Computer Vision

-Introduction and Course Overview-

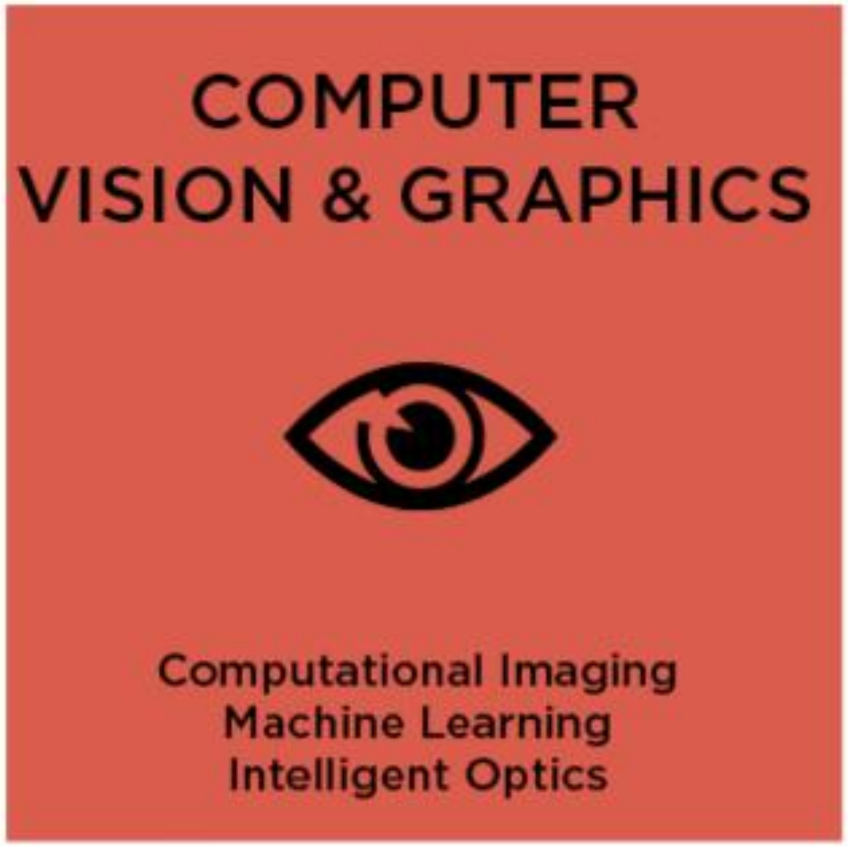
Oliver Bimber

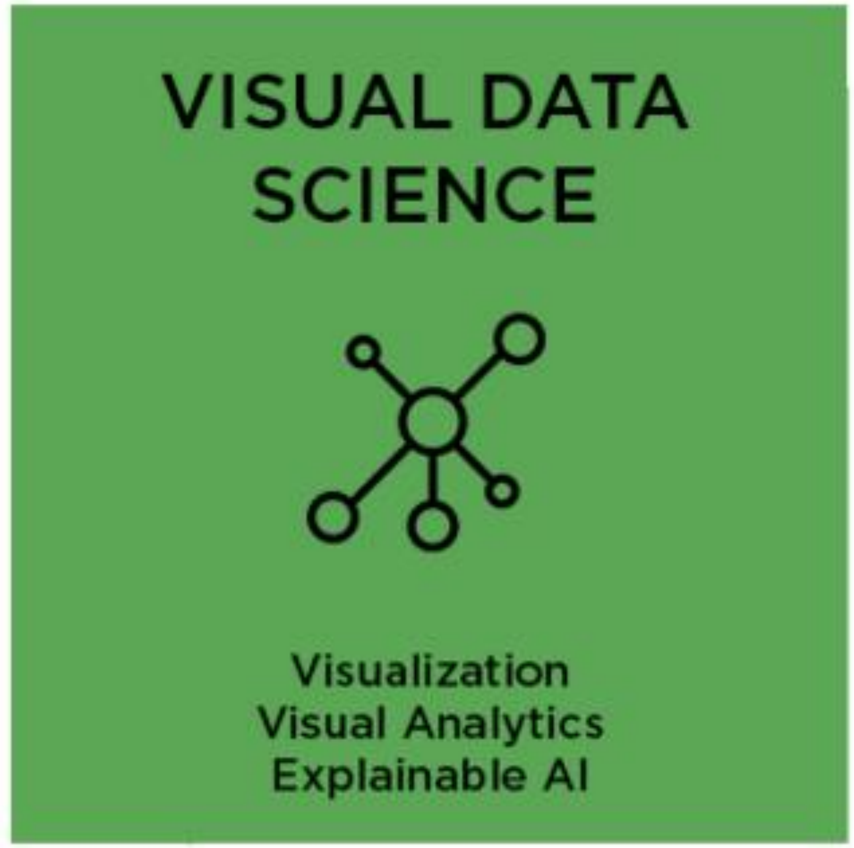
Course Schedule

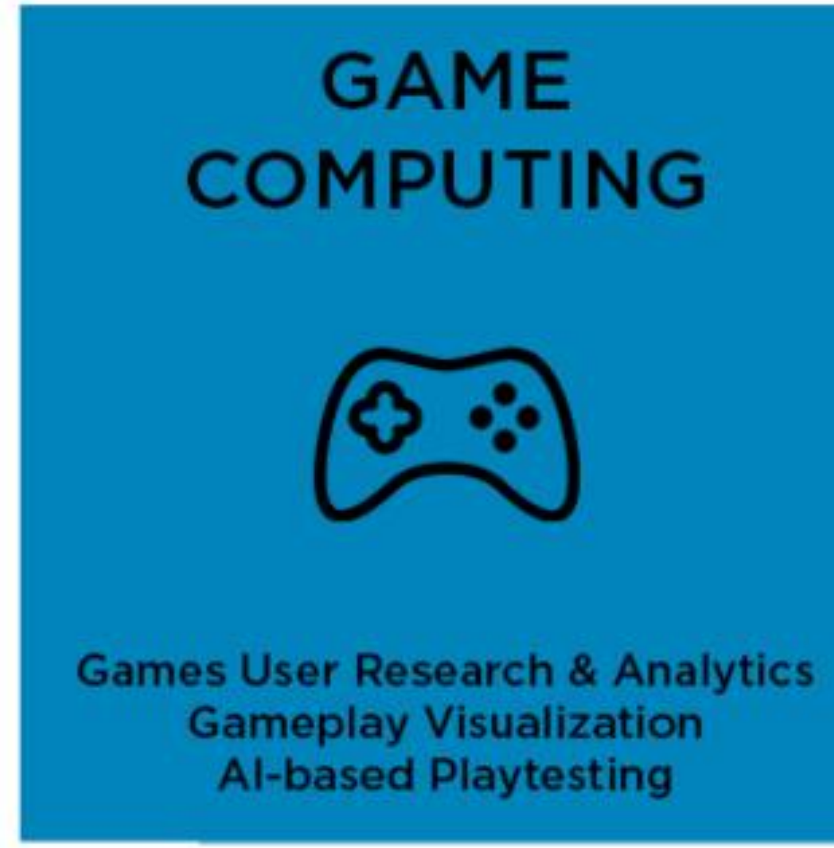
Type	Date	Time	Room	Topic	Comment
Lec1	11.10.2022	12:00-13:30	H1	Introduction and Course Overview	
Lab1	10./11./12./13.10.2022	17:15-18:45	S3055	Introduction to Python	
Lec2	18.10.2022	12:00-13:30	HS 1	Spatial and Frequency Domain Processing	
Lab2	17./18./19./20.10.2022	17:15-18:45	S3055	Introduction to IP/CV Modules	
Lec3	25.10.2022	12:00-13:20	HS 1	Gradient Domain Processing	National Holiday (26.10.)
Lec4	08.11.2022	12:00-13:30	HS 10	Segmentation and Local Features	Allerheiligen (2.11.)
Lab3	07./08./08./10.11.2022	17:15-18:45	S3055	Project Introduction	
Lec5	15.11.2022	12:00-13:30	HS 1	Basics of Cameras	
Lec6	22.11.2022	12:00-13:30	HS 1	Geometric Camera Calibration	
Lab4	21./22./23./24.11.2022	17:15-18:45	S3055	Project Basics and Related Work	
Lec7	29.11.2022	12:00-13:30	HS 1	The Geometry of Multiple Views	
Lec8	06.11.2022	12:00-13:30	HS 1	Stereoscopic Depth Estimation	Mariä Empfängnis (8.12.)
Lec9	13.12.2022	12:00-13:30	HS 1	Range Scanning and Data Processing	
Lab5	12./13./14./15.12.2022	17:15-18:45	S3055	Presentation of Initial Ideas	Christmas Break
Lec10	10.01.2023	12:00-13:30	HS 1	Structure from Motion	
Lab6	09./10./11./12.01.2023	17:15-18:45	S3055	Presentation of Intermediate Results and Final Concepts	
Lec11	17.01.2023	12:00-13:30	HS 1	Computational Imaging	
Lec12	24.01.2023	12:00-13:30	HS 1	Recap and Q&A	
Lab7	23./24./25./26.01.2023	17:15-18:45	S3055	Final Project Presentations	
Ex1	31.01.2023	12:00-13:30	HS 1	Exam (Hauptklausur)	
Ex2	28.02.2023	15:30-17:00	TBA	Retry Exam (Nachklausur)	

The Institute

(We do Visual Computing!)







Oliver Bimber

Marc Streit

Günter Wallner

What is Computer Vision?

…extracting description of the world from images…

What is Computer Graphics?

…synthesizing images from a description of the world…

…in many aspects we can say that CV is the dual of CG…?

Example: Shape from X

Example: Deepfakes

nature machine intelligence

Science Robotics

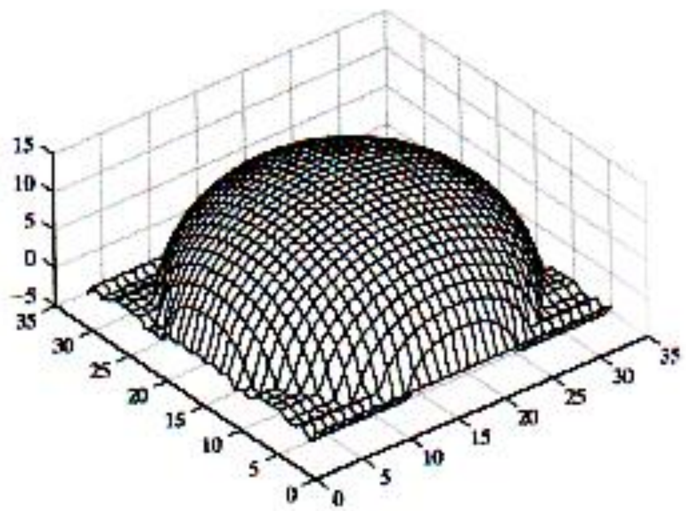
FLIR

JKU LINZ INSTITUTE OF TECHNOLOGY

LAND OBERÖSTERREICH

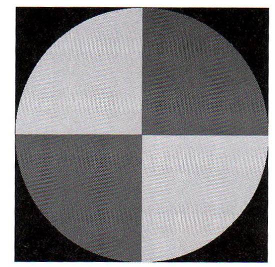
Homework: https://github.com/JKU-ICG/AOS/

Introduction by Example



geometry

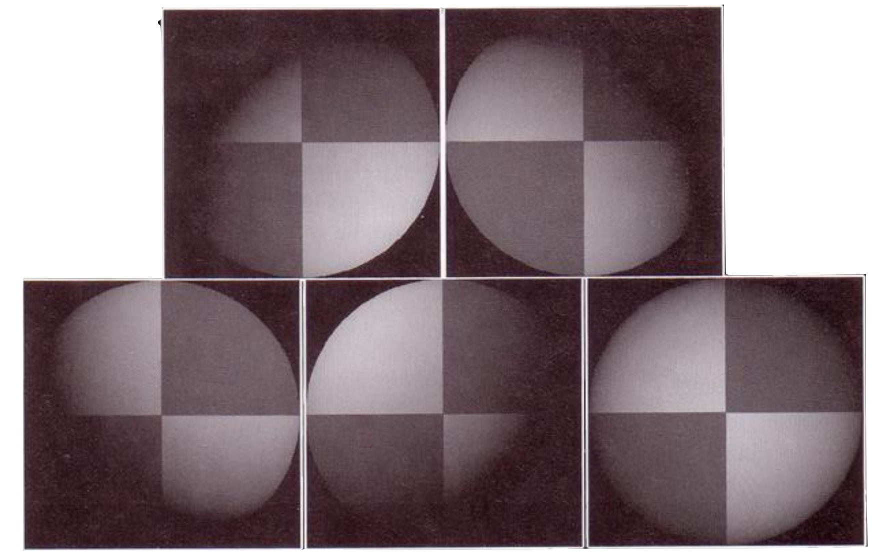
+

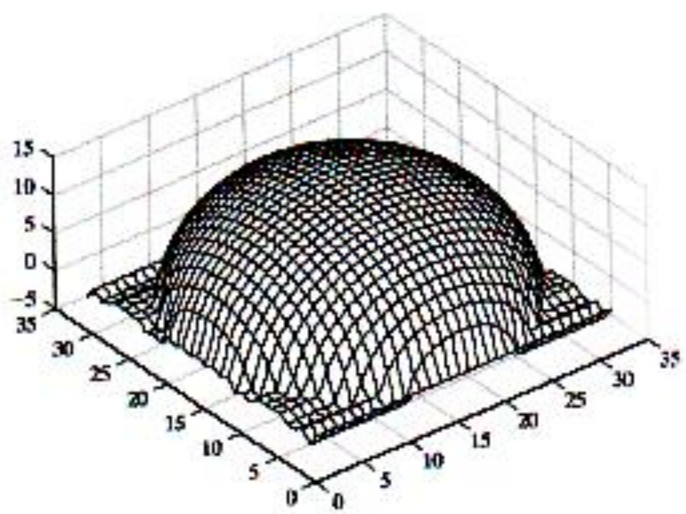


texture

shading

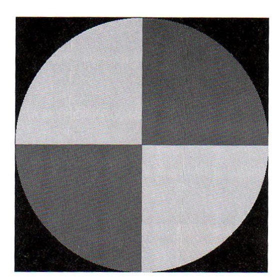
CG →





geometry

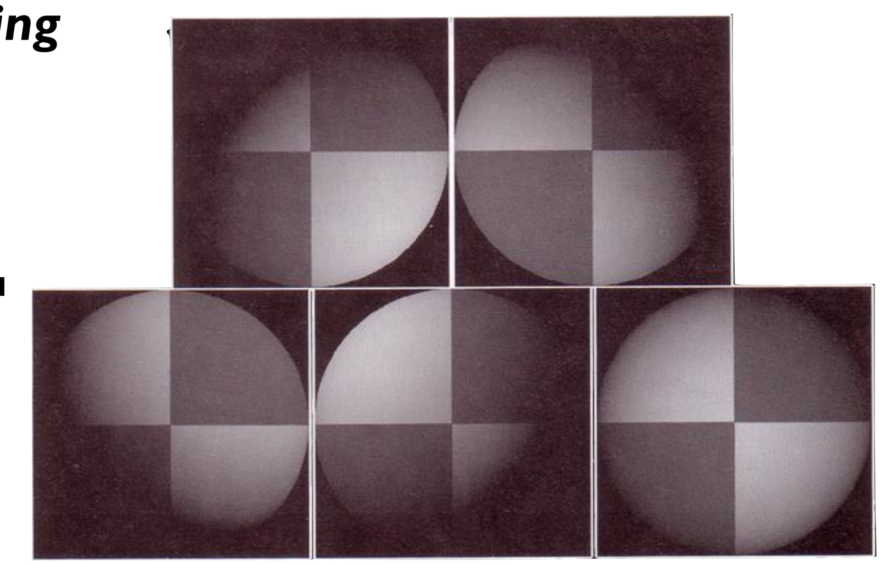
+



texture

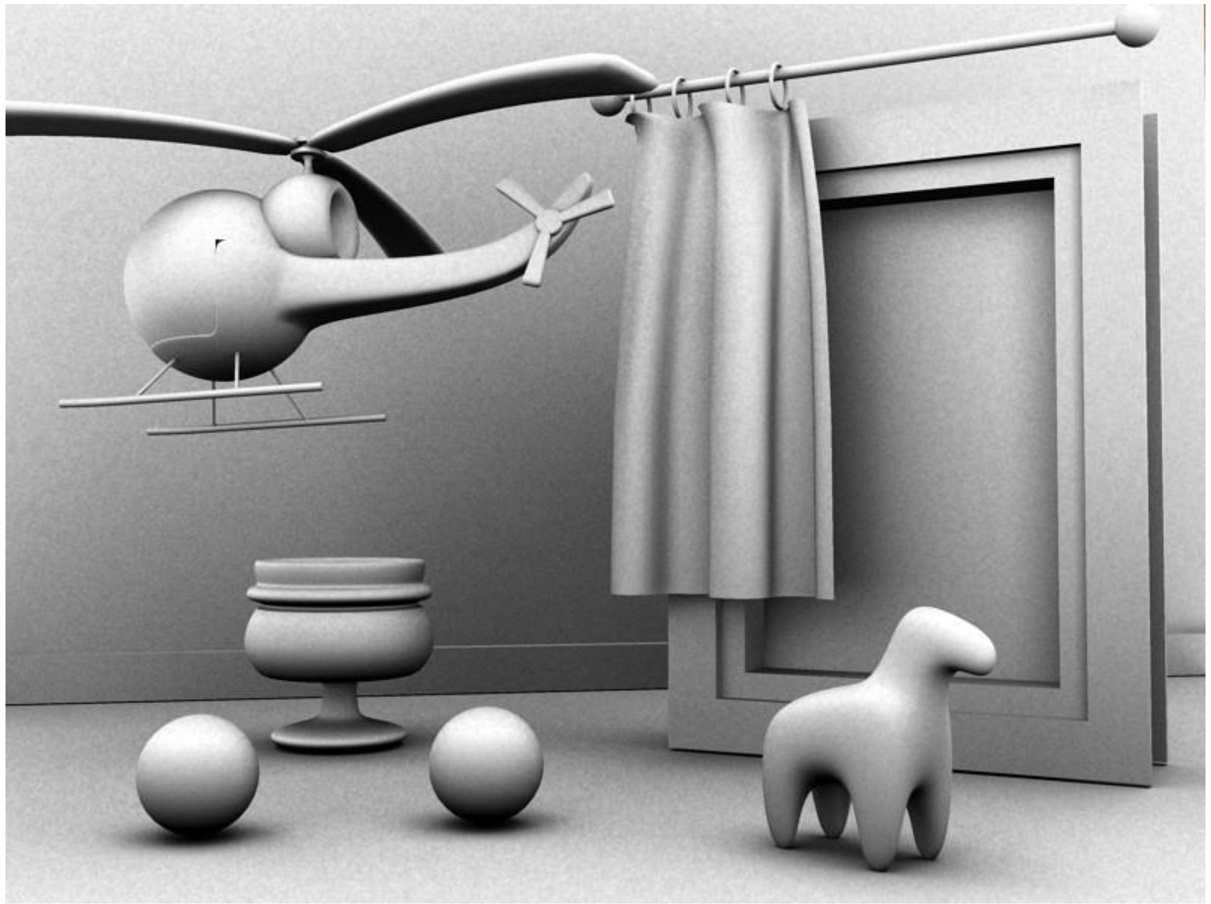
shape from shading

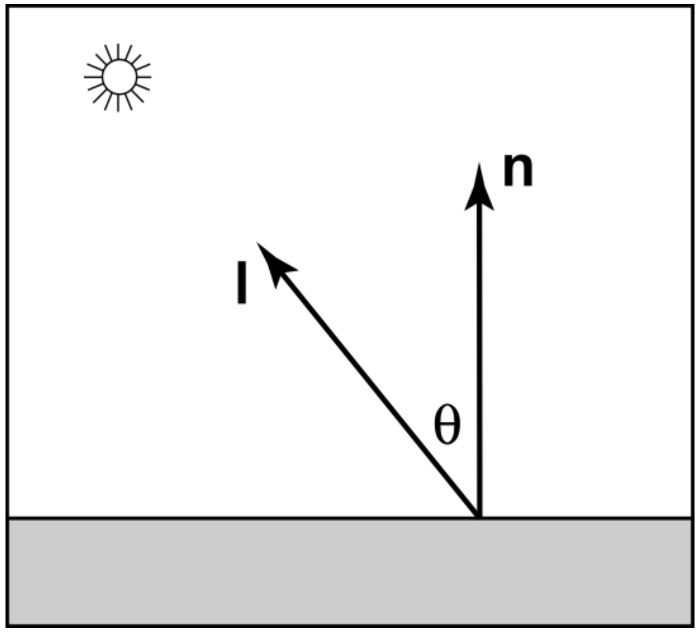
← CV



Recap: Lambertian Shading Model

- Many objects in real world have a matte surface appearance
- They can be considered to behave „Lambertian“ (after Johann Heinrich Lambert)
- Lambert‘s law states that the shading (c) of a surface point is proportional to the cosine of the angle between surface normal (n) and direction of the light source (l)
- This assumption is only valid if the light source is relatively far away from the surface (optimally at infinity, since only in this case all light rays have the same direction)
- If a light source is infinitely far away and can be described only by its direction, this is called a directional light
- If a light source has a position, it is normally a point light
- A point light with restricted solid angle is called spot light

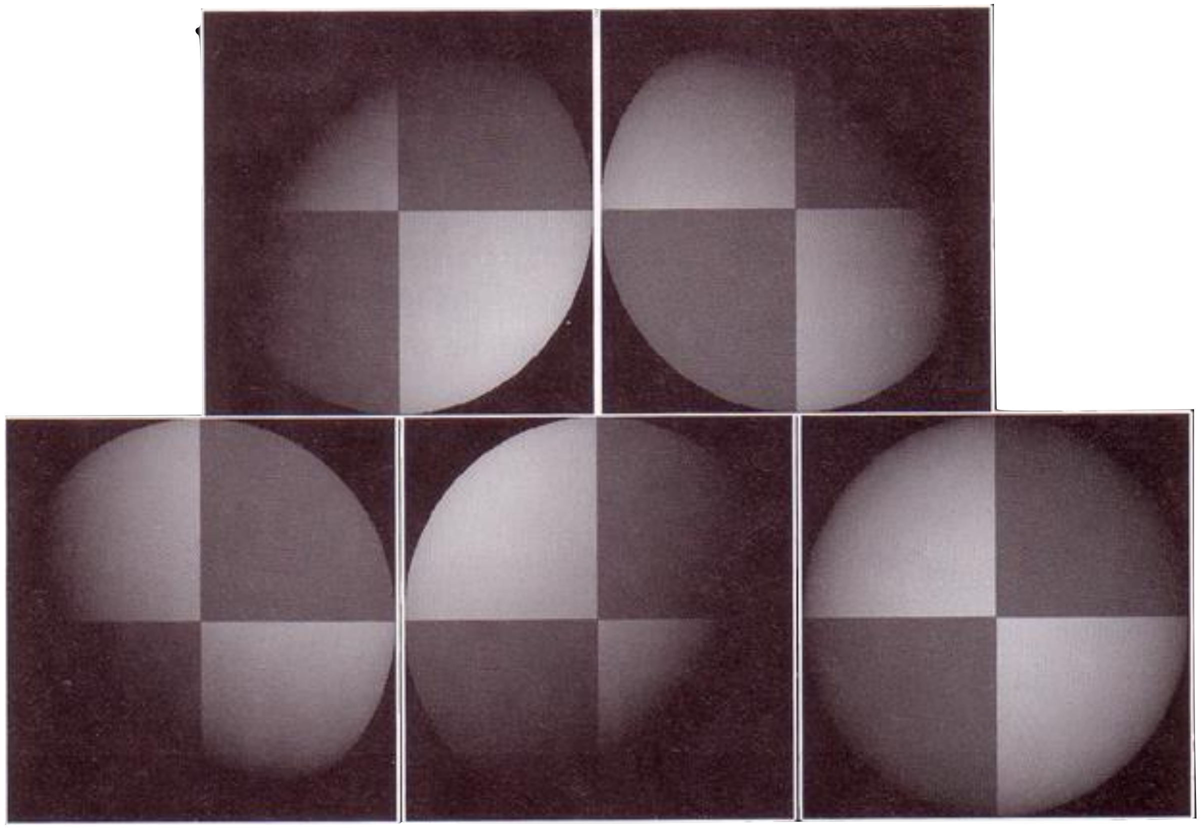




$$c \propto cos(\theta) = |n \cdot l|$$

Example: Shape from Shading

- Given is a set of pictures of a surface under different illuminations
- Camera is fix relative to surface
- Illuminate surface with point light source that is located relatively far away compared to the size of the surface
- Assume that there is no ambient light

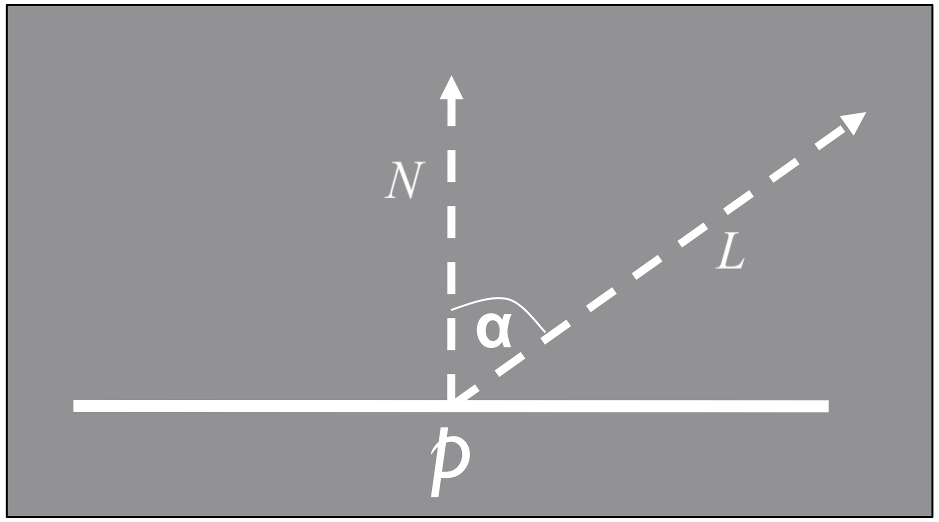


images samples of object under different illuminations

Example: Shape from Shading

- Adopt local shading model (global effects are not taken into account)
- Only one point P on surface for each pixel (x,y)
- Assume linear camera response k (connecting input radiance with response)
- Separate surface information g(x,y) from properties of illumination and camera V

$$I(x,y) = k \cdot \rho(x,y) \cdot N(x,y) \cdot L(x,y)$$
$$= k \cdot \rho(x,y) \cdot \cos(\alpha_{x,y})$$



$$g(x,y) = \rho(x,y) \cdot N(x,y)$$
$$V(x,y) = k \cdot L(x,y)$$
$$I(x,y) = g(x,y) \cdot V(x,y)$$

Example: Shape from Shading

- With enough correspondences between I and V, g can be reconstructed
- For n light sources we have a matrix A of n vectors V_i
- For each pixel, we stack the intensity into a vector i(x,y)
- Now we have i = Ag, which is a linear equation system with three unknowns in g
- Thus, n>3 to find a solution

$$A = \begin{pmatrix} V_1^T \\ V_2^T \\ \dots \\ V_n^T \end{pmatrix}$$

$$i(x,y) = \{I_1(x,y), I_2(x,y), \dots, I_n(x,y)\}^T$$

$$i(x,y) = Ag(x,y)$$

Example: Shape from Shading

- Least square methods can be used for computing solution
- Problem: regions may be in shadow (I=0) for one or the other light source!
- Solution: form a matrix B from the image vectors I and multiply both sides with this matrix. This zeros out any equations of any points in shadows

$$i = Ag$$

$$B(x,y) = \begin{pmatrix} I_1(x,y) & .. & 0 & 0 \\ 0 & I_2(x,y) & .. & 0 \\ .. & .. & .. & .. \\ 0 & 0 & .. & I_n(x,y) \end{pmatrix}$$

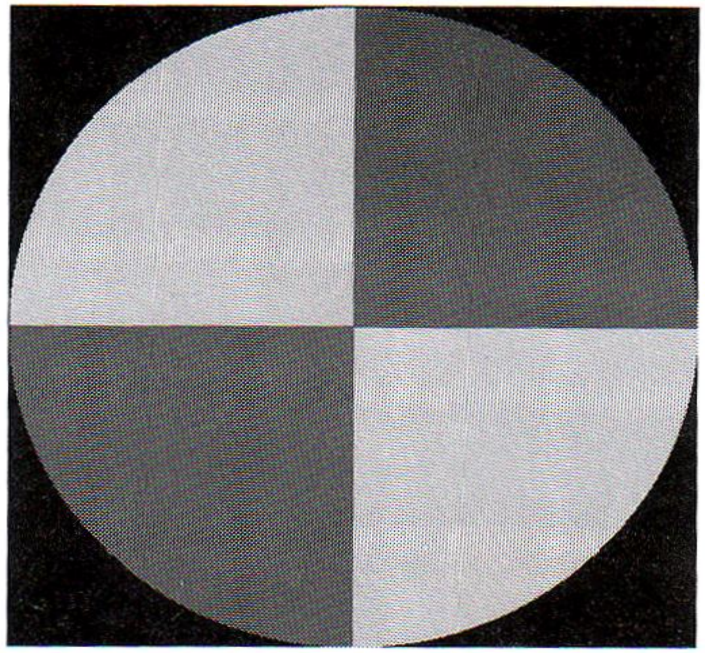
$$Bi = BAg$$

Example: Shape from Shading

- Solve linear equation system to recover g
- Extract albedo from g (knowing that N is unit vector)
- Pixels with albedo not in the range of $0 \leq |\rho| \leq 1$ indicate errors (e.g., in solution of g)

$$g(x,y) = \rho(x,y) \cdot N(x,y)$$

$$|g(x,y)| = \rho(x,y), |N| = 1$$

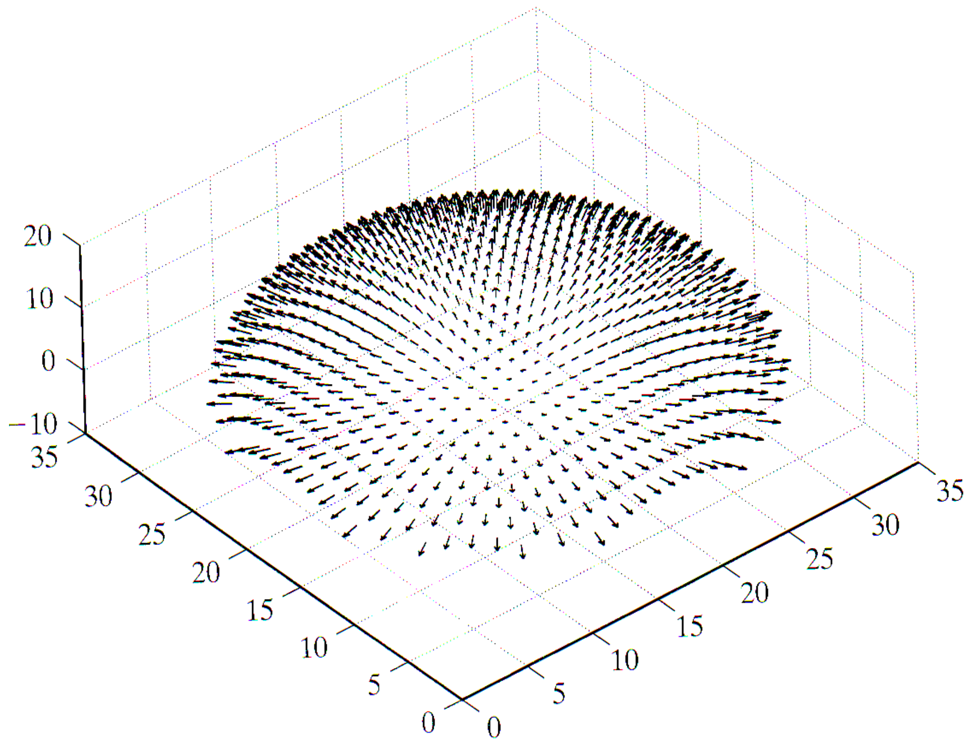


recovered albedo

Example: Shape from Shading

- Recover normals (keeping in mind that they have unit length)

$$N(x,y) = \frac{1}{|g(x,y)|} g(x,y)$$



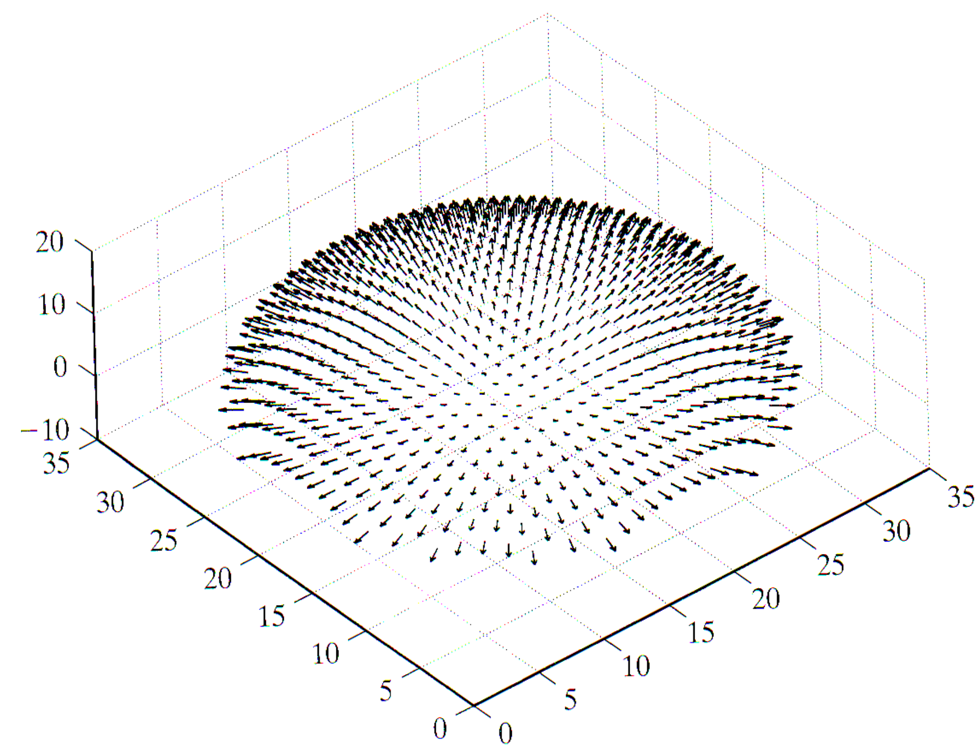
recovered normals

Example: Shape from Shading

- Recover normals (keeping in mind that they have unit length)

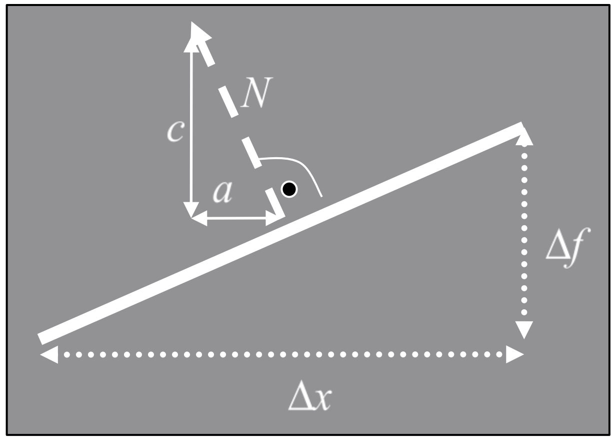
$$N(x,y) = \frac{1}{|g(x,y)|} g(x,y)$$

- Recover shape from normals:
  - N(x,y) can be computed as partial derivative of f(x,y) in x and y directions
  - the partial derivatives allow to reconstruct the height changes within a small step along the x and y directions!



recovered normals

$$\frac{\partial f}{\partial x} = \frac{a}{c}$$



Example: Shape from Shading

- Recover normals (keeping in mind that they have unit length)
- Recover shape from normals:
  - N(x,y) can be computed as partial derivative of f(x,y) in x and y directions
  - the partial derivatives allow to reconstruct the height changes within a small step along the x and y directions!

$$N(x,y) = \frac{1}{|g(x,y)|} g(x,y)$$

$$N(x,y) =$$

$$\frac{1}{\sqrt{1+\left(\frac{\partial f}{\partial x}\right)^2+\left(\frac{\partial f}{\partial y}\right)^2}}\left\{-\frac{\partial f}{\partial x},-\frac{\partial f}{\partial y},1\right\}^T$$

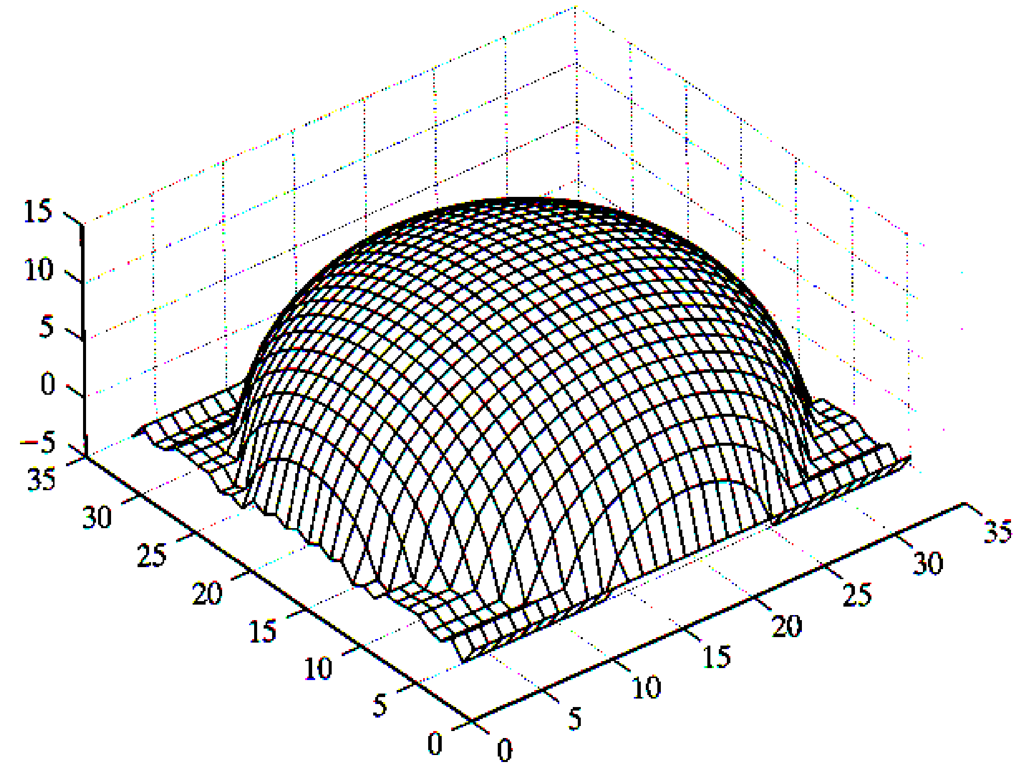
$$N(x,y) = \{a(x,y), b(x,y), c(x,y)\}$$

$$\frac{\partial f}{\partial x} = \frac{a}{c}, \frac{\partial f}{\partial y} = \frac{b}{c}, \partial x = \partial y = 1$$

Example: Shape from Shading

- Shape by integration: reconstruct the surface by summing the height changes along some arbitrary path
- Example: to reconstruct surface height at (u,v), a possible path could be from (0,0) to (0,v) to (u,v)
- The constant c is the height at the start point

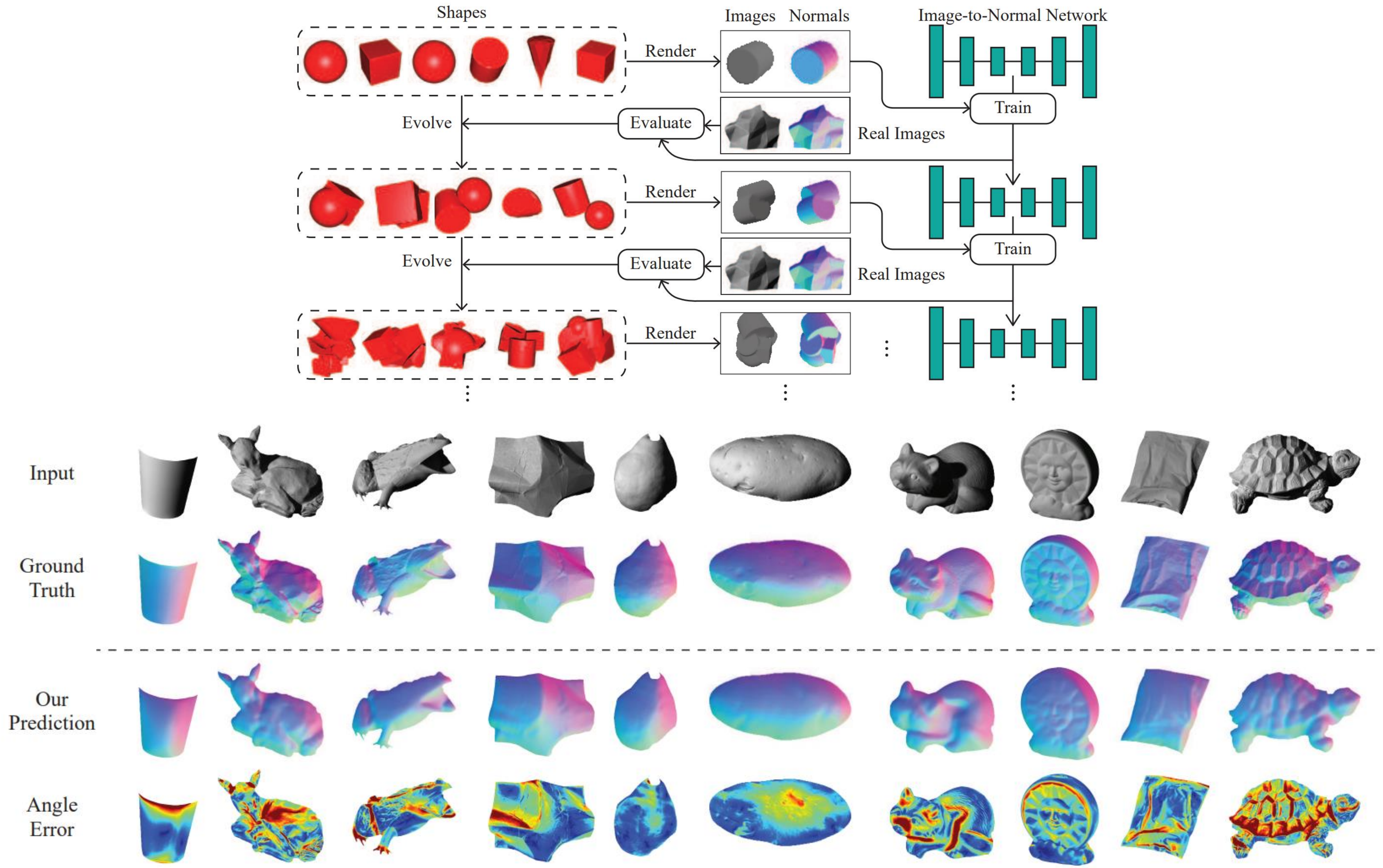
$$f(x,y) = \int_{y=0}^{v} \frac{\partial f}{\partial y}(0,y)\,dy + \int_{x=0}^{u} \frac{\partial f}{\partial x}(x,v)\,dx + c$$



recovered shape

Example: Shape from Shading…

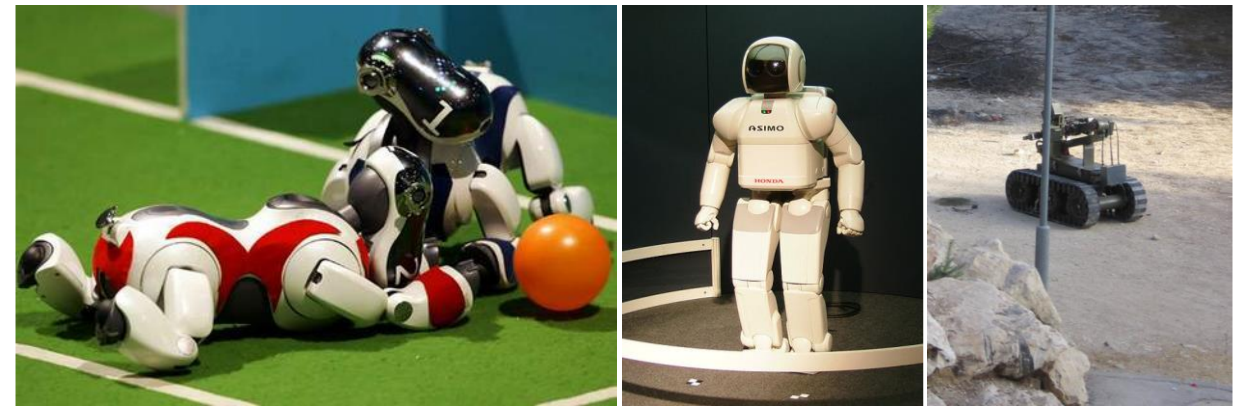
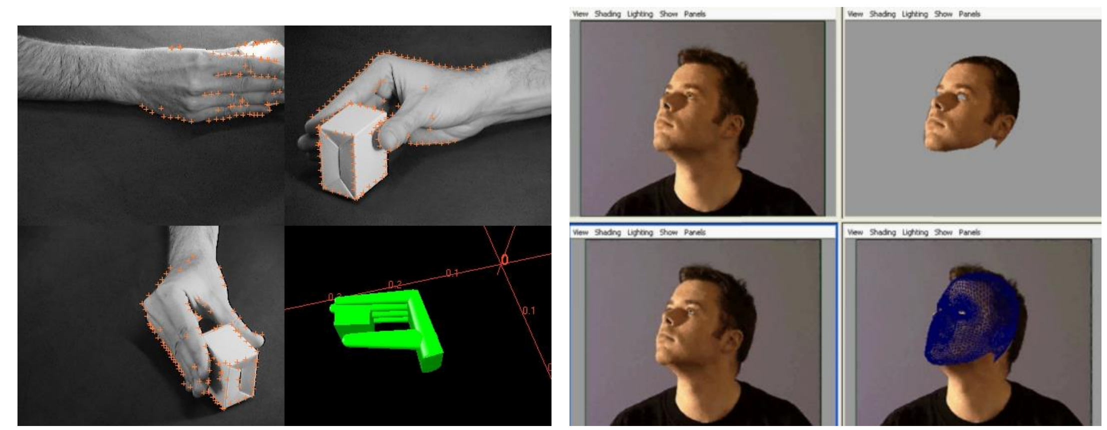
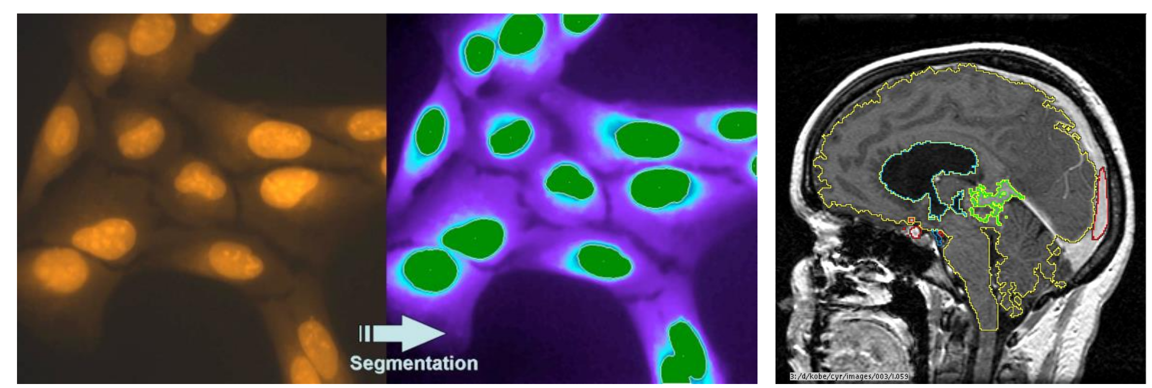
…through Shape Evolution

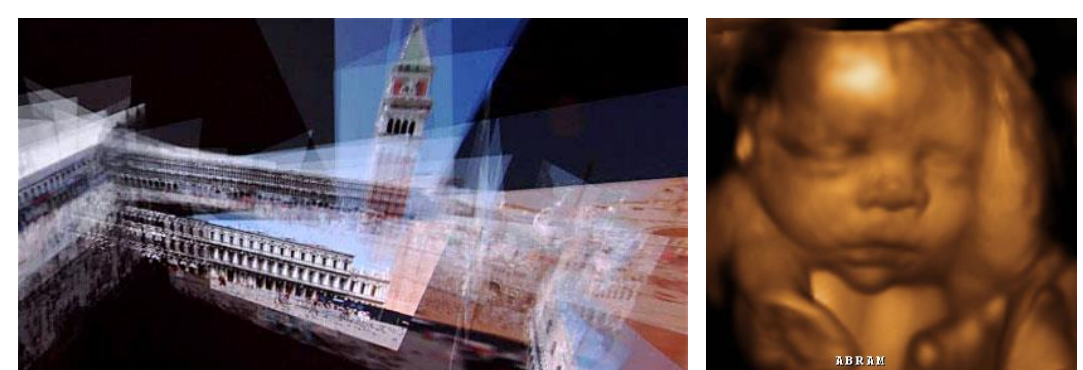


Homework: https://openaccess.thecvf.com/content_cvpr_2018/papers/Yang_Shape_From_Shading_CVPR_2018_paper.pdf

Main Application Areas

- Robotics and Machine Vision (automatisation, military, security, etc)
- Human-Computer Interaction / Human-Computer Interfaces (gesture recognition, face tracking and recognition, body tracking, people tracing)
- Analysis (life science, medicine, biology, material science, etc.)
- Measurement and capture (shape, color, light rays, next-generation photography, etc.)
- etc.



Administrative Issues

- Lecture (2h/week) and labs (2h biweekly) in english, two separate courses
- Slides and other material is available on Moodle: https://moodle.jku.at (Course: 2022W364040, self-enrolment key: ComputerVision2022 or register through KUSSS)
- Discussion forum can also be used in Moodle
- Team assignments (Moodle): **07.11.2022**
- More information on other classes, invited talks, project topics, etc.: http://www.jku.at/cg
- Interested in BSc. or MS. thesis or practical course, contact me (oliver.bimber@jku.at)

Administrative Issues

364.040, VL Computer Vision, Oliver Bimber, 2022W

Dashboard / Meine Kurse / 2022W364040

Bearbeiten einschalten

Navigation

- Dashboard
  - Startseite
  - Website
  - Meine Kurse
    - MoodleInfo
    - 2022W660002
    - 2021W660002
    - 2020W660002
    - 2019W660002
    - 2018W660002
    - 2017W660002
    - Seminar in AI WS22
    - 2022W364021/2/3/41/42/43/44/45
    - 2022W364000
    - **2022W364040**
      - Teilnehmer/innen
      - Bewertungen
      - INTRODUCTION AND COURSE OVERVIEW
      - SPATIAL AND FREQUENCY DOMAIN PROCESSING
      - GRADIENT DOMAIN PROCESSING
      - SEGMENTATION AND LOCAL FEATURES
      - BASICS OF CAMERAS
      - GEOMETRIC CAMERA CALIBRATION

Objectives

While Computer Graphics focusses on image synthesis, Computer Vision is all about image analysis and image understanding. It finds many applications in domains such as, 3D reconstruction, robotics, medical engineering, media technology, automatization, biometry, human-computer-interaction, contact free measurement, remote sensing, quality control, etc. This lecture will give first insights into the basics of Computer Vision. At the end of the semester, participants of this class will be able to apply and implement computer vision methods independently. A basic understanding of programming concepts is required. Detailed knowledge in a programming language, however, is not necessary. The associated lab will provide a sufficient introduction into python, python modules, and hands-on computer vision techniques to prepare students for their team projects.

Subject

Spatial and frequency domain processing, gradient domain processing, segmentation and object recognition, basics of cameras, geometric camera calibration, the geometry of multiple views, stereoscopic depth estimation, range scanning and data processing, structure from motion, computational photography.

Selected Readings

1) Computer Vision – A Modern Approach, Forsyth and Ponce, Addison Wesley
2) Multiple View Geometry in Computer Vision, Hartley and Zisserman, Cambridge Press
3) Computer Vision: Algorithms and Applications, Richard Szeliski, Springer
4) Image Processing: The Fundamentals, Maria Petrou and Costas Petrou, Wiley
5) Learning OpenCV: Computer Vision with the OpenCV Library, Gary Bradski, Adrian Kaehler, Mike Loukides, Robert Romano, O'Reilly
6) Handbook of Mathematical Models in Computer Vision, Nikos Paragios and Yunmei Chen, Springer
7) Machine Vision. Theory , Algorithms, Practicalities: Theory, Algorithms, Practicalities: Theory , Algorithms, Practicalities, E. R. Davies, Academic Press
8) Computational Vision: Information Processing in Perception and Visual Behavior, Hanspeter A. Mallot, MIT Press
9) Three-Dimensional Computer Vision – A Geometric Approach, Olivier Faugeras, MIT Press

Criteria for Evaluation

eExam (Moodle Test)

COVID-19 Information

We plan for regular lectures in the lecture hall. In case the COVID situation escalates in winter semester, we might switch to hybrid or online only modes. We will inform you if this is the case.

Messageboard

INTRODUCTION AND COURSE OVERVIEW

Administrative Issues

- Grading: Lab (project), Lecture (exam)
- Exam: written (electronically through Moodle) at the end of the semester
- Project: four groups (A,B,C,D), teams of five, 6-7 min presentations (slides) per team, same grade for each team member (based on presentations, results, code)
- Team assignment will be done through Moodle (starting: 13.10.):
  - Team A0,...,A9, B0,...,B9, C0,...,C9, D0,...,D04(,...,D09)
  - Limited to 5 students per team (first come first served)
  - We have 4x5x10 teams (=200 students). Only if all teams are complete (5 Students) we allow more teams if necessary, we reassign teams to balance them
- If you have no KUSSS / Moodle access yet, contact cg@jku.at

Administrative Issues

364.021/2/3/41/42/43/44/45, UE Computer Vision, Indrajit Kurmi / Oliver Bimber / Rakesh Amala, 2022W

Dashboard / Meine Kurse / 2022W364021/2/3/41/42/43/44/45

Bearbeiten einschalten

Navigation

- Dashboard
  - Startseite
  - Website
  - Meine Kurse
    - MoodleInfo
    - 2022W660002
    - 2021W660002
    - 2020W660002
    - 2019W660002
    - 2018W660002
    - 2017W660002
    - Seminar in AI WS22
    - **2022W364021/2/3/41/42/43/44/45**
      - Teilnehmer/innen
      - Bewertungen
      - INTRODUCTION TO PYTHON
    - 2022W364000
    - Mehr ...
  - Kurse

Administration

- Kurs-Administration
  - Einstellungen bearbeiten
  - Nutzer/innen
  - Filter
  - Berichte
  - Setup für Bewertungen
  - Lernziele

Objectives

While Computer Graphics focusses on image synthesis, Computer Vision is all about image analysis and image understanding. It finds many applications in domains such as 3D reconstruction, robotics, medical engineering, media technology, automatization, biometry, human-computer interaction, contact free measurement, remote sensing, quality control, etc. The associated lecture will give first insights into the basics of Computer Vision. At the end of the semester, participants of this class will be able to apply and implement computer vision methods independently. A basic understanding of programming concepts is required. Detailed knowledge of a programming language, however, is not necessary. This lab w
techniques to prepare students for their team projects.

Subject

Introduction to Python, Introduction to python modules (Scikit-im

Selected Readings

1) Computer Vision – A Modern Approach, Forsyth and Ponce, Ad
2) Multiple View Geometry in Computer Vision, Hartley and Zisser
3) Computer Vision: Algorithms and Applications, Richard Szeliski,
4) Image Processing: The Fundamentals, Maria Petrou and Costas
5) Learning OpenCV: Computer Vision with the OpenCV Library, G
6) Handbook of Mathematical Models in Computer Vision, Nikos
7) Machine Vision. Theory, Algorithms, Practicalities: Theory, Algo
8) Computational Vision: Information Processing in Perception an
9) Three-Dimensional Computer Vision – A Geometric Approach,

Criteria for Evaluation

Team project (project presentations and results)

Organization

We offer four lab appointments per week: Mondays, Tuesdays, W
simultaneously. For distance learning students from Vienna, we o
appointments, and they will be offered in presence (in our PC poo
cannot support remote students as well as students being presen
For registration in KUSSS, students from Vienna should only regis
register for all other lab groups (364.021, 364.041, 364.042, 364.04
overflown, if groups have too few students, and to balance the nu
will be relevant. You should attend the lab appoints assigned to y
From the 4th lab appointment on, you will start your semester res
teams (0-9) per appointment (A=Mondays, B=Tuesdays, C=Wedn
members are present at the same lab appointments) will be done
fourth lab appointment, and you need to enroll until **07.11.2022**

Announcements

This forum is used by the CV team for announcements to all participants.

Messageboard

Please use the messageboard to communicate with us and your colleagues. Important information will be posted here too.

Schedule

These are the lab appointments.

	Week	Group A (17:15-18:45)	Group C (17:15-18:45)	Group D (17:15-18:45)	Group E (17:15-18:45)
Lab I	41	Mon, 10 Oct 2022	Tue, 11 Oct 2022	Wed, 12 Oct 2022	Thu, 13 Oct 2022
Lab II	42	Mon, 17 Oct 2022	Tue, 18 Oct 2022	Wed, 19 Oct 2022	Thu, 20 Oct 2022
Lab III	45	Mon, 7 Nov 2022	Tue, 8 Nov 2022	Wed, 9 Nov 2022	Thu, 10 Nov 2022
Lab SI	47	Mon, 21 Nov 2022	Tue, 22 Nov 2022	Wed, 23 Nov 2022	Thu, 24 Nov 2022
Lab SII	50	Mon, 12 Dec 2022	Tue, 13 Dec 2022	Wed, 14 Dec 2022	Thu, 15 Dec 2022
Lab SIII	2	Mon, 9 Jan 2023	Tue, 10 Jan 2023	Wed, 11 Jan 2023	Thu, 12 Jan 2023
Lab SIV	4	Mon, 23 Jan 2023	Tue, 24 Jan 2023	Wed, 25 Jan 2023	Thu, 26 Jan 2023

Online Lab Sessions

Due to the ongoing COVID-19 situation, we opt for a hybrid setup for the lab. The lab will be offered in presence (in our PC pool S3055). The online lab will make it easily accessible for those who cannot attend lab sessions in person. We will use the permanent zoom link

https://jku.zoom.us/j/92257166704

for conducting the online lab sessions. Remember, we cannot support remote students as well as students being present in the PC pool. Hence we recommend attending the lab in person if possible.

Slides Course Organization

Github repository

INTRODUCTION TO PYTHON

Selected Readings

- Computer Vision – A Modern Approach, Forsyth and Ponce, Addison Wesley
- Multiple View Geometry in Computer Vision, Hartley and Zisserman, Cambridge Press
- Computer Vision: Algorithms and Applications, Richard Szeliski, Springer
- Image Processing: The Fundamentals, Maria Petrou and Costas Petrou, Wiley
- Learning OpenCV: Computer Vision with the OpenCV Library, Gary Bradski, Adrian Kaehler, Mike Loukides, Robert Romano, O'Reilly
- Handbook of Mathematical Models in Computer Vision, Nikos Paragios and Yunmei Chen, Springer
- Machine Vision. Theory , Algorithms, Practicalities: Theory, Algorithms, Practicalities: Theory , Algorithms, Practicalities, E. R. Davies, Academic Press
- Computational Vision: Information Processing in Perception and Visual Behavior, Hanspeter A. Mallot, MIT Press
- Three-Dimensional Computer Vision – A Geometric Approach, Olivier Faugeras, MIT Press

Course Schedule

Type	Date	Time	Room	Topic	Comment
Lec1	11.10.2022	12:00-13:30	H1	Introduction and Course Overview	
Lab1	10./11./12./13.10.2022	17:15-18:45	S3055	Introduction to Python	
Lec2	18.10.2022	12:00-13:30	HS 1	Spatial and Frequency Domain Processing	
Lab2	17./18./19./20.10.2022	17:15-18:45	S3055	Introduction to IP/CV Modules	
Lec3	25.10.2022	12:00-13:20	HS 1	Gradient Domain Processing	National Holiday (26.10.)
Lec4	08.11.2022	12:00-13:30	HS 10	Segmentation and Local Features	Allerheiligen (2.11.)
Lab3	07./08./08./10.11.2022	17:15-18:45	S3055	Project Introduction	
Lec5	15.11.2022	12:00-13:30	HS 1	Basics of Cameras	
Lec6	22.11.2022	12:00-13:30	HS 1	Geometric Camera Calibration	
Lab4	21./22./23./24.11.2022	17:15-18:45	S3055	Project Basics and Related Work	
Lec7	29.11.2022	12:00-13:30	HS 1	The Geometry of Multiple Views	
Lec8	06.11.2022	12:00-13:30	HS 1	Stereoscopic Depth Estimation	Mariä Empfängnis (8.12.)
Lec9	13.12.2022	12:00-13:30	HS 1	Range Scanning and Data Processing	
Lab5	12./13./14./15.12.2022	17:15-18:45	S3055	Presentation of Initial Ideas	Christmas Break
Lec10	10.01.2023	12:00-13:30	HS 1	Structure from Motion	
Lab6	09./10./11./12.01.2023	17:15-18:45	S3055	Presentation of Intermediate Results and Final Concepts	
Lec11	17.01.2023	12:00-13:30	HS 1	Computational Imaging	
Lec12	24.01.2023	12:00-13:30	HS 1	Recap and Q&A	
Lab7	23./24./25./26.01.2023	17:15-18:45	S3055	Final Project Presentations	
Ex1	31.01.2023	12:00-13:30	HS 1	Exam (Hauptklausur)	
Ex2	28.02.2023	15:30-17:00	TBA	Retry Exam (Nachklausur)	

Thank You!