Project 2022-2023 Image Analysis and Computer Vision

Visual motion analysis
of a player’s fingers

Kissani Angeliki 10939189 | supervisor: V. Caglioti | Politecnico di Milano

What is visual motion analysis?

- Visual Motion Analysis is a technique that produces information from examining moving objects in a video sequence ,e.g produced by a video camera
- Motion analysis is a technique that used in a lot of scientific fields, such as **Computer Vision**, **Image processing**, **High-speed photography** and **Machine vision**.

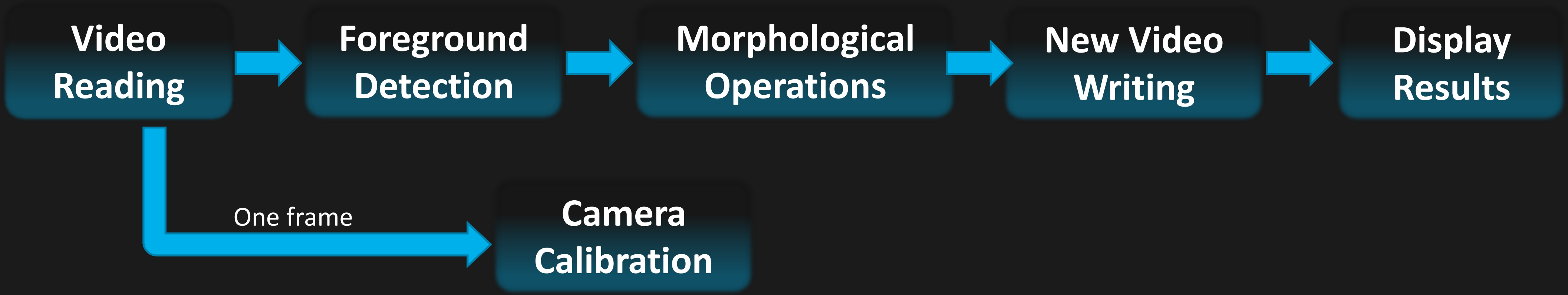
The **goal** of the project is to capture a musician's finger motion while playing keyboard instruments like organ, piano, accordion etc, by using **Visual Motion Analysis**.

Here is an example video of the **Chicago's largest pipe organ**, where a musician performs one of the most well-known organ compositions.

As we can see from the video,
the background is the instrument's keys,
the **camera is fixed** with respect to the scene.

Process

This is the process that I followed in order to extract the fingers from the video:



Foreground Detection

- To determine whether specific pixels are in the foreground or background I used the **Foreground Detector**.
- A specific number of video frames are necessary for the detector to form the **Gaussian Mixture Models**.
- The probabilistic model Gaussian Mixture Model implies that all data points were produced by combining a limited number of Gaussian distributions with unknown parameters.

After that, a **foreground mask** is computed.

Morphological Operations

I used some **morphological operations** to eliminate the noise from the mask that we created and fill in gaps.

I selected a **disk-shaped** structuring element to perform the morphological opening and closing.

Mask Application

It is time to insert the mask on the original video.

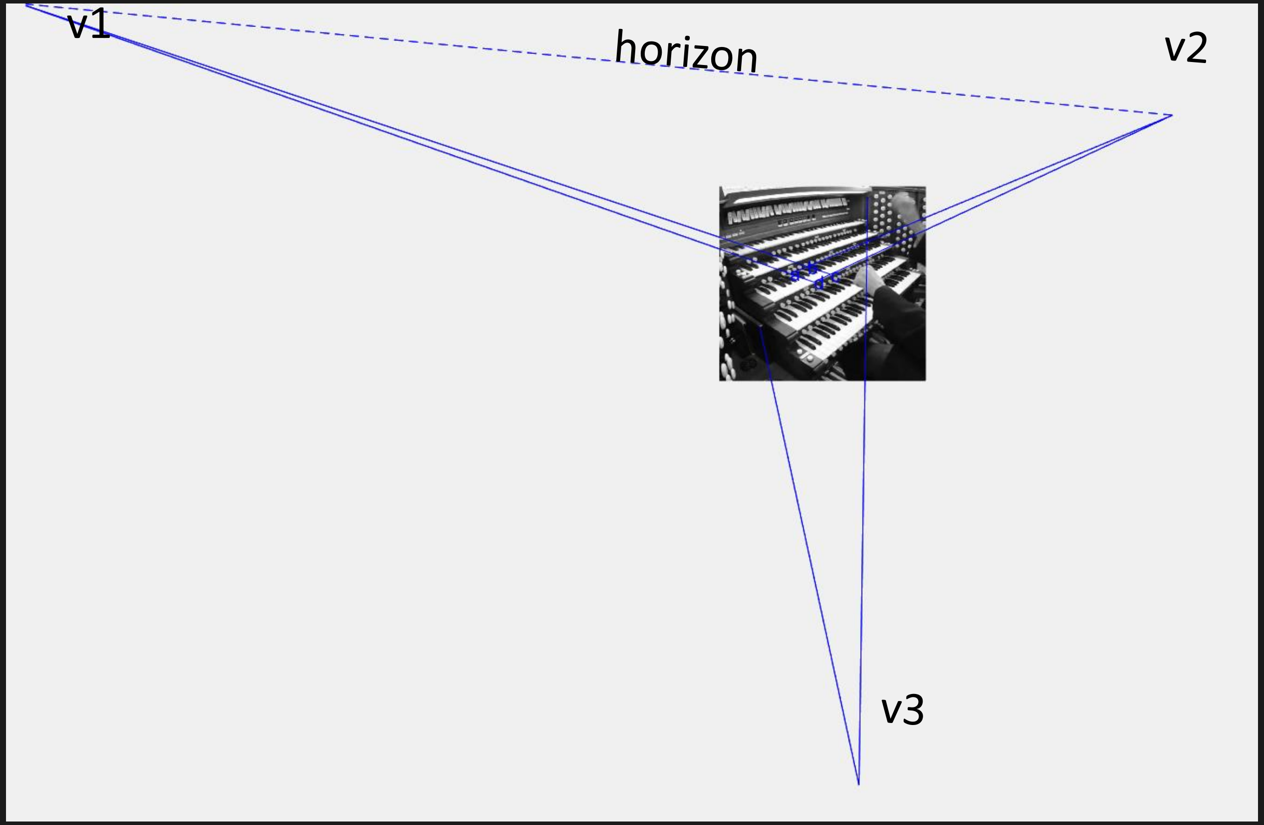
For each frame of the video sequence, we apply the mask that we created after the morphological operation.

As we can see from the results, the background is now largely obscured by the mask.

Now that the new frames have the mask applied, a new video can be produced.

Affine Reconstruction - from projective to affine

At first, I found the **vanishing points** and the **line at the infinity** (horizon) by using the image of two pairs of parallel lines at the horizontal plane. Then, I select one pair of parallel lines for a **vertical vanishing point** that will also be helpful for the calibration.



The goal of the Affine rectification is to maintain and restore line parallelism while bringing back the image of the line at infinity at its own canonical position.

I used the following matrix to apply the affine reconstruction to the image-frame:

$$H_{\mathrm{aff}} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ & l_\infty' & \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ -2\times10^{-4} & 26\times10^{-4} & 1 \end{pmatrix}$$

This is the reconstructed scene, which is **affine** to the original:

Affine Rectification

Metric (Euclidean) Reconstruction-from affine to metric

I used the image that came as a result from the affine rectification to continue with the process.

The goal of the Metric rectification is to recover a **Similarity transformation** of the scene.

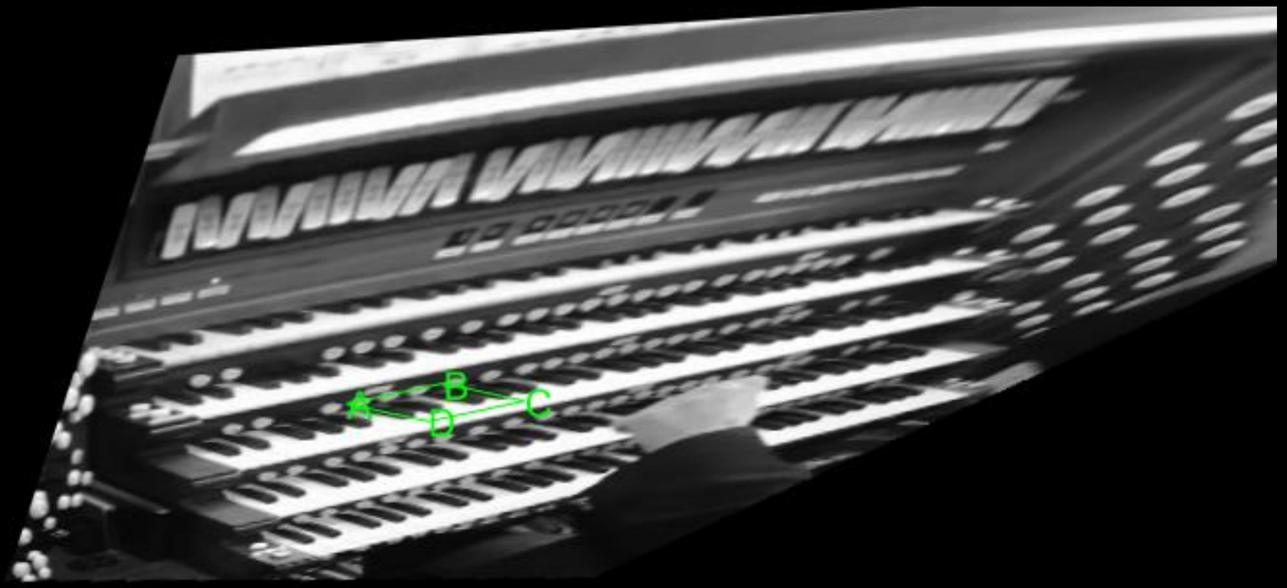
The following image shows the five orthogonal segment pairs that I chose manually:

The resulting matrix is:

$$H_{met} = \begin{pmatrix} -0.0735 & 1.1210 & 0 \\ 1.1210 & -0.3572 & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

Here we can see the rectified image after the affine and metric rectification, which resembles the original in **shape**.

Rectified Image



Camera Calibration

The calculation of **intrinsic** and **extrinsic** parameters is referred to as **Camera Calibration**.

Intrinsic parameters : focal length, skew, distortion, image center
Extrinsic parameters : position, orientation in the world

Calibration matrix: $K = \begin{pmatrix} fx & 0 & U_0 \\ 0 & fy & V_0 \\ 0 & 0 & 1 \end{pmatrix}$

Camera Calibration

I can now locate the absolute conic IAC's image in order to calibrate the camera. I have all the information I require from the reconstruction of the horizontal façade:

- the reconstructing homography ***H*= [h1, h2, h3]**
- the image of the line at the infinity l'_∞
- the vertical vanishing point **v**

The answer will be provided by the following equations:

- $l'_\infty = \omega v$
- $h_1^T \omega h_2 = 0$

$$\mathrm{h}_1^T \omega\, \mathrm{h}_1 - h_2^T \omega\, h_2 = 0$$

Now I can obtain the calibration matrix from

Cholesky Decomposition of $\boxed{\omega = (\mathrm{KK}^T)^{-1}}$

The **calibration matrix K** that was produced as a result of the prior section can now be used for the reconstruction of the vertical façade.

The image of the absolute conic is $\boxed{\omega = (KK^T)^{-1}}$,which can be used to compute **the line at the infinity and the Image of the Circular points** with respect to the vertical plane.

Vertical Façade reconstructed Image

Sources

- Video: https://www.youtube.com/watch?v=vfySQBxAA4w