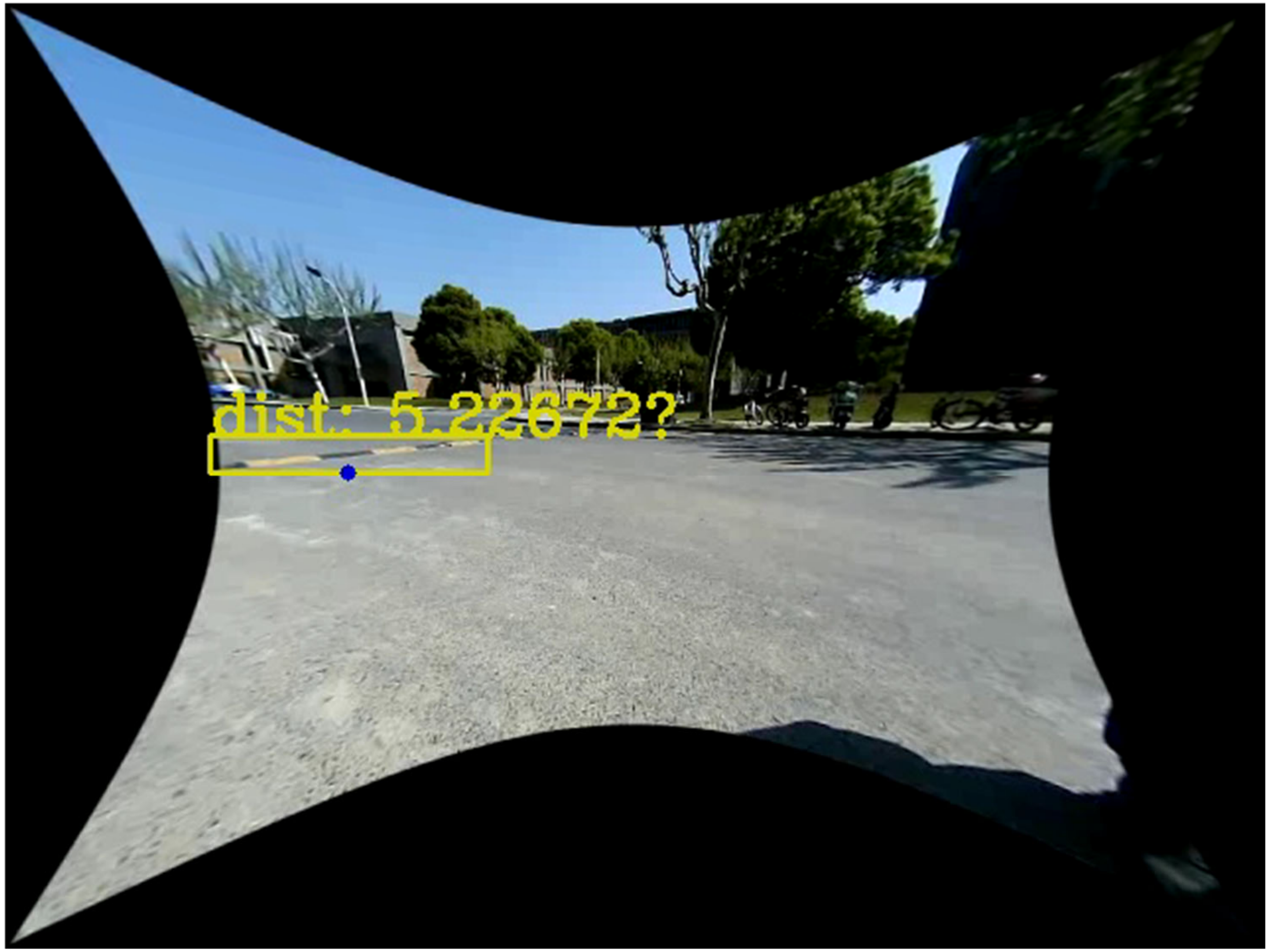
Chapter 07
Flowchart of Single-camera Measurement
(Theme 2)

Lin ZHANG
School of Computer Science and Technology
Tongji University

Problem definition of single-camera measurement

Can you tell me the diameter of the coin shown in the image?

Problem definition of single-camera measurement



- In this demo, the system detects persons and speed-bumps and outputs their horizon distances to the robot
- Only one camera is used

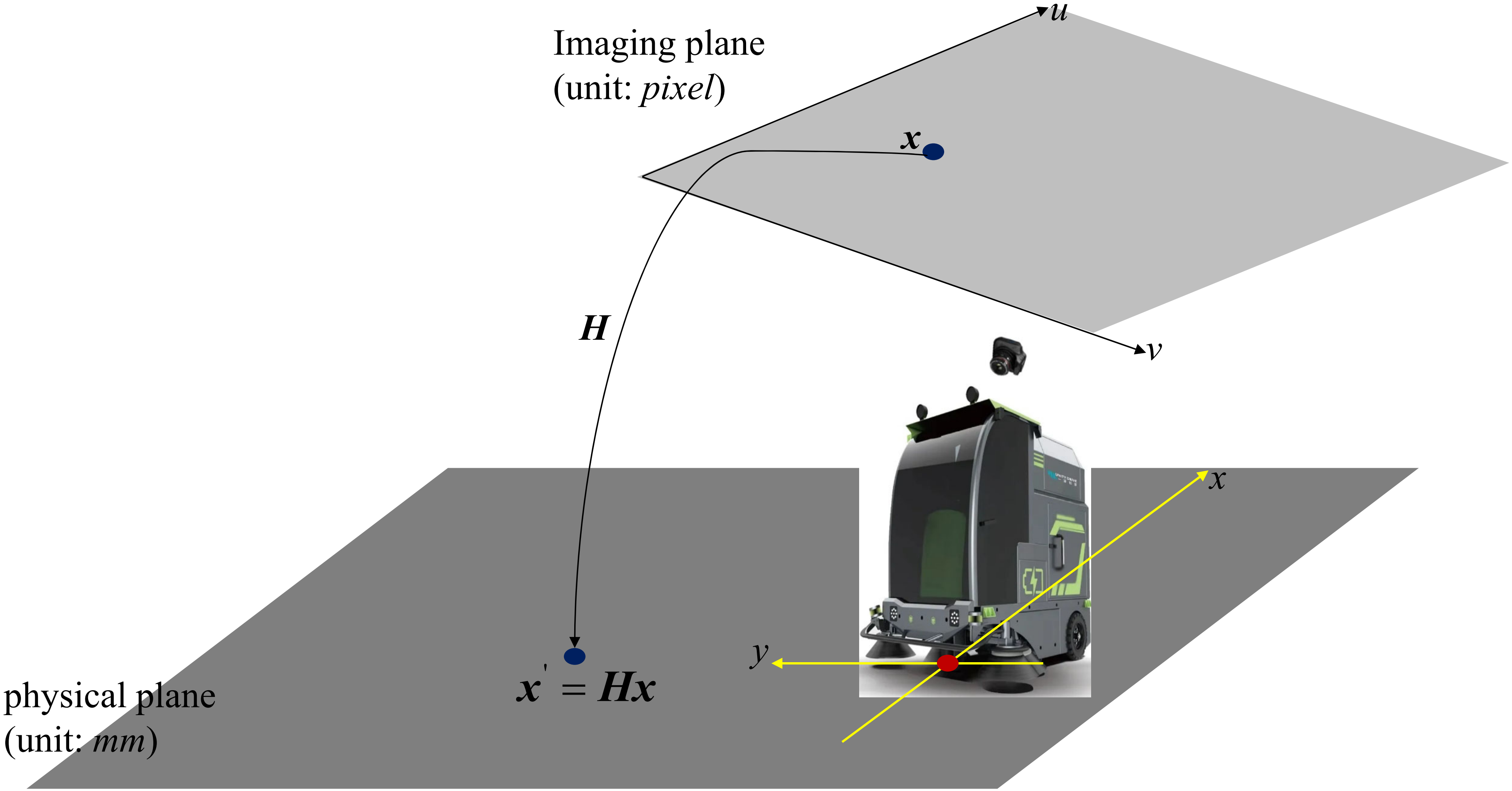
How to achieve this goal?

Problem definition of single-camera measurement

- To solve the aforementioned two problems, we need to have some assumptions
  - The object to be measured should locate on a (physical) plane
  - The imaging plane and the physical plane satisfy projective transformation, i.e., the **imaging process should satisfy the ideal pin-hole camera model**

There is a projective transformation matrix $\boldsymbol{H}$ linking the physical plane and the imaging plane. For a point $\boldsymbol{x}$ on the imaging plane, we can get its position on the physical plane as $\boldsymbol{Hx}$

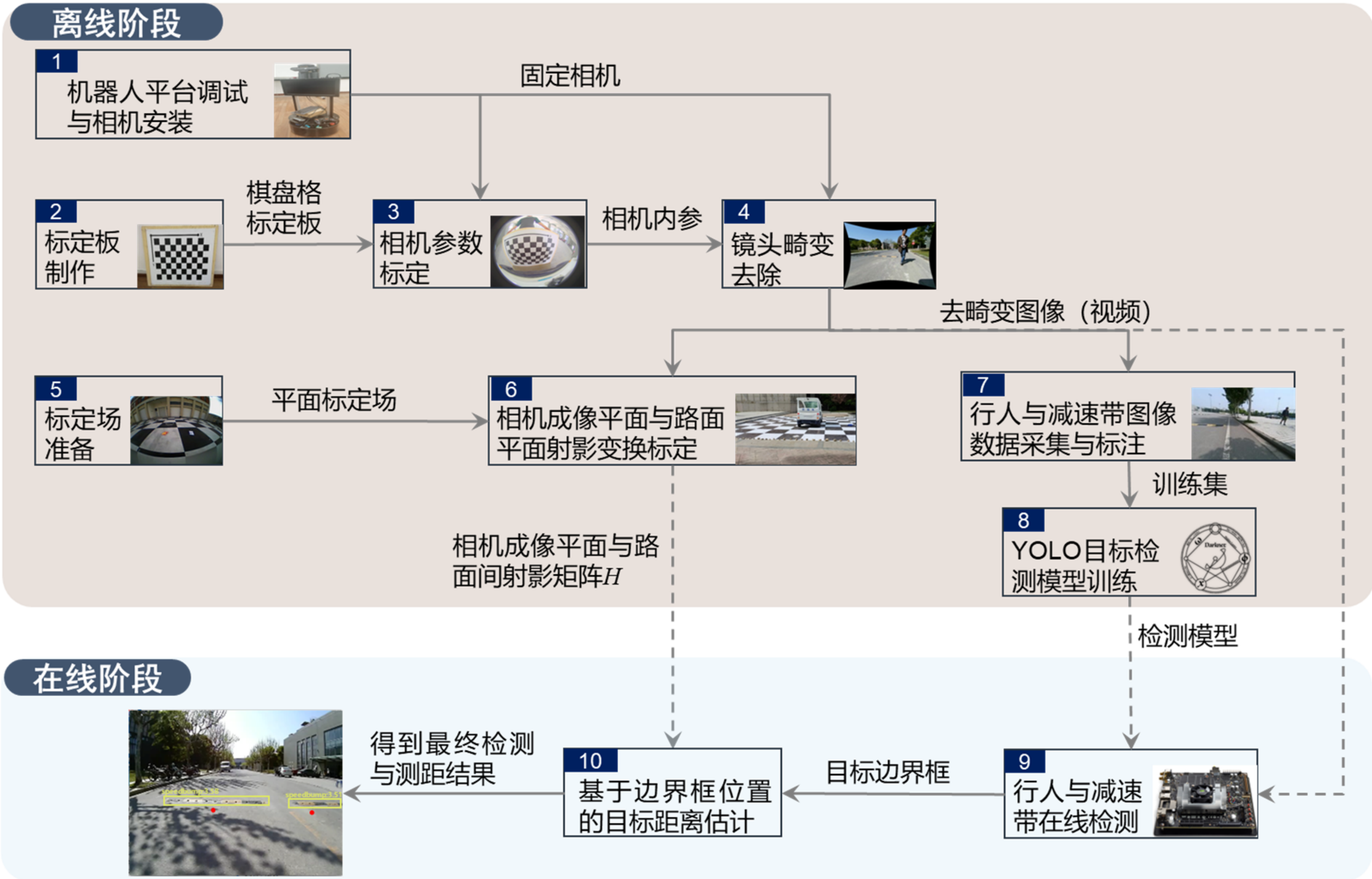
Problem definition of single-camera measurement



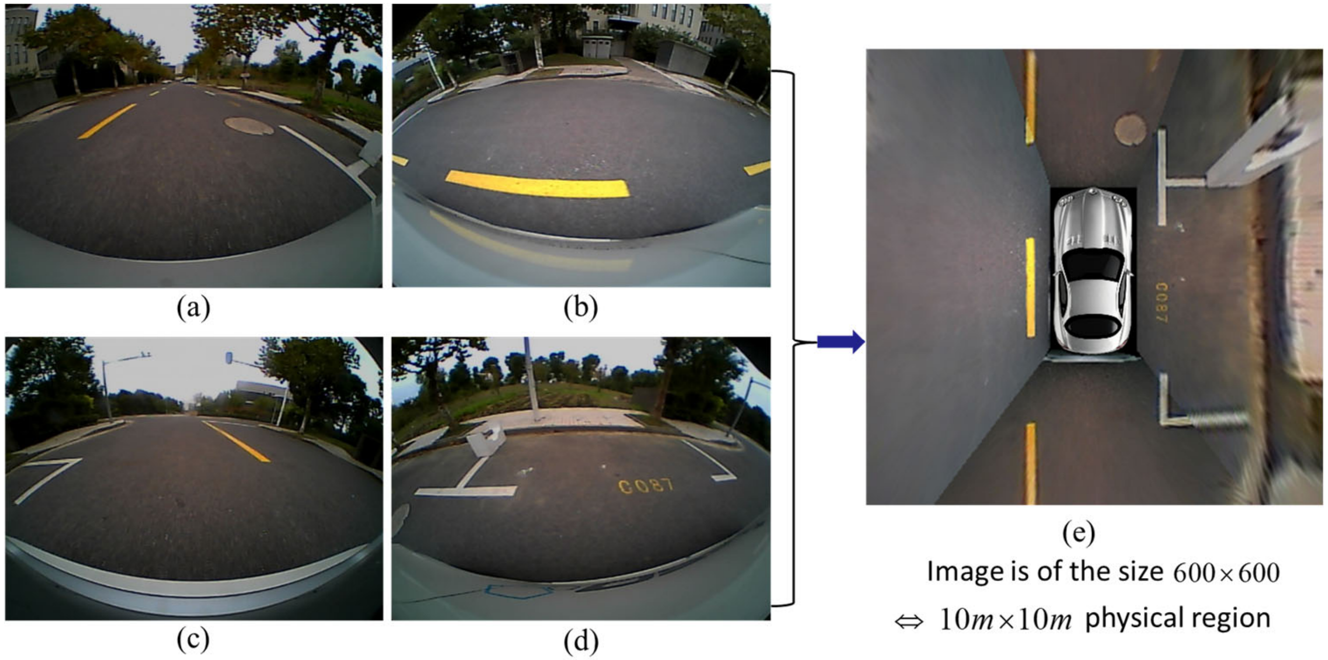
Steps for achieving single-camera measurement

- ✓ Calibrate the camera to get its intrinsic parameters
- ✓ With the intrinsic parameters, un-distort the images to **make the imaging process satisfy the ideal pin-hole imaging model**
- ✓ With a set of marker-points (their positions on the physical plane are known, and their images on the (undistorted) imaging plane are also known), get $\boldsymbol{H}$
- ✓ With $\boldsymbol{H}$, for any point on the imaging plane, we can get its position on the physical plane

Pedestrian and speed-bump detection and distance measurement using a single-camera



One step further—Bird's-eye view



(e)

Image is of the size 600×600

$\Leftrightarrow$ $10m\times10m$ physical region

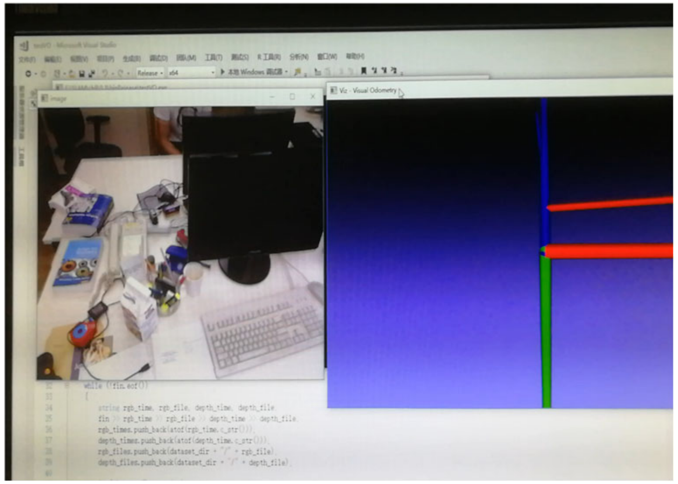
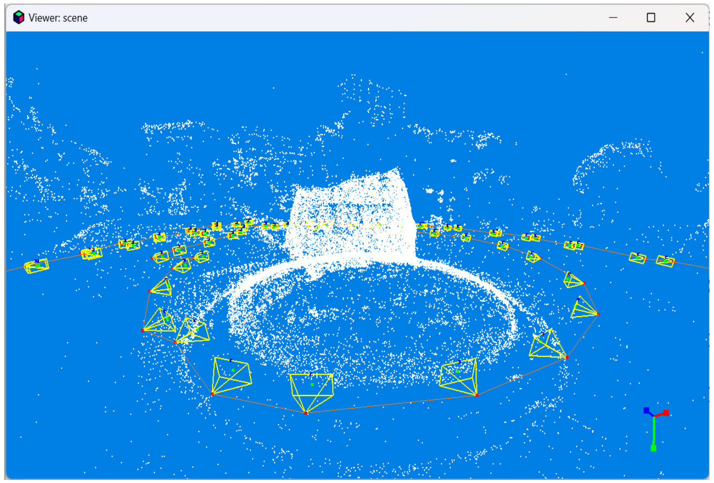
- ✓ With ***H***, to go one step further, we can generate the bird's-eye view of the physical plane, which is very useful to perform detection and measurement of plane objects
- ✓ The geometric transformation between the physical plane and its bird's-eye view is a similarity transformation

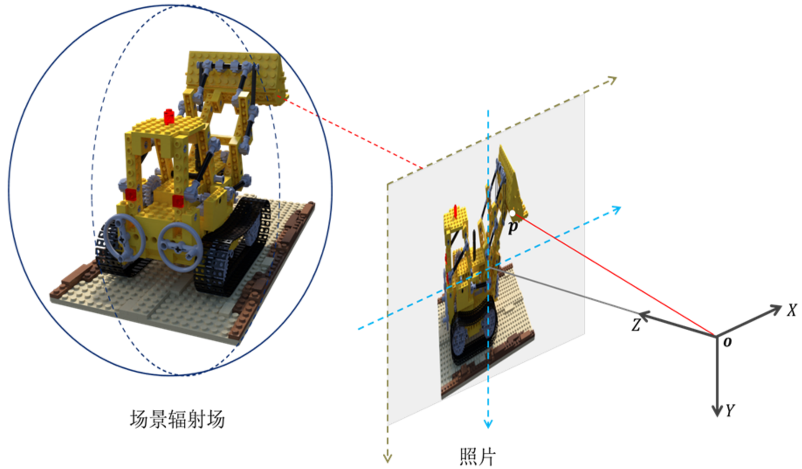
Application examples

Application examples

More potential applications of camera intrinsics

- In this theme, we use the intrinsics to undistort images to make the imaging process satisfy the ideal pin-hole model; actually, camera intrinsics are indispensable in a wide range of applications
  - Visual odometry
  - Binocular vision
  - Multiple-view stereo
  - Radiance field rendering



Contents of this theme

- ✓ To study the camera calibration algorithm, we need to have some knowledge about projective geometry, which will be introduced in Chapter 8
- ✓ Camera calibration is a non-linear least-squares problem; Chapter 9 will formally defines such a kind of problem and the algorithms to solve it
- ✓ Imaging model and the camera calibration algorithm will be detailed in Chapter 10
- ✓ In Chapter 11, we will learn how to generate the bird's-eye view for the physical plane

Contents of this theme

应用

- 单目测距
- 平面目标尺寸测量
- 视觉里程计
- 立体视觉
- 新视角合成

技术

- 相机标定与单目测量

CV算法

- 相机成像流程建模
  - 世界坐标系
  - 相机坐标系
  - 成像平面坐标系
  - 归一化成像平面坐标系
  - 像素坐标系
  - 主点坐标
  - 内参矩阵
  - 畸变系数
  - 扭曲系数
  - 镜头畸变建模
    - 径向畸变
    - 切向畸变
    - 鱼眼镜头畸变
- 相机内参平面标定法
  - 问题建模
  - 参数初始化估计
  - 迭代求解
- 图像去镜头畸变
- 逆透视投影
- 图像插值

数学知识点及数学算法

- 射影几何初步
  - 射影平面
  - 点的齐次坐标
  - 无穷远点
  - 线的齐次坐标
  - 射影平面上的点与线
- 消失点
- 矩阵的特征值分解
- 线性最小二乘问题及其解法
- 三维空间旋转的轴角表达与罗德里格斯公式
- 无约束优化问题
- 阻尼法
- 增益比
- 非线性最小二乘问题及其解法
  - 非线性最小二乘问题
  - 泰勒展开
  - 雅可比矩阵
  - 高斯牛顿法
  - 列文伯格-马夸特法
  - 凸函数


Q+A