CS-E4850 Computer Vision

Exercise Round 8

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Exercise 1

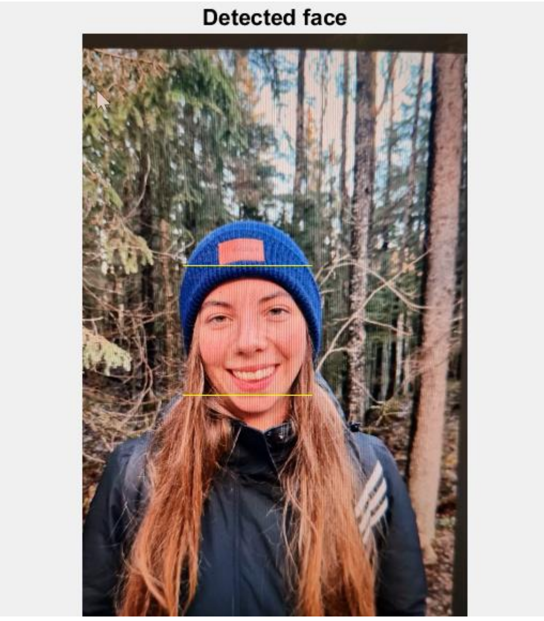
c) What could be the main reasons why most of the features are not tracked very long in case b) above?

Firstly, when the image undergoes **rotation**, the distinctive patterns that feature tracking relies on can become unrecognizable, leading to a significant drop in tracked features. Secondly, **higher camera movement** speeds result in features moving too far between frames, violating the assumption of minimal displacement, causing features to be lost during tracking. These two factors emphasize the importance of image stability and feature consistency. Lastly, the quality and robustness of feature descriptors used in the tracking algorithm play a critical role in maintaining feature tracking over time. Addressing these factors is essential for enhancing the longevity and accuracy of feature tracking in such scenarios.

d) How one could try to avoid the problem that the features are gradually lost? Suggest a one or more improvements.

To prevent the gradual loss of features in feature tracking, several key improvements can be considered. First, by **restricting rotation** and curved movements and **stabilizing the camera** or object, you can ensure that features remain within a manageable range of motion. Smoothing camera movements can reduce abrupt position and orientation changes, maintaining the stability of tracked features. Lastly, incorporating more advanced feature detection and matching algorithms that can handle variations in rotation and camera motion will make the tracking system more resilient and prevent the loss of features. These measures collectively enhance the reliability and longevity of feature tracking, even in scenarios with constrained movement and minimized large motions over short durations.

e) Voluntary task: Capture a video of your own face or of a picture of a face, and check that whether the tracking works for you. That is, replace obama.avi with your own video.



Exercise 2

- Equation (10) in BakerMatthews:

$$\Delta p = H^{-1} \sum_x \left[\nabla I \frac{\partial W}{\partial p}\right]^T [T(x) - I(W(x;p))]$$

- Solution on slide 25 Lecture 7:

$$\begin{bmatrix} \sum I_x I_x & \sum I_x I_y \\ \sum I_y I_x & \sum I_y I_y \end{bmatrix} \begin{bmatrix} u \\ v \end{bmatrix} = - \begin{bmatrix} \sum I_x I_t \\ \sum I_y I_t \end{bmatrix}$$

Based on the paper $W(x;p)$ denotes the parameterized set of all allowed warps, where $p = (p_1, \dots p_n)^T$ is a vector of parameters.

The warp $W(x;p)$ might be the translation:

$$W(x;p) = \begin{pmatrix} x+u \\ y+v \end{pmatrix}, \quad \Delta p = \begin{pmatrix} u \\ v \end{pmatrix}$$

where the vector $p = (u, v)^T$ is then the optical flow.

The Jacobian the warp is.

$$\frac{\partial W}{\partial p} = \begin{bmatrix} \frac{\partial W_x}{\partial u} & \frac{\partial W_x}{\partial v} \\ \frac{\partial W_y}{\partial u} & \frac{\partial W_y}{\partial v} \end{bmatrix} = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix} = I_{2\times 2}$$

If we use this in equation (10) from BakerMatthews:

$$\Delta p = H^{-1} \sum_x \left[\nabla I \frac{\partial W}{\partial p} \right]^T \left[T(x) - I\left(W(x;p) \right) \right]$$

$$\Delta p = H^{-1} \sum_x \nabla I^T \left[T(x) - I\left(W(x;p) \right) \right]$$

$$H \, \Delta p = \sum_x \begin{bmatrix} I_x \\ I_y \end{bmatrix} \left[T(x) - I\left(W(x;p) \right) \right]$$

where, according to equation (11), H is:

$$H = \sum_{(x,y)} \left[\nabla I \frac{\partial W}{\partial p} \right]^T \left[\nabla I \frac{\partial W}{\partial p} \right]$$

$$H = \sum_{(x,y)} \left[\frac{\partial W}{\partial p} \right]^T \cdot \nabla I^T \, \nabla I \left[\frac{\partial W}{\partial p} \right]$$

$$H = \sum_{(x,y)} \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix} \begin{pmatrix} I_x \\ I_y \end{pmatrix} \begin{pmatrix} I_x & I_y \end{pmatrix} \cdot \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}$$

$$H = \sum_{(x,y)} \begin{bmatrix} I_x I_x & I_x I_y \\ I_x I_y & I_y I_y \end{bmatrix}$$

$$H = \begin{bmatrix} \sum I_x I_x & \sum I_x I_y \\ \sum I_x I_y & \sum I_y I_y \end{bmatrix}$$

Using this in equation (11), we obtain:

$$\begin{bmatrix} \sum I_x I_x & \sum I_x I_y \\ \sum I_x I_y & \sum I_y I_y \end{bmatrix} \Delta p = \sum_x \begin{bmatrix} I_x \\ I_y \end{bmatrix} \left[T(x) - I\left(W(x;p) \right) \right]$$

$$\begin{bmatrix} \sum I_x I_x & \sum I_x I_y \\ \sum I_x I_y & \sum I_y I_y \end{bmatrix} \begin{pmatrix} u \\ v \end{pmatrix} = \sum_x \begin{bmatrix} I_x \\ I_y \end{bmatrix} \left[T(x) - I\left(W(x;p)\right) \right]$$

Since the template $T(x)$ is an extracted sub-region of the image at $t=1$ and $I(x)$ is the image at $t=2$:

$$\begin{bmatrix} \sum I_x I_x & \sum I_x I_y \\ \sum I_x I_y & \sum I_y I_y \end{bmatrix} \begin{pmatrix} u \\ v \end{pmatrix} = \sum_x \begin{bmatrix} I_x \\ I_y \end{bmatrix} \left[-I_t \right]$$

$$\begin{bmatrix} \sum I_x I_x & \sum I_x I_y \\ \sum I_x I_y & \sum I_y I_y \end{bmatrix} \begin{pmatrix} u \\ v \end{pmatrix} = -\sum_x \begin{bmatrix} I_x I_t \\ I_y I_t \end{bmatrix} = -\begin{bmatrix} \sum I_x I_t \\ \sum I_y I_t \end{bmatrix}$$