# 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