Chapter 11
Bird's-eye-view

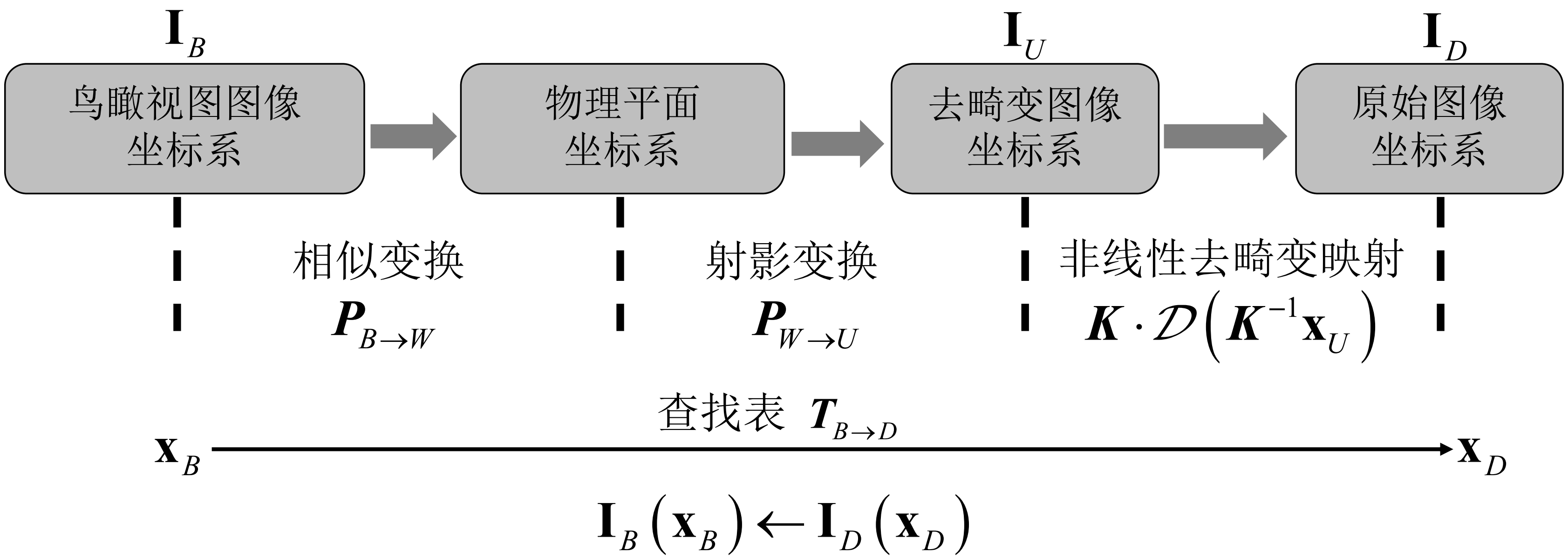
Lin ZHANG
School of Computer Science and Technology
Tongji University

Bird's-eye-view Generation

- Our task is to measure the geometric properties of objects on a plane (e.g., conveyor belt)
- Such a problem can be solved if we have its bird's-eye-view image; bird's-eye-view is easy for object detection and measurement

Bird's-eye-view Generation

- Four coordinate systems are required
  - Bird's-eye-view image coordinate system
  - Physical plane coordinate system
  - Undistorted image coordinate system
  - Original image coordinate system



- Basic idea for bird's-eye-view generation

Suppose that the transformation matrix from bird's-eye-view to the physical plane CS is $\boldsymbol{P}_{B\to W}$, the transformation matrix from the physical plane CS to the undistorted image is $\boldsymbol{P}_{W\to U}$, and the camera intrinsics are known

Then, given a position $\mathbf{x}_B = \left(x_B, y_B\right)^T$ on bird's-eye-view $\mathbf{I}_B$, we can get its corresponding position in the original fisheye image $\mathbf{I}_D$ as,

$$\mathbf{x}_D = \boldsymbol{K}\mathcal{D}\left(\boldsymbol{K}^{-1}\boldsymbol{P}_{W\to U}\boldsymbol{P}_{B\to W}\begin{pmatrix} x_B \\ y_B \\ 1 \end{pmatrix}\right)$$

Then, the intensity of the pixel $\mathbf{I}_B(\mathbf{x}_B)$ can be determined using some interpolation technique based on the neighborhood around $\mathbf{x}_D$ on $\mathbf{I}_D$

Bird's-eye-view Generation

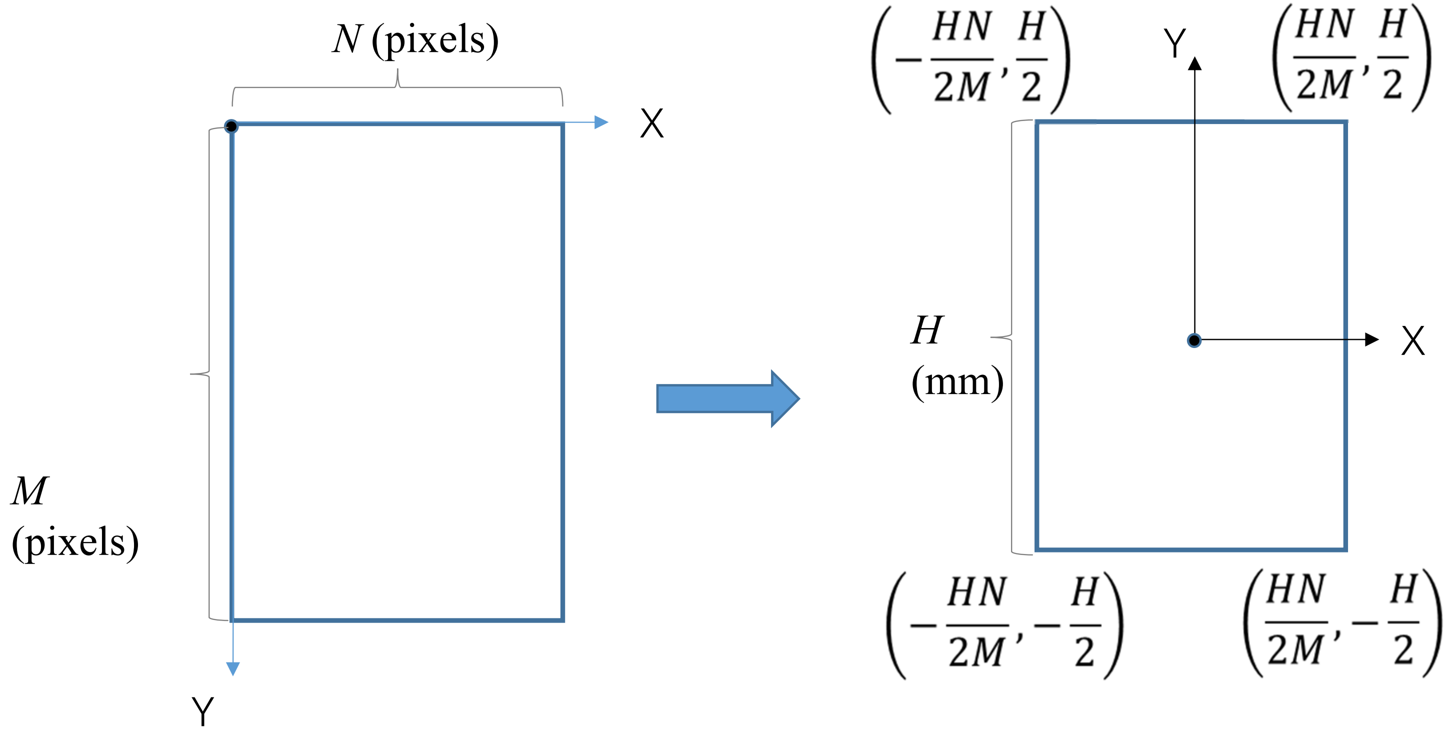
- Basic idea for bird's-eye-view generation

Suppose that the transformation matrix from bird's-eye-view to the physical plane CS is $\boldsymbol{P}_{B\to W}$, the transformation matrix from the physical plane CS to the undistorted image is $\boldsymbol{P}_{W\to U}$, and the camera intrinsics are known

The key problem is how to obtain $\boldsymbol{P}_{B\to W}$ and $\boldsymbol{P}_{W\to U}$?

Bird's-eye-view Generation

- Determine $\boldsymbol{P}_{B \to W}$



Note: It is valid only when you think the origin of the world CS is at the center of the bird's-eye-view image

Bird's-eye-view Generation

- Determine $\boldsymbol{P}_{B\to W}$

For a point $(x_B, y_B, 1)^T$ on bird's-eye-view, the corresponding point on the physical plane coordinate system is,

$$\begin{pmatrix} x_W \\ y_W \\ 1 \end{pmatrix} = \begin{bmatrix} \frac{H}{M} & 0 & -\frac{HN}{2M} \\ 0 & -\frac{H}{M} & \frac{H}{2} \\ 0 & 0 & 1 \end{bmatrix} \begin{pmatrix} x_B \\ y_B \\ 1 \end{pmatrix} \equiv \boldsymbol{P}_{B\to W} \begin{pmatrix} x_B \\ y_B \\ 1 \end{pmatrix}$$

Bird's-eye-view Generation

- Determine $\boldsymbol{P}_{W \to U}$

The physical plane and the undistorted image plane can be linked via a homography matrix $\boldsymbol{P}_{W \to U}$

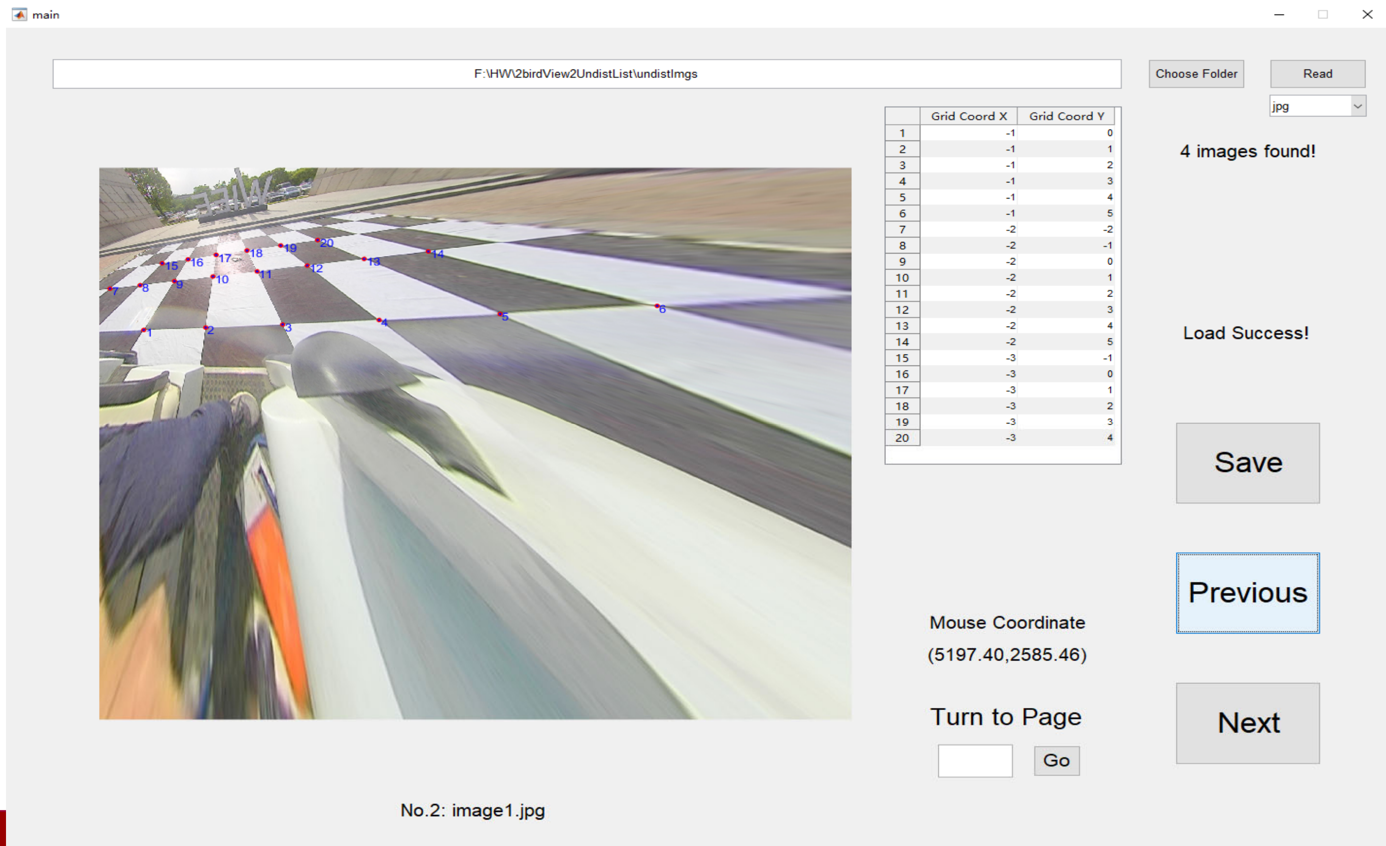
$$\mathbf{x}_U = \boldsymbol{P}_{W \to U} \mathbf{x}_W$$

If we know a set of correspondence pairs $\left\{ \mathbf{x}_U^i \leftrightarrow \mathbf{x}_W^i \right\}_{i=1}^p, p > 4$,
$\boldsymbol{P}_{W \to U}$ can be estimated using the least-square method

Bird's-eye-view Generation

- Determine $P_{W \to U}$

A set of point correspondence pairs; for each pair, we know its coordinate on the undistorted image plane and its coordinate in the physical plane CS



Bird's-eye-view Generation

When $\boldsymbol{P}_{B \to W}$ and $\boldsymbol{P}_{W \to U}$ are known, the mapping between $\mathbf{I}_B$ and $\mathbf{I}_D$ can be described as,

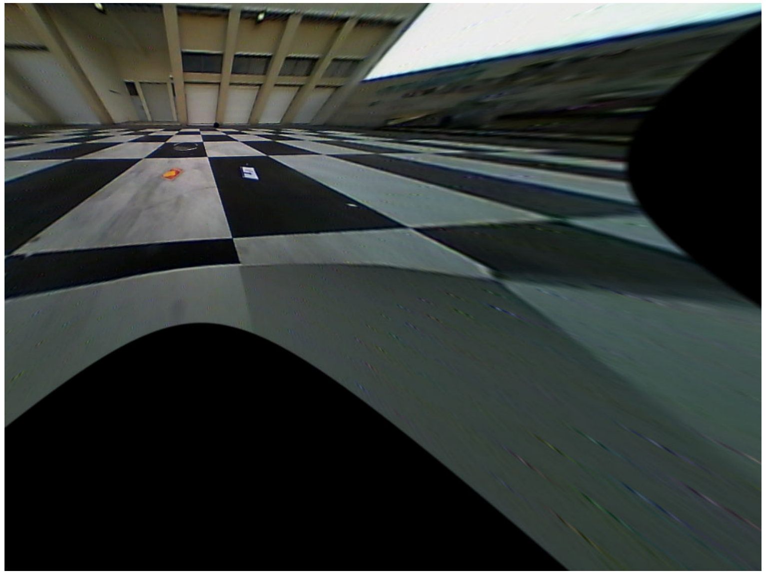
$$\mathbf{x}_D = \boldsymbol{K}\mathcal{D}\left(\boldsymbol{K}^{-1}\boldsymbol{P}_{W \to U}\boldsymbol{P}_{B \to W}\begin{pmatrix} x_B \\ y_B \\ 1 \end{pmatrix}\right)$$

The mapping look-up table $\boldsymbol{T}_{B \to D}(\mathbf{x}_B) \to \mathbf{x}_D$ can be created offline, and it can be used to generate online bird's-eye-view images

Bird's-eye-view Generation

Example

Original fish-eye image

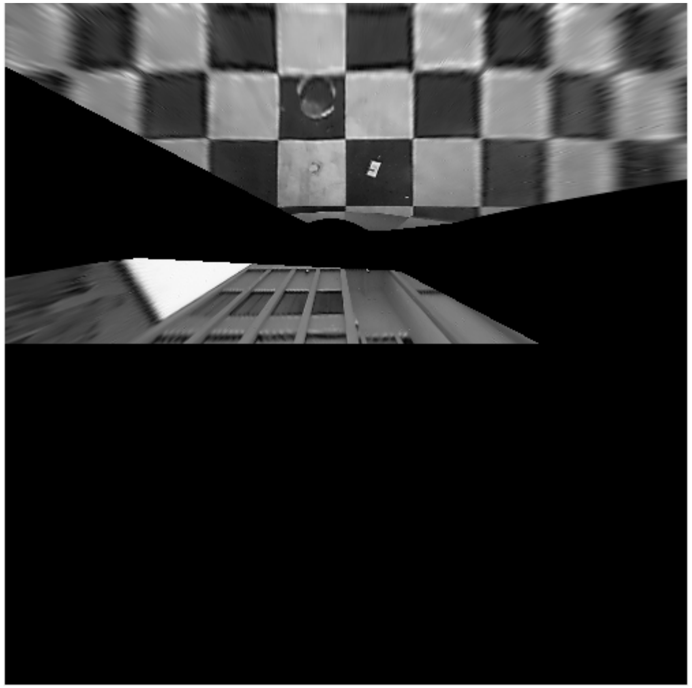


Undistorted image

Bird's-eye-view Generation

Example

Original fish-eye image



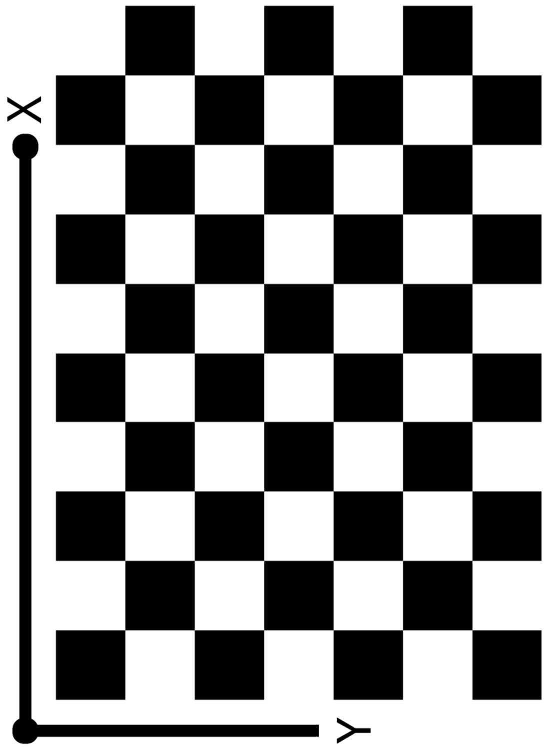
Bird's-eye-view

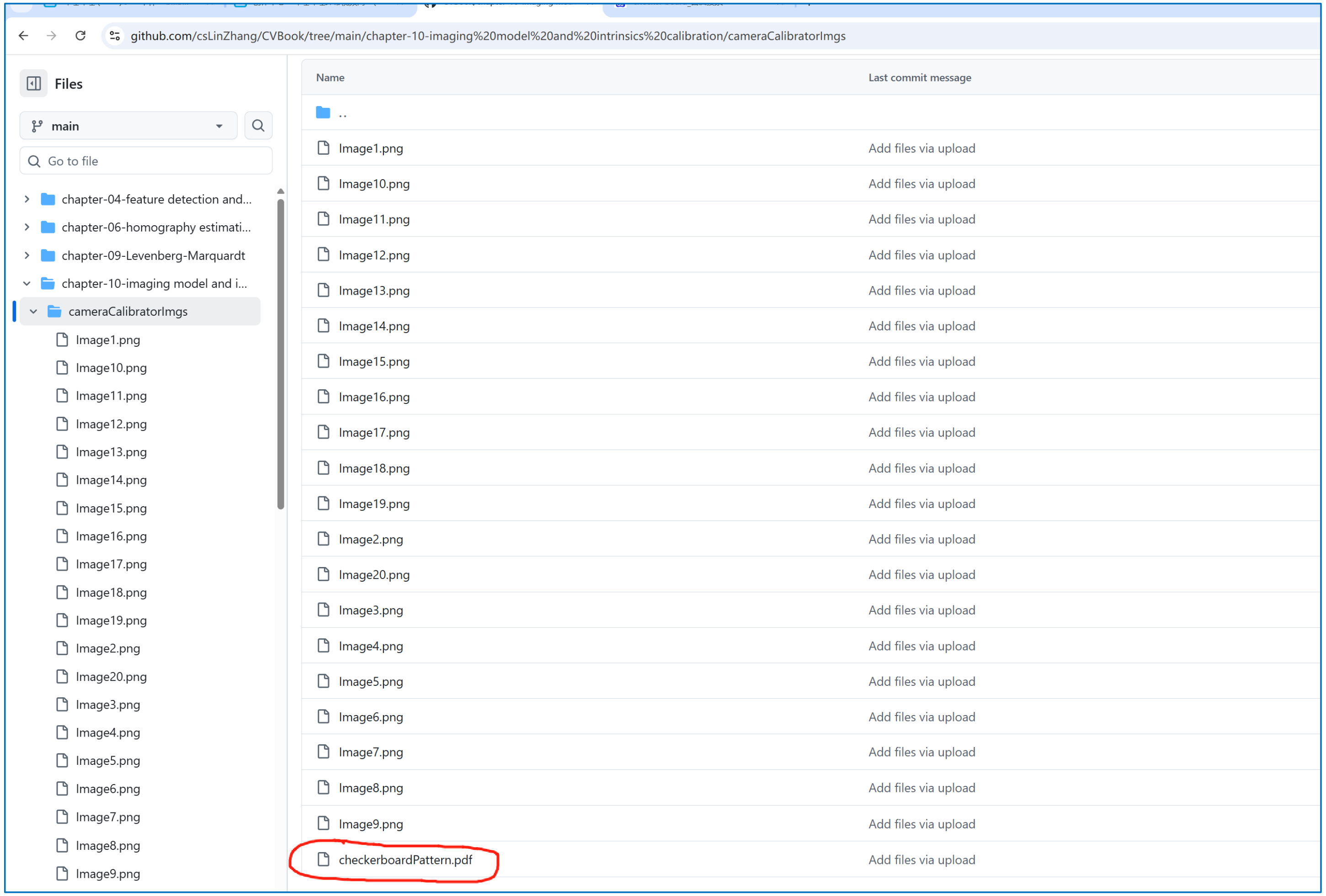
Bird's-eye-view Generation

With multiple bird's-eye-view from multiple cameras, a surround-view can be synthesized

Practice for Theme 2

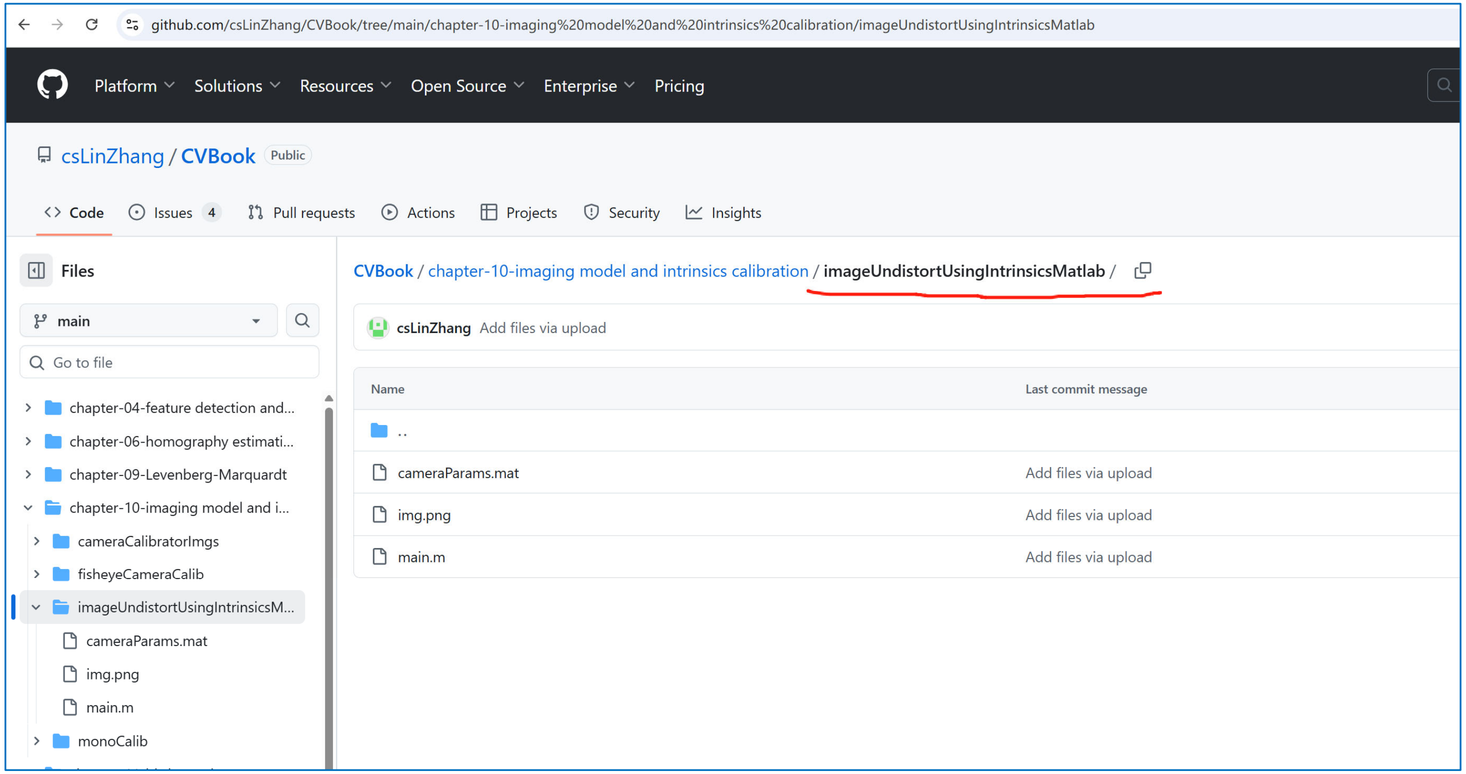
Checker-board pattern file





Camera calibration using Matlab toolbox

- About how to use the Matlab toolbox to perform camera calibration, please refer to the textbook

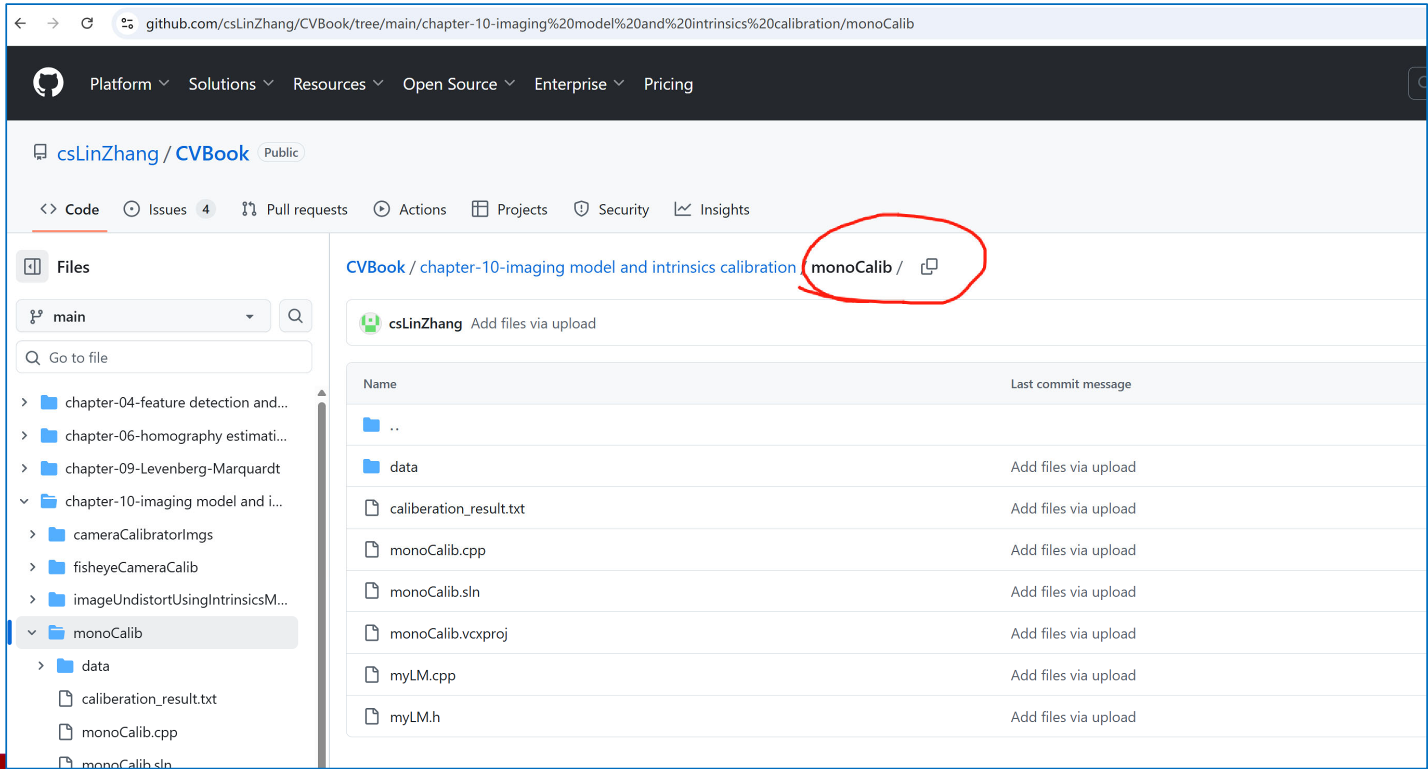


(demo time)

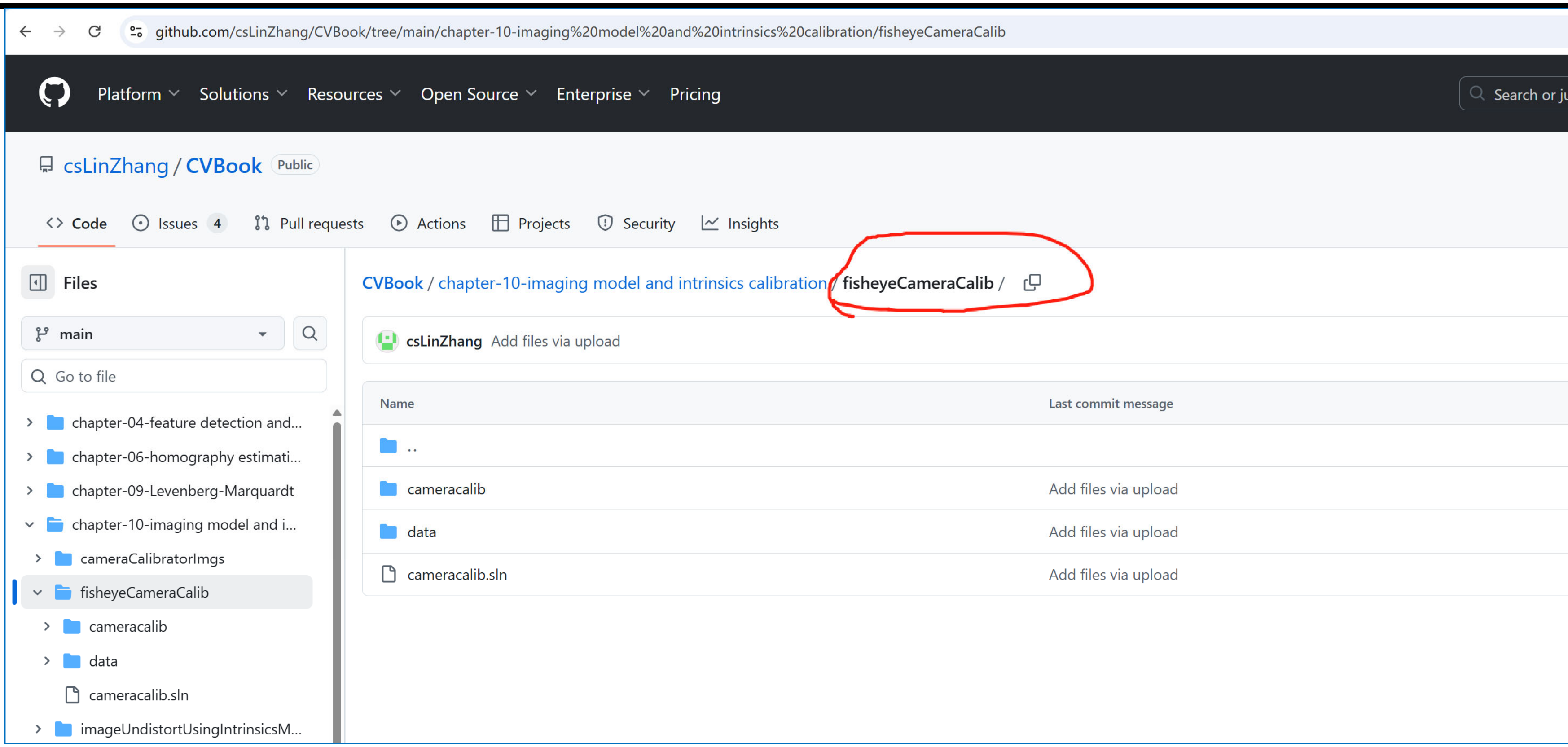
Matlab code to perform image un-distortion with camera intrinsics

OpenCV source code for camera calibration

- Pore over the core implementations of camera calibration in OpenCV
- I have added necessary comments to help your understanding
- I strongly recommend you to perform this practice!!! You will have a **deep** understanding of the theories mentioned in our lectures



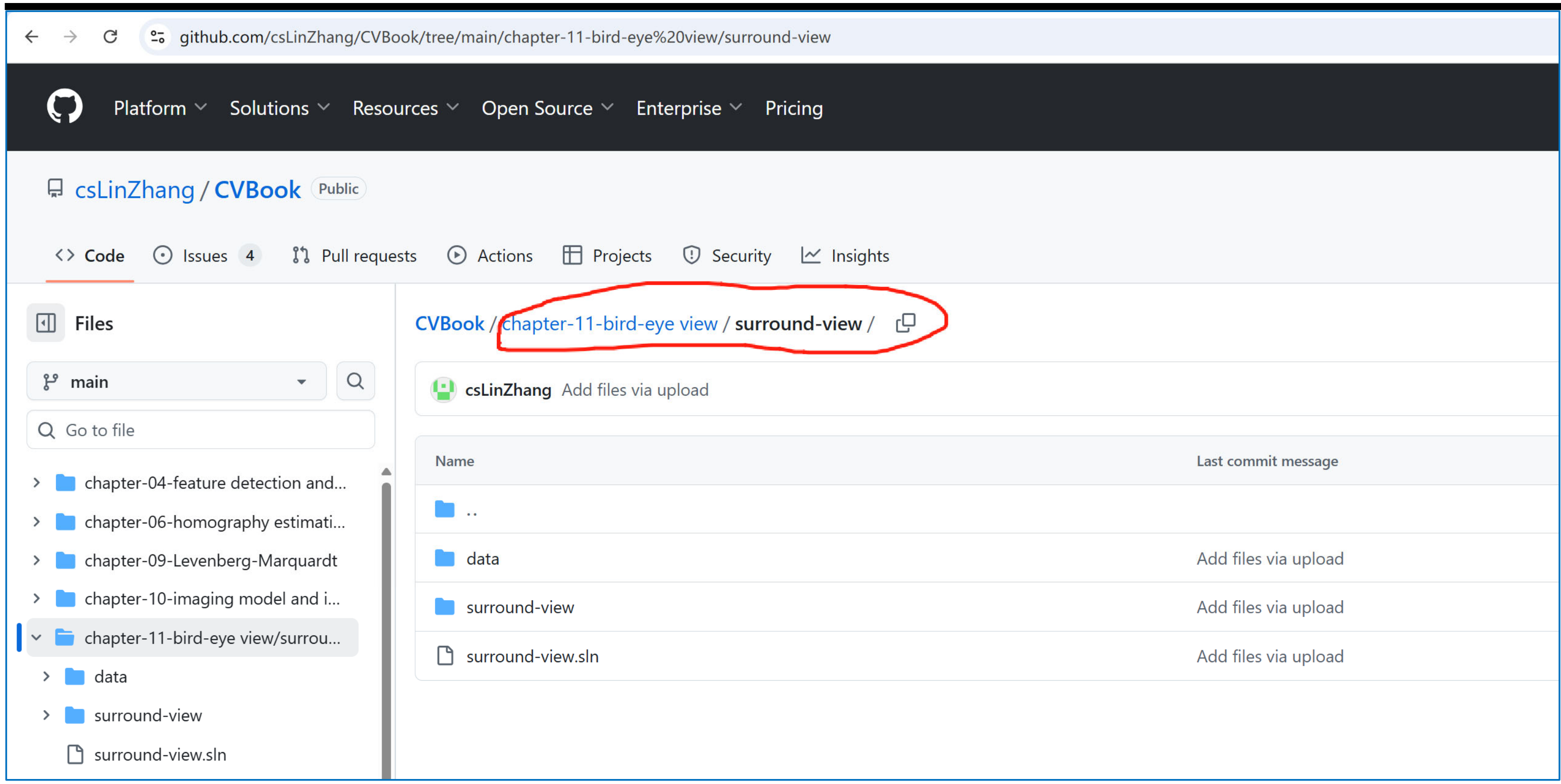
Fisheye camera calibration using C++ and OpenCV



- Step 1: collect checker-board images
- Step 2: perform camera intrinsics calibration
- Step 3: with the obtained intrinsics, perform real-time image un-distortion

(demo time)

Surround-view



(demo time)

- Original fisheye videos, intrinsics for the four fisheye cameras, and the homography between each imaging plane and the road surface is provided
- Generate the mapping tables between four bird's-eye-views and the four fisheye images and synthesize the surround-view video


Q+A