**MP7 Report**

In this project the objective is to explore classical template matching techniques to track a person’s face across a sequence of image frames. The primary goal is to maintain consistent tracking despite appearance changes, lighting variations, and temporary occlusions.

**SSD (Sum of Square Differences):** Measures dissimilarity between the template and patches by summing the squared pixel-wise differences.

* Very sensitive to noise, lighting changes, and occlusions.
* Highly unstable: In our outputs, the bounding box fluctuated frequently.
* Often locked onto incorrect regions, especially during partial occlusion or light variation.
* Despite speed, lacks robustness in real world conditions.

**CC (Cross Correlation):** Calculates the similarity between the template and image patches using dot product-based correlation.

* Better than SSD at handling illumination inconsistencies.
* Still exhibited noticeable jittering during motion or partial occlusions.
* Could track at least part of the face, but was still vulnerable to drift and false positives, especially when a second person appeared.

**NCC (Normalized Cross-Correlation):** Normalizes both the template and patches before computing correlation, effectively removing intensity offsets and scale.

* Most stable and reliable among the three methods.
* Successfully maintained tracking across minor lighting shifts and small occlusions.
* Did occasionally mistake background textures or other people’s faces but recovered well.
* Demonstrated the best confidence consistency in frame-to-frame tracking.

**Handling Occlusion with Confidence-Based Tracking**

Classical template matching suffers greatly during occlusion. When another person enters the scene or the target's face is only partially visible, the tracker often jumps to the wrong subject.

**Methodology**

* Manual Template Initialization: User selects the face region in the first frame.
* Confidence Thresholding:
  + After each match, the NCC score is computed.
  + If score < 0.5, the tracker considers the match as occlusion or poor match.
* Fallback Behavior:
  + When confidence is low:
    - Hide the bounding box to avoid incorrect visual feedback.
    - Widen the search window to scan the full frame in future iterations.
  + When confidence is high:
    - Resume drawing bounding box and narrow search region again.
* Search Optimization:
  + A local search around the previous known position is used to increase speed and reduce false matches.

**Observations:**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Method** | **Stability** | **Recovery** | **False Matches** | **Occlusion Handling** |
| SSD | Very unstable | Poor | Frequent | Not Handled |
| CC | Moderate Jitter | Partial | Sometimes | Not Handled |
| NCC | Stable | Recovers | Occasionally | Not Handled |
| NCC + Extra Credit | Stable | Recovers | Few | Handled |

* SSD fluctuates heavily because it lacks normalization and amplifies even minor pixel differences.
* CC is better but still cannot handle light variation effectively.
* NCC’s mistakes arise when another person enters the frame with a similar face.
* When only half the face is visible, even NCC’s score drops, causing false negatives.
* The extra credit solution correctly hides tracking during occlusion, avoiding misleading visual cues.

**Strengths and Limitations of Extra Credit**

**Strengths**

* Confidence-aware:Prevents mis-tracking by setting a dynamic threshold.
* Fails gracefully: Rather than locking onto the wrong person, it waits for a reliable match.
* Recovers quickly once the target reappears.

**Limitations**

* Hard threshold may fail for low-light scenes or tilted faces, even if the correct person is partially visible.
* Full-frame search during recovery is computationally expensive.

**Conclusion**

This project demonstrated that NCC is significantly more robust than SSD or CC for template-based tracking in video sequences. However, real-world conditions like occlusion, lighting variation, and similar-looking intruders require additional logic beyond raw similarity metrics.

The extra credit approach of combining NCC with confidence-based occlusion handling greatly enhances robustness, but could be further improved by depending on the use case and video quality