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
Advantages (1)

- Contact-free sensing

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.
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

- object
  - geometry
  - location
  - type
  - ...

- camera
  - intrinsics
  - extrinsics

- physics

- image
The Inverted Mapping

images → algorithm → background knowledge → physics

object → geometry location type ...

camera → intrinsics extrinsics
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
Applications
Application: Maps

[Courtesy: Google Maps]
Application: Maps

[Courtesy: Google Maps]
Application: Terrain Models

[Courtesy: NEXTMap]
Application: Environment Monitoring
Application: Environment Monitoring
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
Application: Digital Preservation of Cultural Heritage
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
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?

- poses
- 3D geometry
- semantics
- instances
- tracking
- predictions
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
- 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.

Cyrill Stachniss, cyrill.stachniss@igg.uni-bonn.de