Exercise 3D Maschine Vision

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Sheet 1

In this exercise we cover the *introductory chapter*, as well as *3D camera systems* and basics of *stereo vision*. The questions are small-part and can be seen as examples of potential exam problems.

Task 1.1: Terms & Applications

1.1a)

Which application fields of 3D machine vision deal only with 3D reconstruction of 3D pose and/or 3D motion of rigid bodies without creating a 3D reconstruction of the environment?

- ☐ Visual SLAM
- ☐ Visual odometry
- ☐ Multi-View Reconstruction
- ☐ Visual Servoing
- ☐ Structure from Motion
- ☐ 3D Tracking
- ☐ Hand-Eye Calibration
- ☐ Optical Flow
- ☐ Ray Tracing

1.1b)

What is the difference between depth images and volume images?

1.1c)

Name three real-world challenges that 3D vision algorithms must deal with?

1.1d)

What is the baseline? Why does the choice of baseline affect the choice of algorithms for 3D reconstruction from images?

Task 1.2: 3D Camera Techniques

1.2a)

When recording point clouds with 3D cameras, what conditions must be met to avoid large errors in depth measurement?

- ☐ Objects do not move
- ☐ Light sources are moving
- ☐ Camera system does not move
- ☐ Illuminance remains constant
- ☐ For a time-of-flight camera, the exposure time must be less than the run time
- ☐ When configuring a stereo system, the ratio of baseline and disparity must be matched to the selected depth range

1.2b)

Explain the difference between the measurement principle of a stereo system consisting of two cameras and a projector compared to a stereo system with one camera and one projector? What is the minimum requirement for the respective principle for a measurement to be possible?

1.2c)

What is the advantage of using amplitude modulated light compared to pulsed light in time-of-flight cameras? Is there also a disadvantage of amplitude modulated light?

1.2d)

What systematic errors can be compensated for in a 3D camera by appropriate calibration?

- ☐ errors because of occlusion
- ☐ errors because of multipath reflections
- ☐ errors due to object motion
- ☐ errors because of temperature changes
- ☐ errors due to variations in the strength of the reflected light
- ☐ error due to the selected measurement time duration
- ☐ constant offsets in depth
- ☐ errors due to interference light influence
- ☐ errors due to camera noise

Task 1.3: Stereo Vision

1.3a)

What is special about the stereo configuration of two cameras? What are the advantages?

1.3b)

From the equation of depth reconstruction $Z = c\frac{b}{d}$, which holds for a calibrated stereo system, calculate the

1. depth resolution $\frac{\partial Z(Z)}{\partial d}$ and
2. the sensitivity of the disparity $\frac{\partial d(Z)}{\partial Z}$.

as a function of absolute depth Z.

1.3c)

Calculate the distance D of a 3D point as a function of the quantities x, y, c, b and d. If you cannot assign the letters to the characteristic values, then refer to the lecture notes.

1.3d)

Calculate the change in parallax in px/m (pixels per meter) for a stereo system with a baseline of $200mm$, a focal length of $f = 100mm$, and a pixel width of $10\mu m$ for distances $10m$ and $100m$, taking into account the approximation for far-field images: $c \approx f$.

1.3e)

Compare the accuracy of the angular measurement of triangulation with stereo vision by calculating the angular change for a measurement accuracy of $\pm 1px$ in disparity a pixel width of $10\mu m$ and a camera constant of $c = 3mm$. Assume a disparity reference value of $100px$.