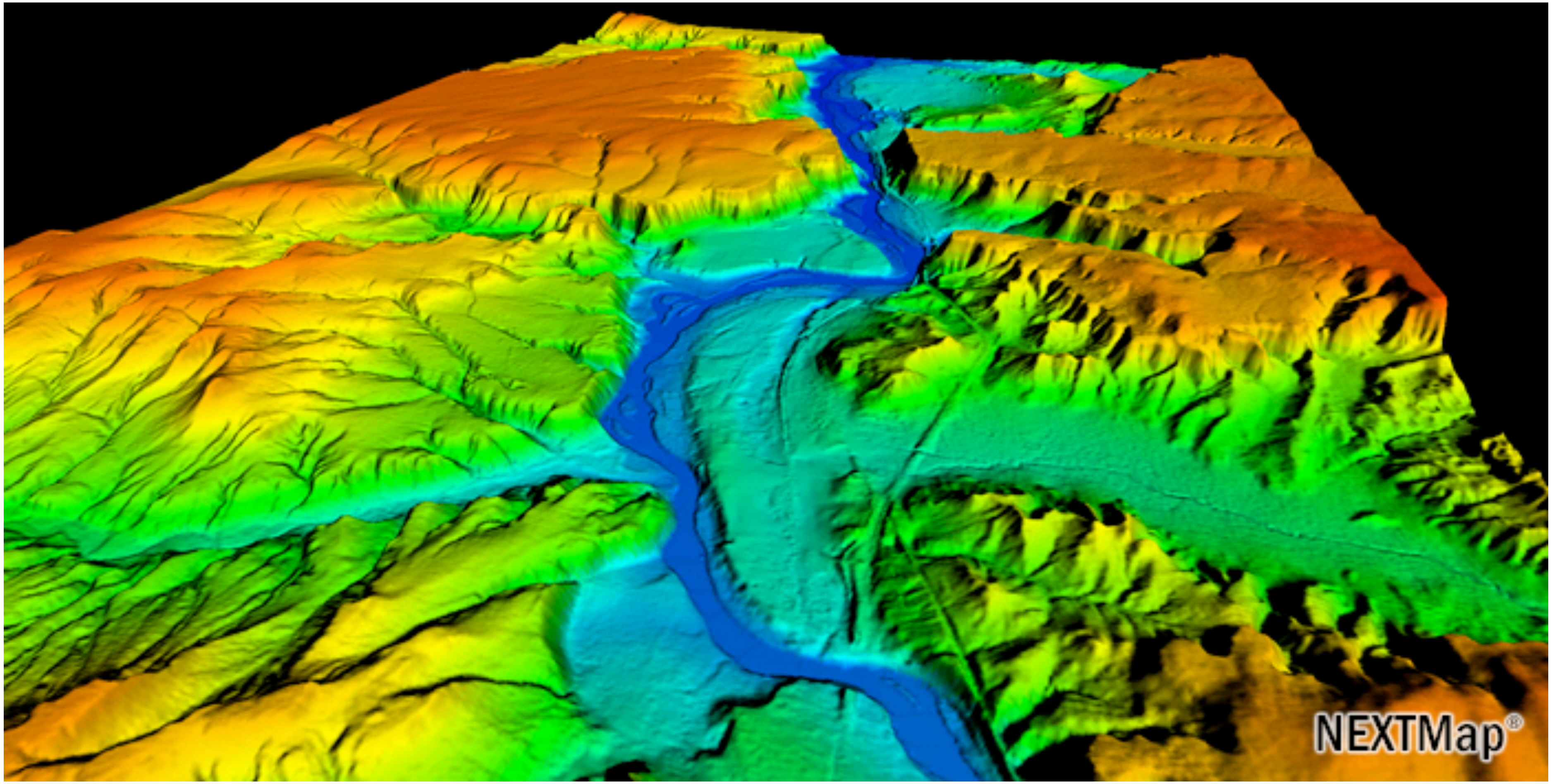


[Courtesy: Google Maps]

Application: Maps

[Courtesy: Google Maps]

Application: Terrain Models



[Courtesy: NEXTMap]

Application: Environment Monitoring

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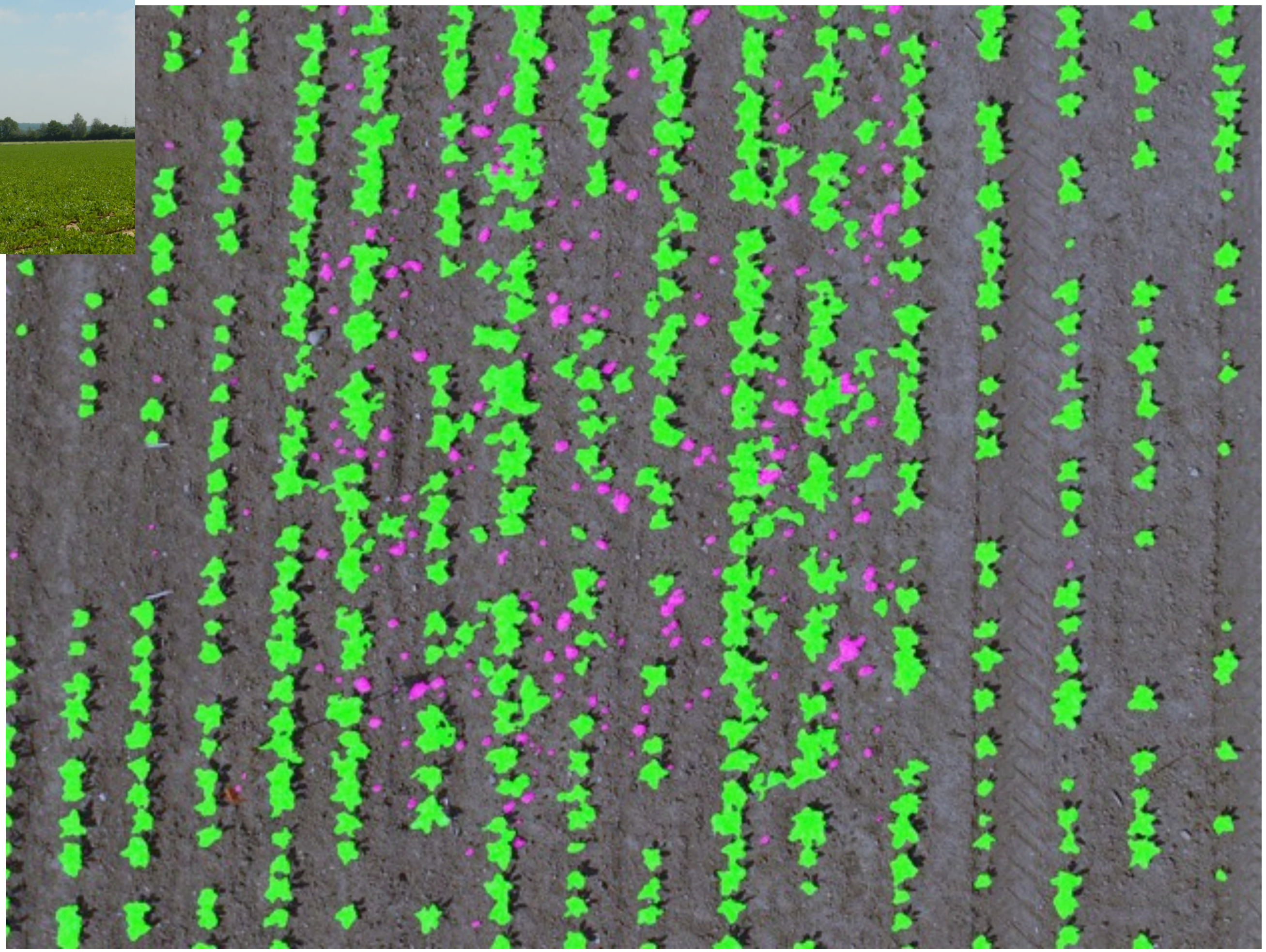
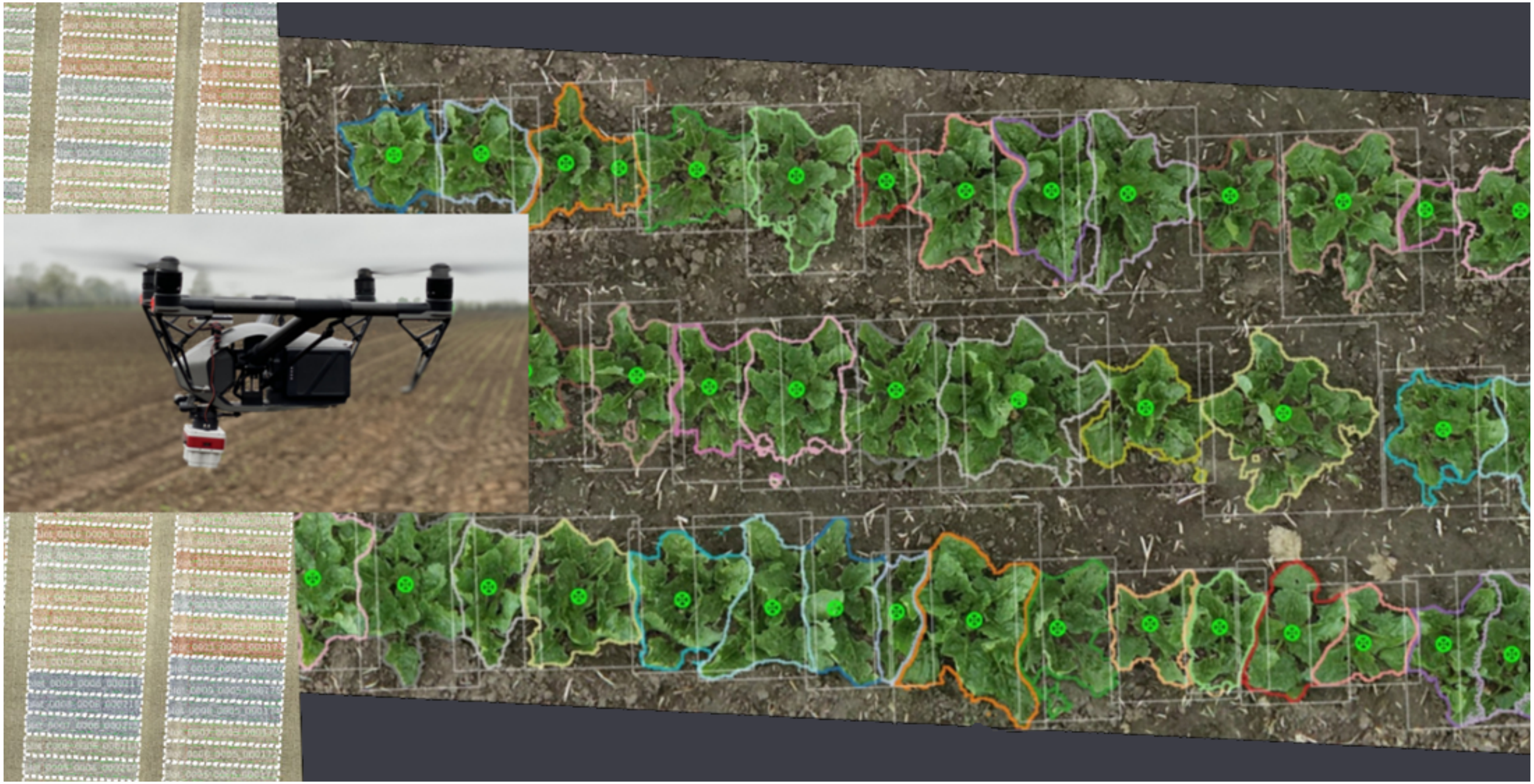
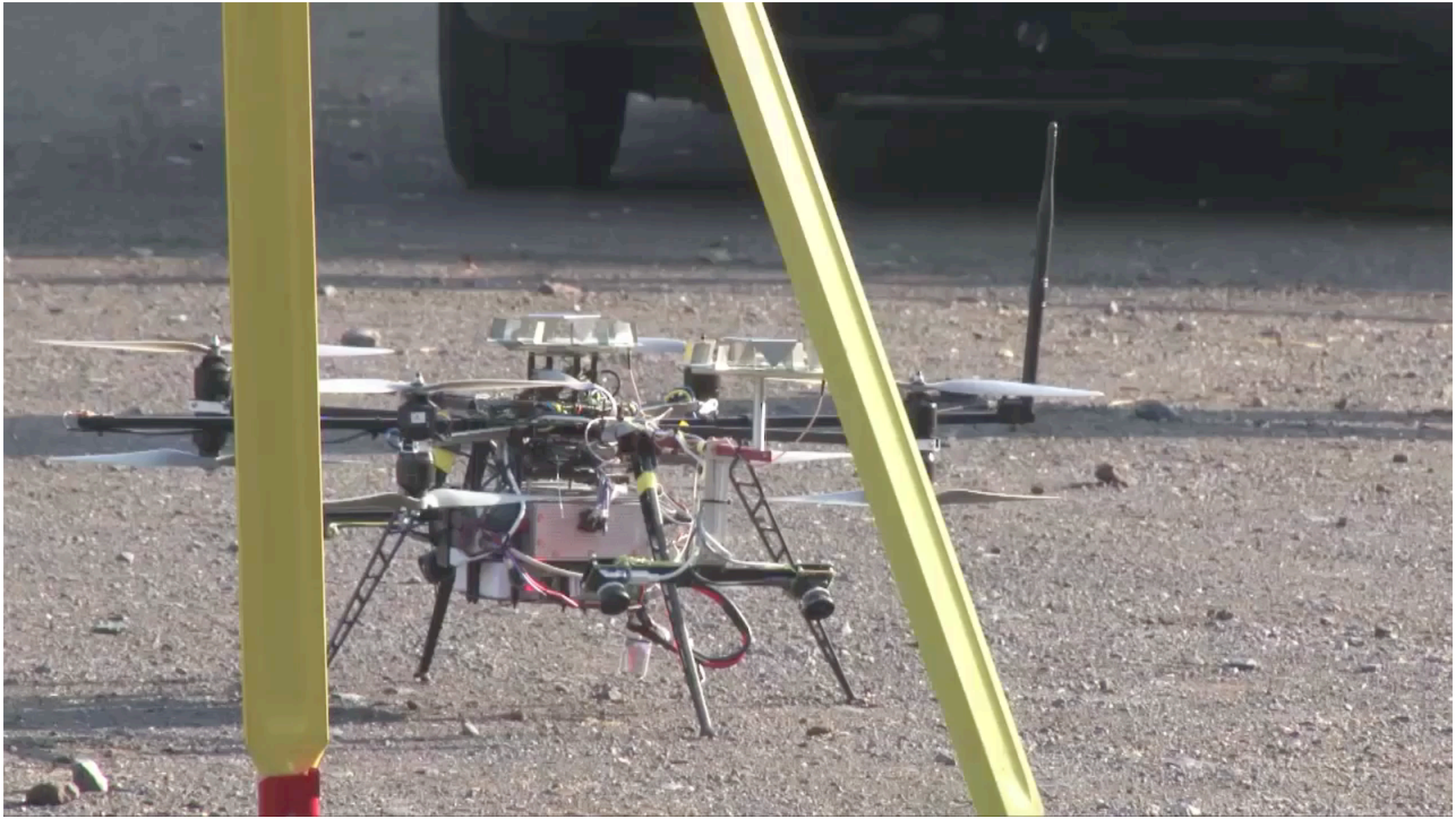


Segmentation and Instances

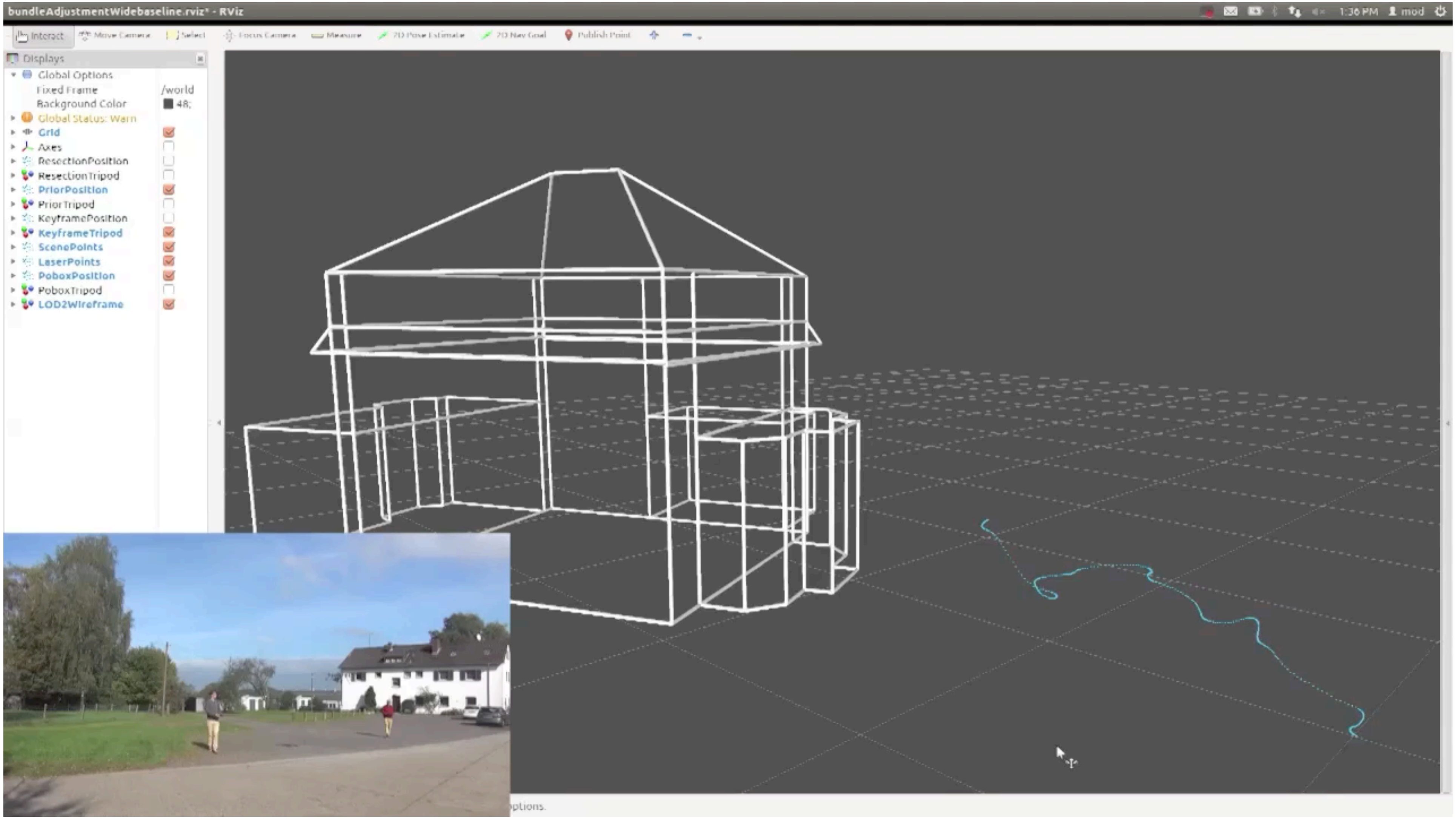
Segmentation and Instances



Application: Aerial Mapping (1)



Application: Aerial Mapping (2)



Application: Orthophotos

[Courtesy: SIGPAC]

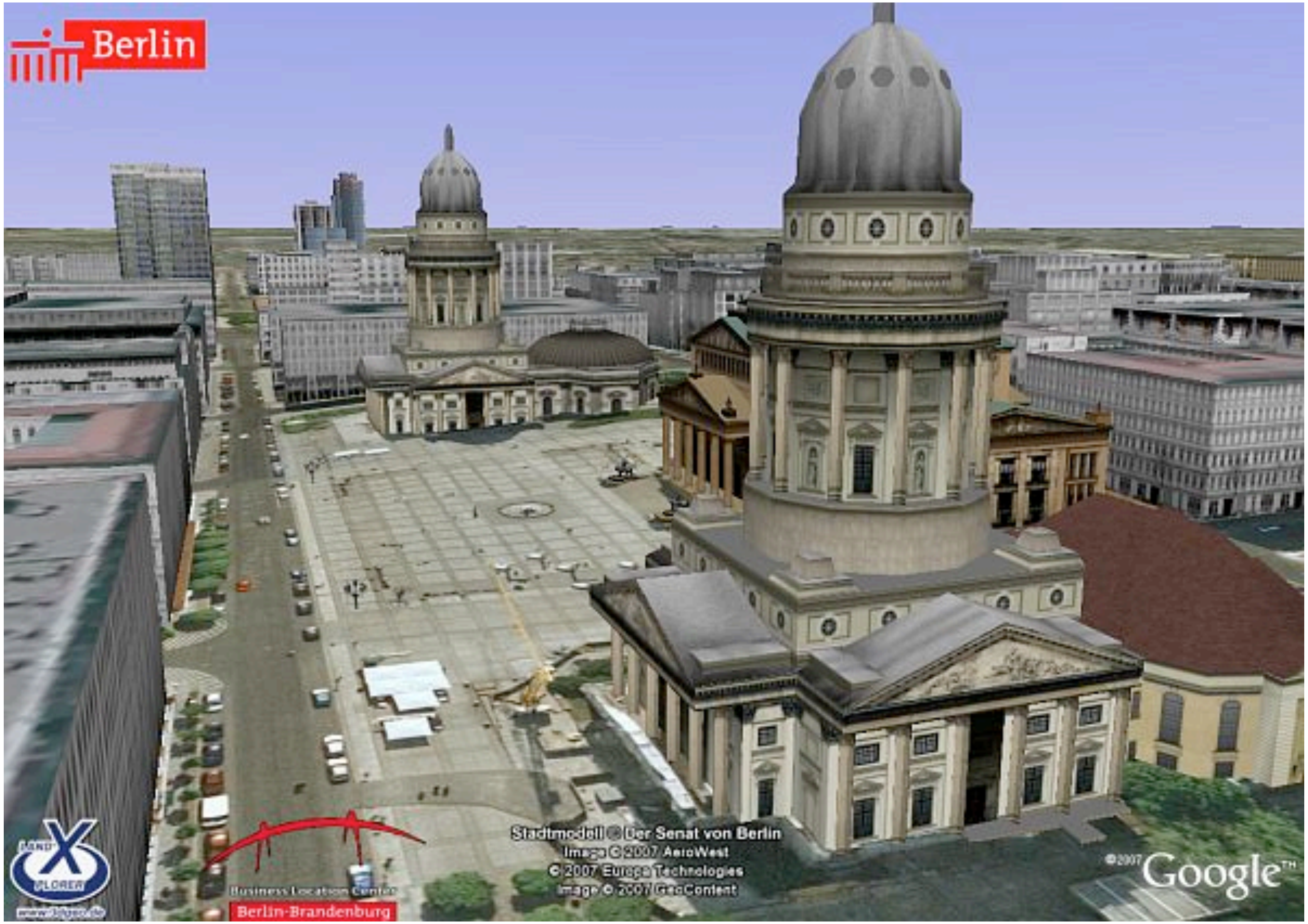
Application: City Mapping

[Courtesy: GeoAutomation & van Gool]

Application: 3D City Models

[Courtesy: Früh]

Application: 3D City Models



[Courtesy: Google]

Application: Digital Preservation of Cultural Heritage

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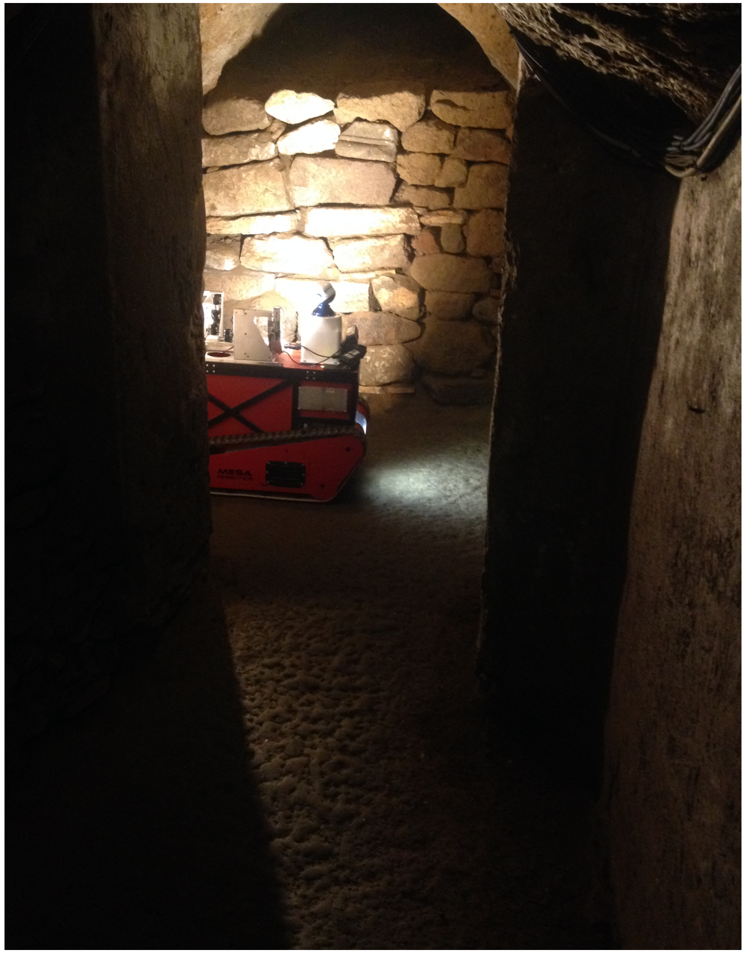


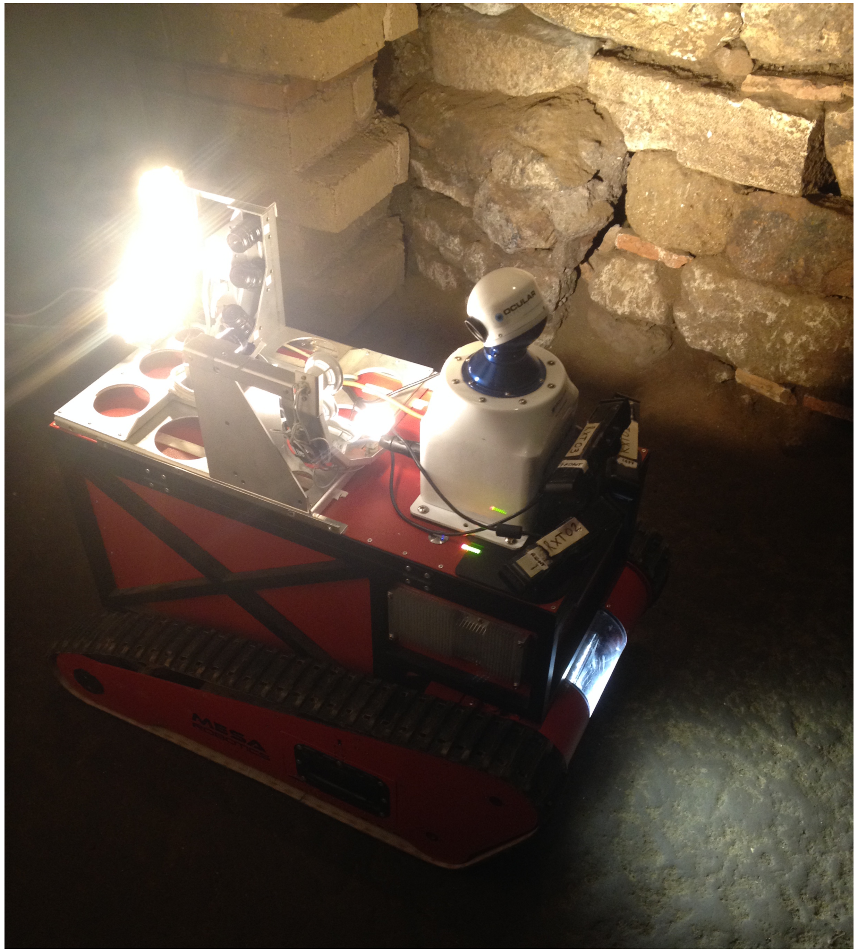
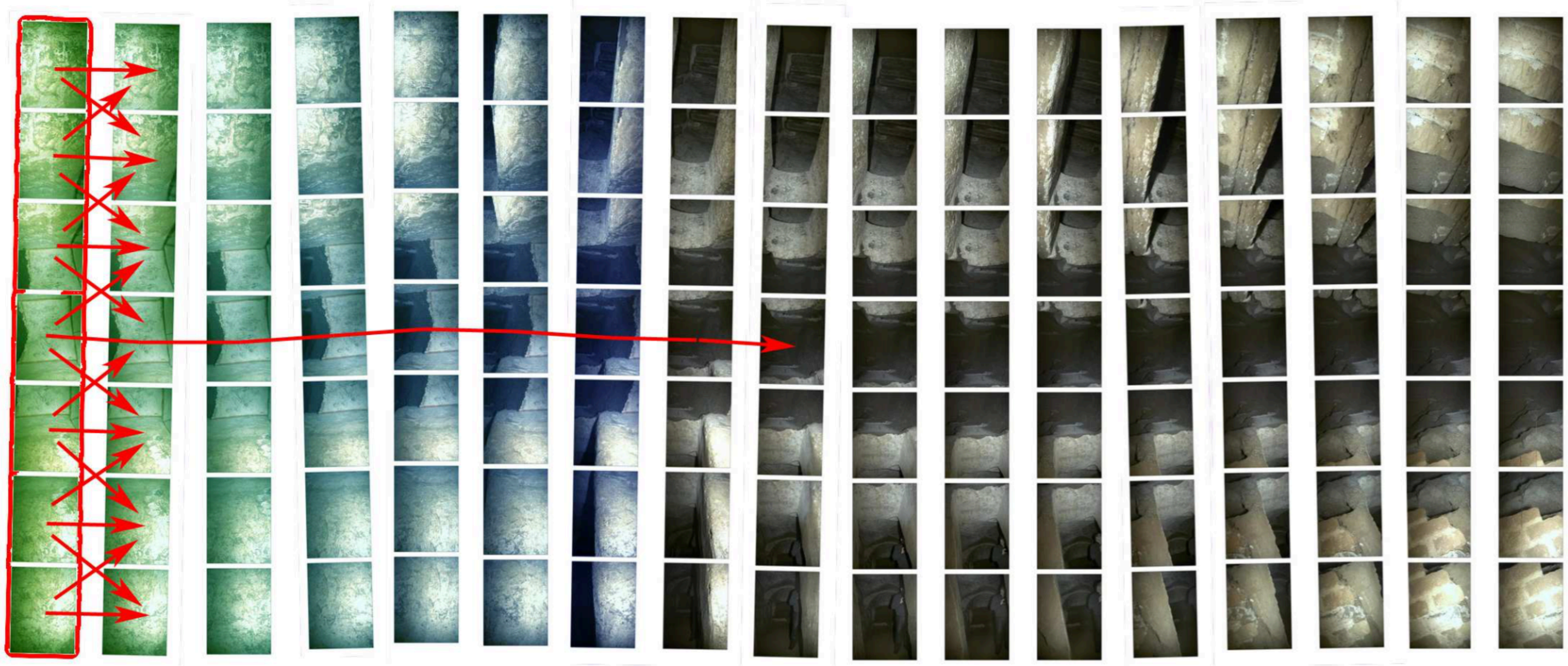


Image-Based 3D Reconstruction

- Seven cameras in known configuration
- Seeing points in multiple images allows for estimation 3D locations



3D Model of Cultural Heritage Site (Catacombe di Priscilla)

Application: Digital Preservation of Cultural Heritage

Catacombs of Priscilla
Access February 14, 2013 - ROBOT PATH (1th floor)

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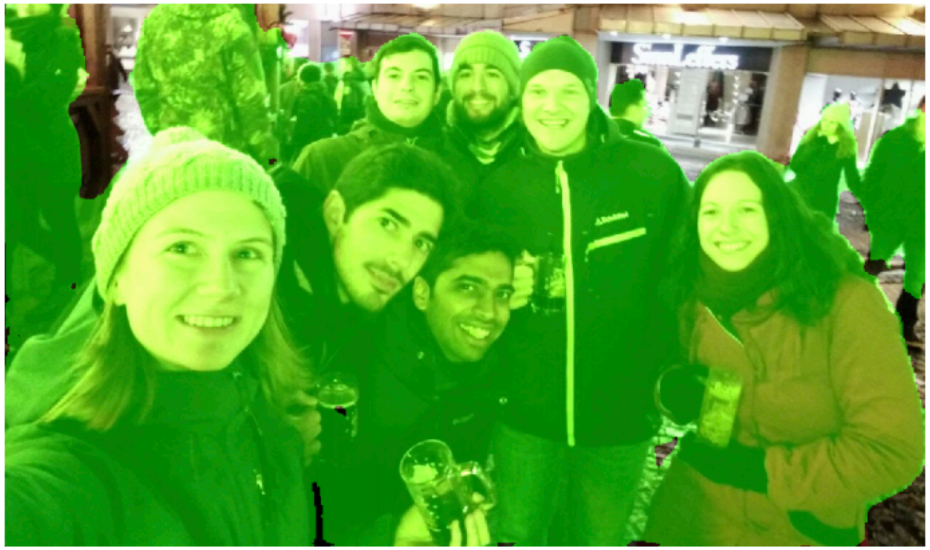
Application: Robotics

Semantics in Robotics

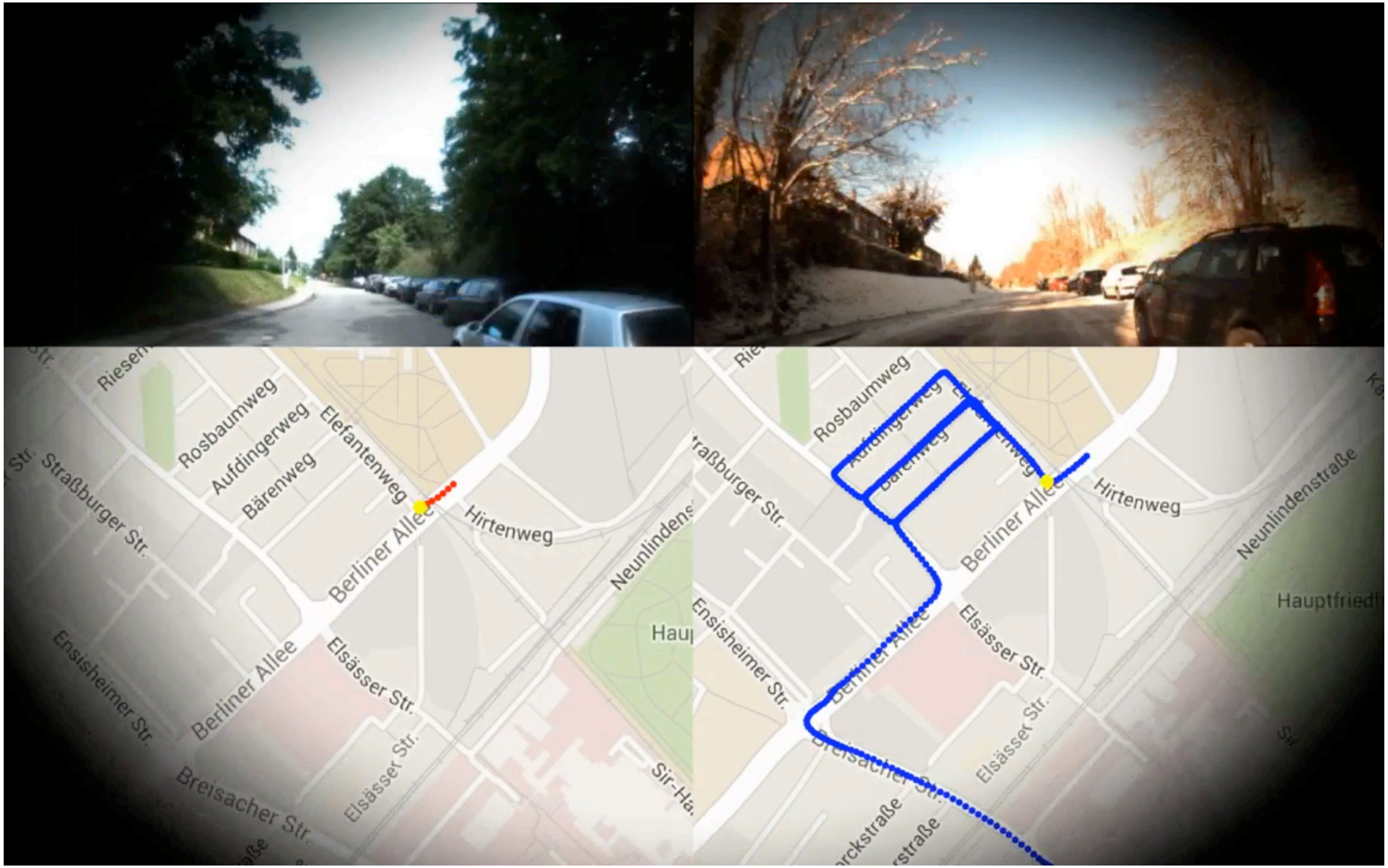



Visual Localization

Is this the same place?

Requires to Solve Challenging Image Matching Problems

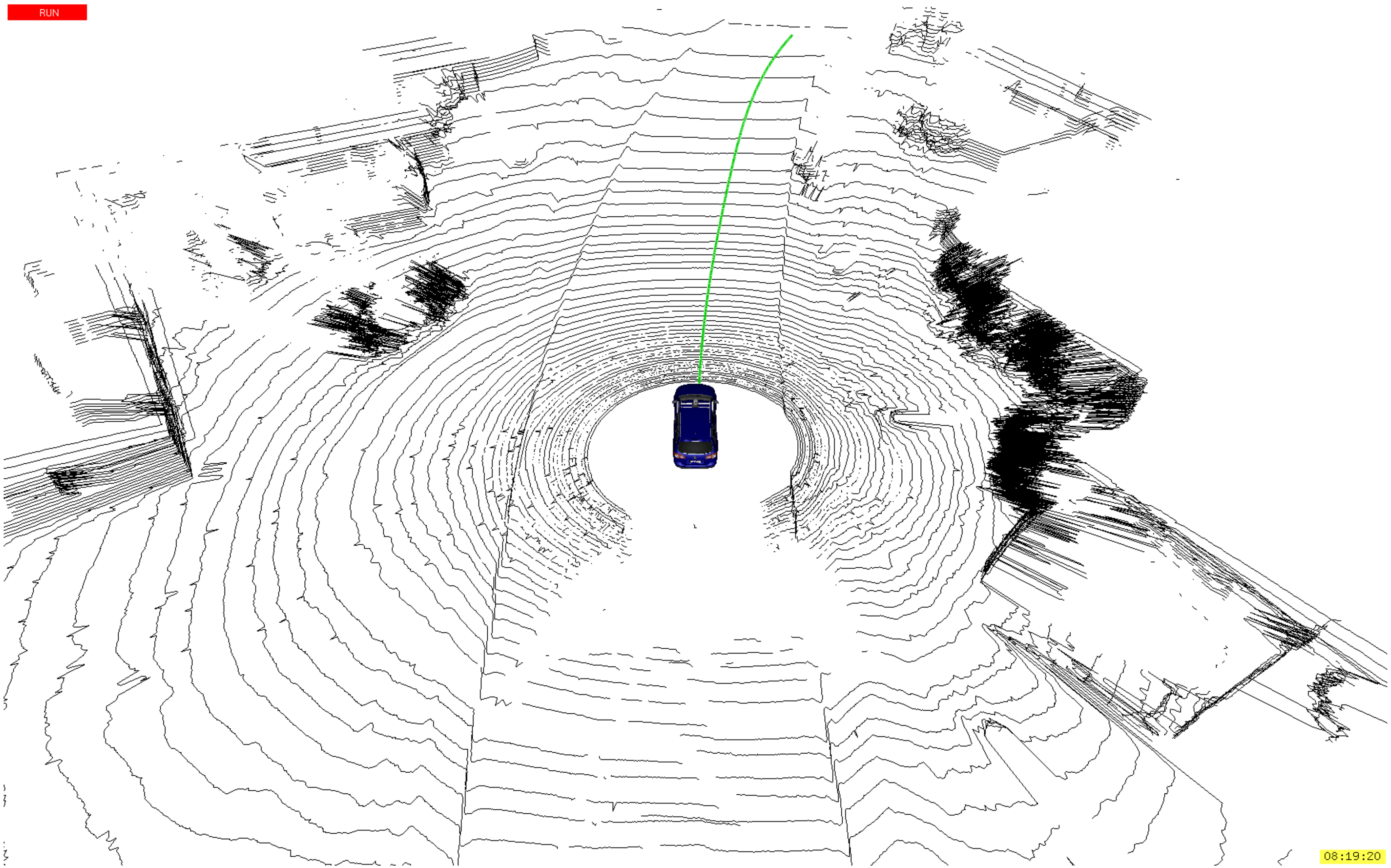
Purely Vision Localization Across Seasonal Changes



Robotic Cars

[Courtesy: Google]

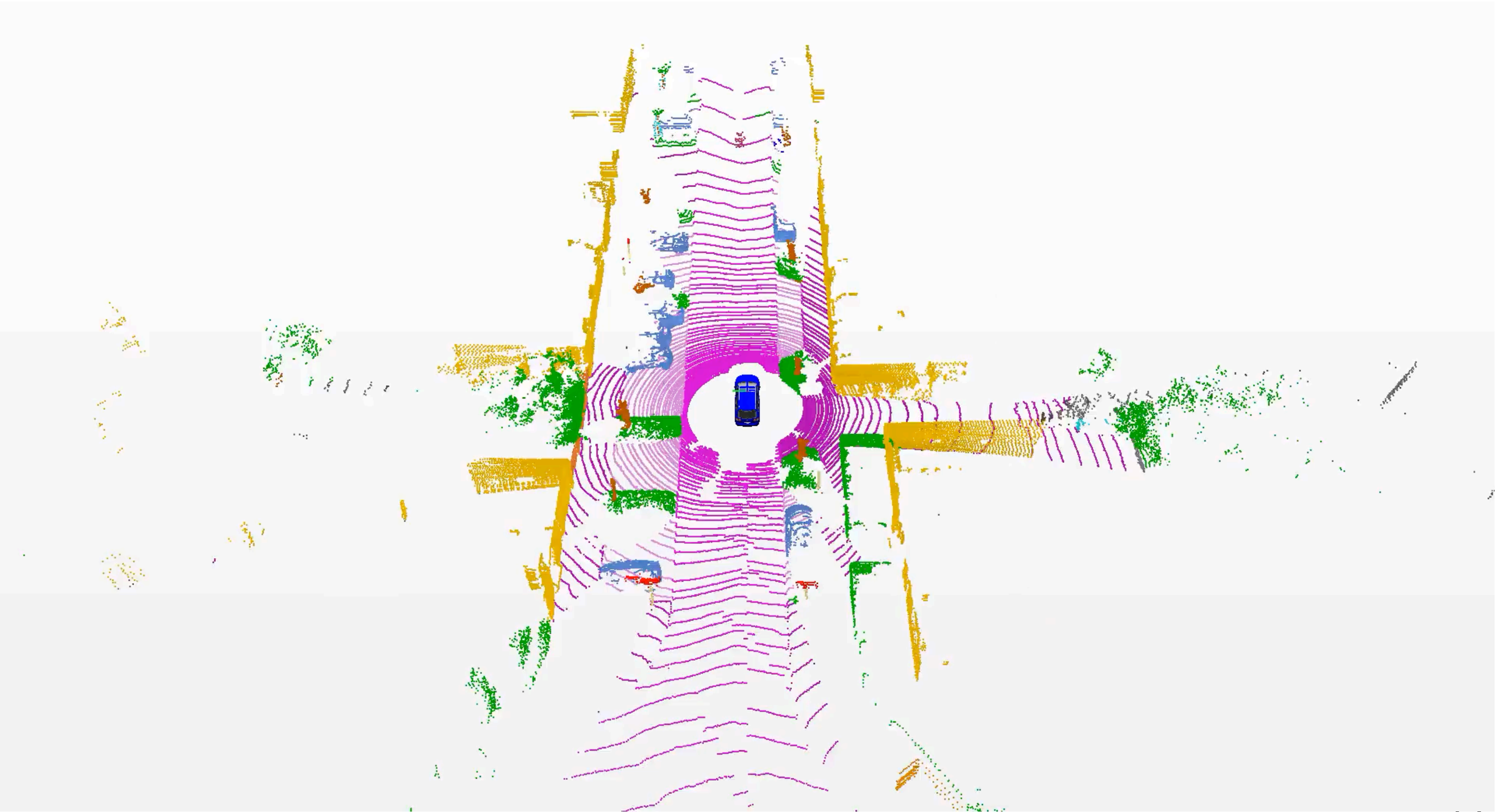
What Does the Car See?



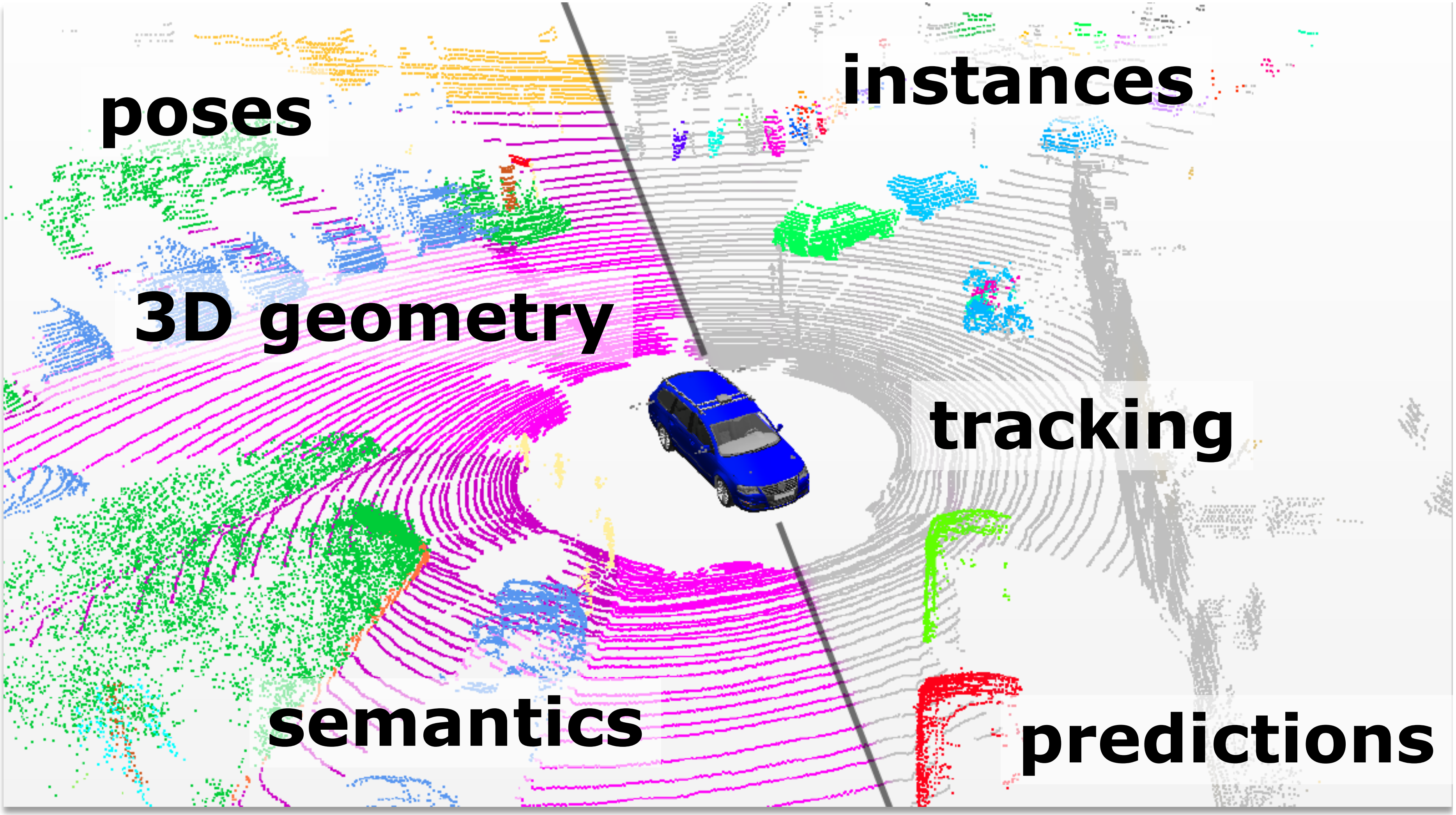
[Courtesy: Google]

Camera-based Semantic Segmentation

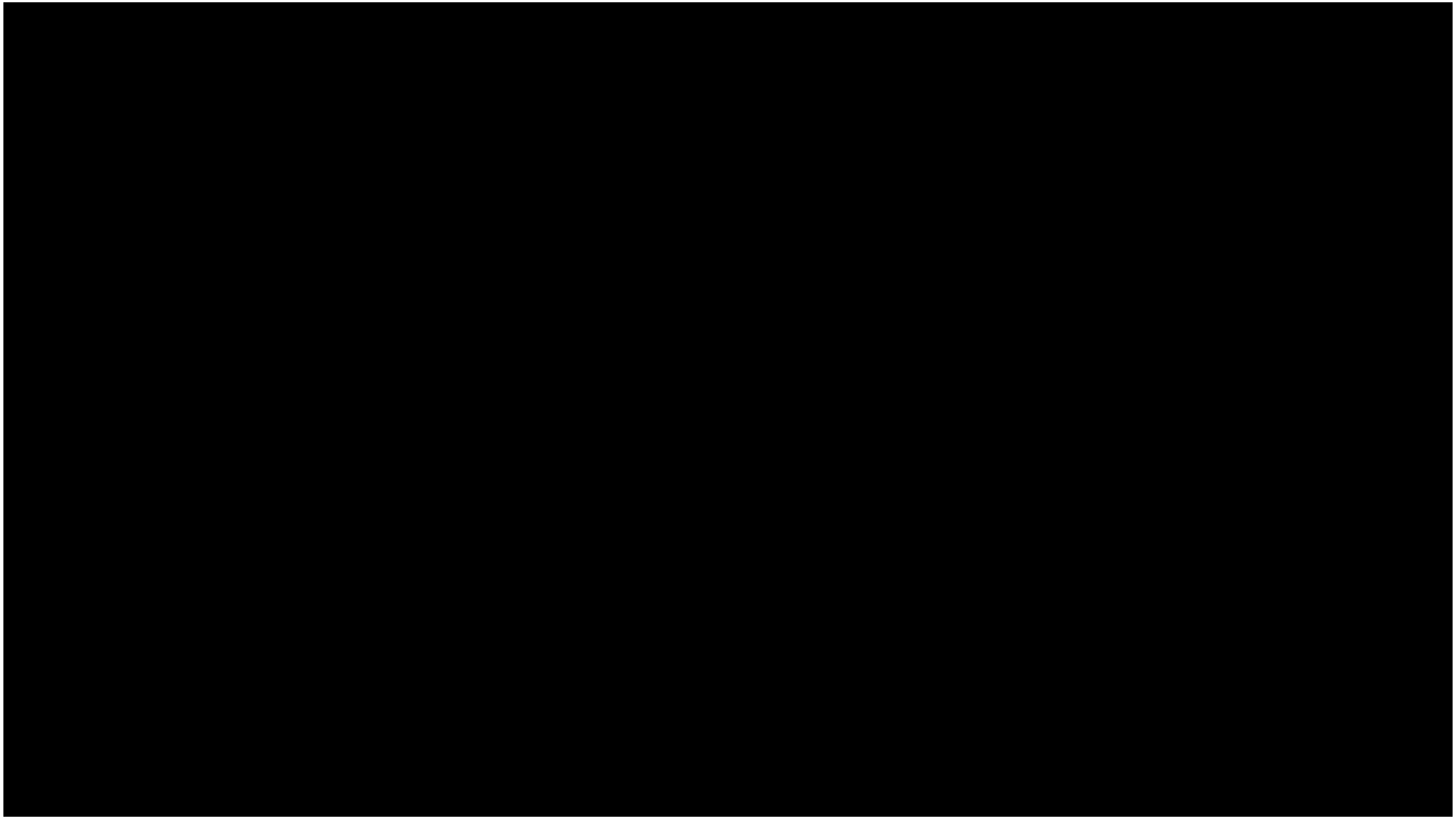
LiDAR-based Semantic Segmentation



What Do We Need to Estimate?



Today's Autonomous Cars



[Courtesy: Google/Waymo]

Photogrammetry I + II

- This module (Photo I + II) is intended to provide the foundations of photogrammetry
- Key building blocks for interesting and exciting applications

Relevant Literature

Used in this course

- Förstner & Wrobel: Photogrammetric Computer Vision
- Förstner: Photogrammetrie I Skriptum
- Szeliski: Computer Vision: Algorithms and Applications. Springer, 2010
- Alpaydin: Introduction to Machine Learning, 2009
- Hartley & Zisserman: Multiple View Geometry in Computer Vision, 2004

Slide Information

- The slides have been created by Cyrill Stachniss as part of the photogrammetry and robotics courses.
- **I tried to acknowledge all people from whom I used images or videos. In case I made a mistake or missed someone, please let me know.**
- The photogrammetry material heavily relies on the very well written lecture notes by Wolfgang Förstner and the Photogrammetric Computer Vision book by Förstner & Wrobel.
- Parts of the robotics material stems from the great Probabilistic Robotics book by Thrun, Burgard and Fox.
- If you are a university lecturer, feel free to use the course material. If you adapt the course material, please make sure that you keep the acknowledgements to others and please acknowledge me as well. To satisfy my own curiosity, please send me email notice if you use my slides.

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