Master in Computer Vision *Barcelona*

Module: Video Analysis

Lecture 2: Video segmentation

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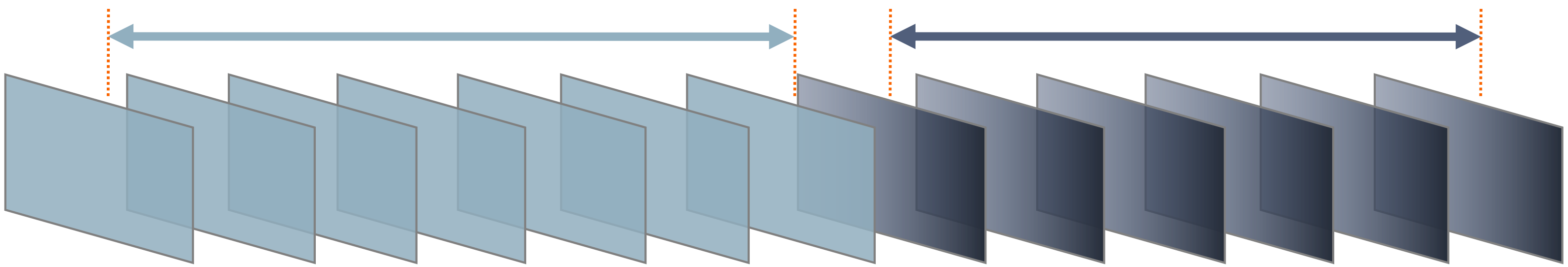
Outline

- Introduction to video segmentation
- Shot segmentation
- Moving object segmentation
    - Introduction
    - Still background estimation
    - Variable background estimation: Single Gaussian
    - Variable background estimation: Multiple Gaussians
    - Other change detection techniques
  - Shadow detection
  - Connected component analysis and tracking
- Region segmentation
  - Spatial segmentation and tracking
  - Spatio-temporal segmentation

Introduction to video segmentation

- **Different meanings**:
  - **Shot detection**: The segmentation is seen as a 1D (temporal) problem.
  - A **temporal segmentation** is performed, dividing the video into segments that should be related to the different shots in the sequence.



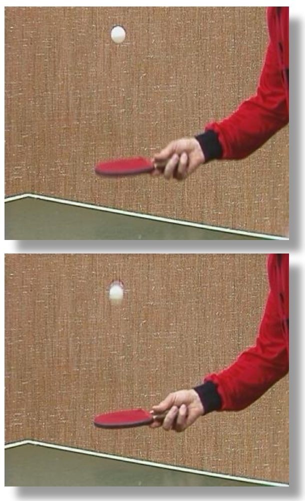
Introduction to video segmentation

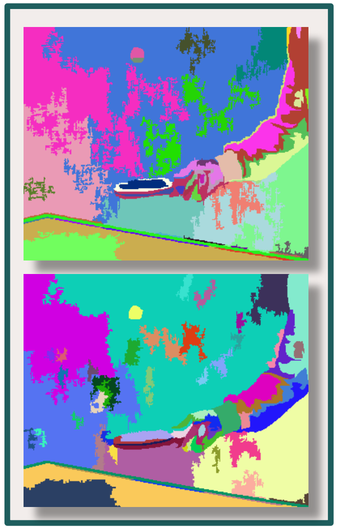
- **Different meanings**:

  Moving object segmentation: Detect and segment moving objects from a video sequence of a fixed camera
  - Background – static scene
  - Foreground – moving objects

Introduction to video segmentation

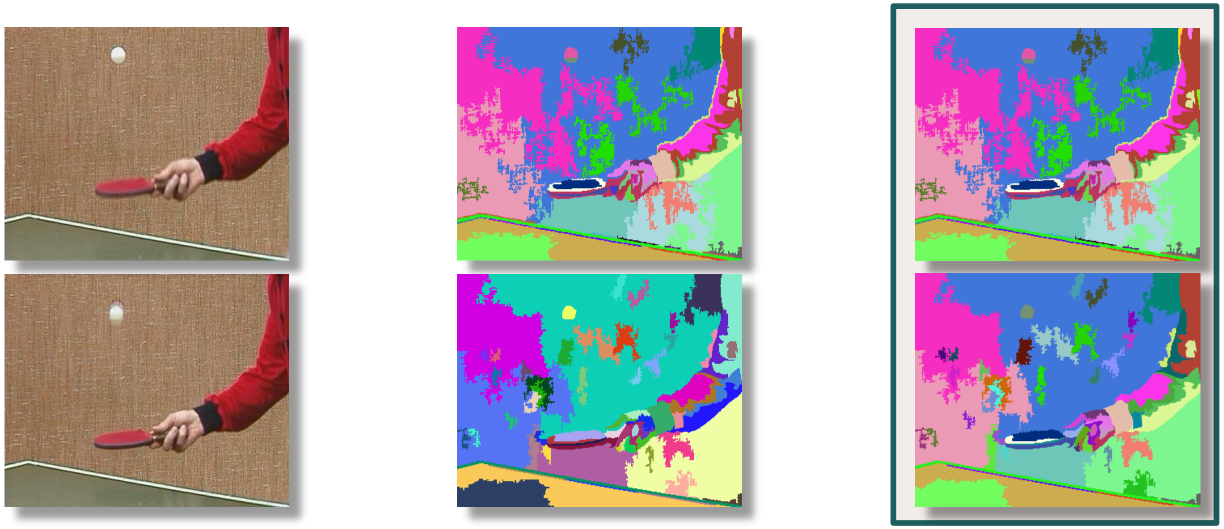
- **Different meanings**:
  - **2D Region segmentation**: The sequence is understood as a set of isolated images. **Spatial segmentation** is performed on each separated image (2D signal) in the sequence. Regions have to be related to the objects in the scene.
    - It is the same problem as the **image segmentation** problem.
    - Object labels in consecutive images **may not be coherent**.





Introduction to video segmentation

- **Different meanings**:
  - **3D region segmentation**: The sequence is understood as a set of temporally related images. **Spatial/Temporal segmentation** is performed on the sequence (3D signal). Regions have to be related to the objects in the scene and their temporal evolution.
    - Direct extension of the **image segmentation** problem to the 3D case.
    - Object labels in consecutive images **should be coherent**.



Introduction to video segmentation

- The division in three steps proposed for image segmentation can be adopted:

- **Remove useless or annoying information**
- **Preserve shape information**

- Elements belonging to the same regions should correspond to **homogeneous features**

- **Feature space**:
  Gray level/Color
  Texture
  Depth
  Motion
  Frame difference
  DFD
  Histogram

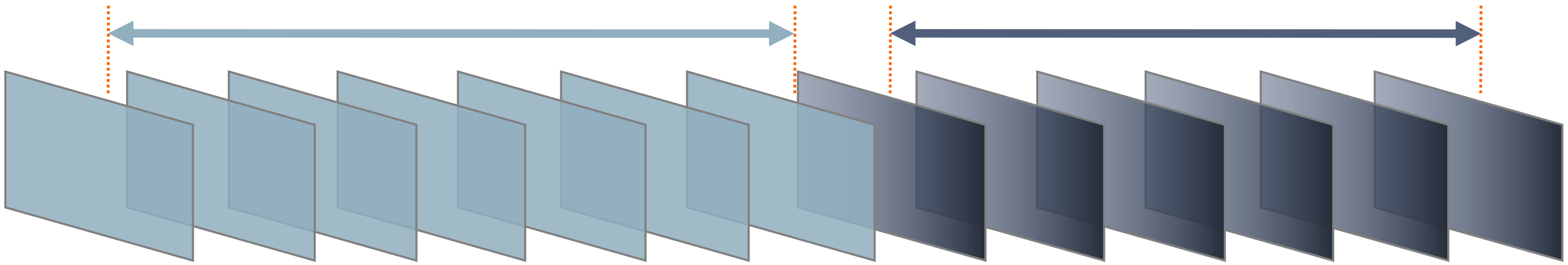
- **Decision space**:
  1D: Temporal
  2D: Spatial
  3D: Spatial/temporal

- **Partition definition**:
  ✓ Transition
  ✓ Homogeneity

Outline

- Shot segmentation
- Moving object segmentation
- Region segmentation

Shot segmentation (I)

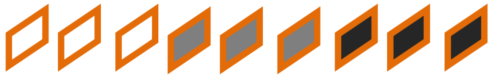


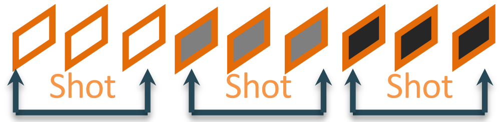
- A **video shot** is a sequence of frames captured by one camera in a single continuous action in time and space.

- **Feature extraction and decision**
  - Frame difference (FD)
  - Frame histogram comparison
  - Displaced frame difference (DFD)

Temporal gradients

Shot segmentation (I)





Feature extraction → **Similarity measurement** → **Detection**

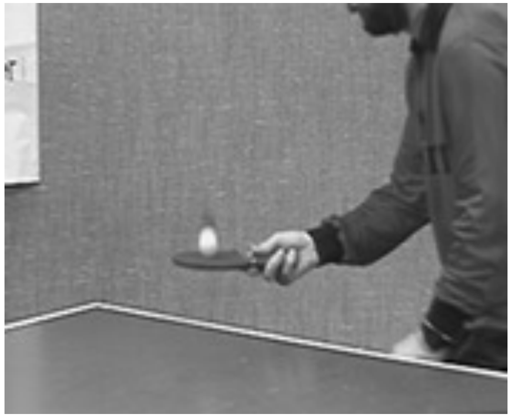
Feature extraction
- Color histogram
- Edge change ratio
- Motion vectors
- Corner points
- Information saliency maps
- Scale invariant feature transform
- MPEG-7 descriptors

Similarity measurement
- 1-norm cosine dissimilarity
- Euclidean distance
- Histogram intersection
- Chi-squared similarity
- Earth mover's distance
- Mutual information

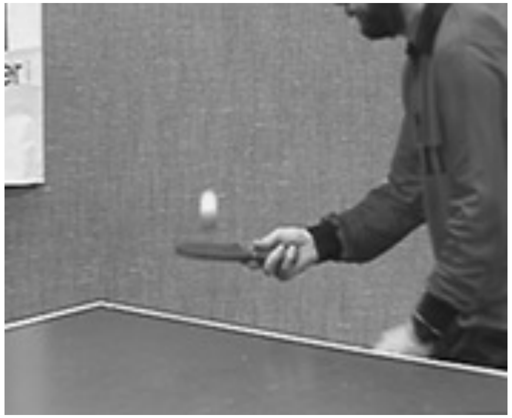
Detection
- Threshold-based
- Statistical learning-based
  - Supervised learning
    - Support vector machine
    - Adaboost
    - K nearest-neighbor (kNN)
  - Unsupervised learning
    - Frame similarity-based
    - Frame-based
      - Clustering algorithms
      - K-means

W. Hu, A survey on visual content-based video indexing and retrieval
IEEE Transactions on Systems, November 2011

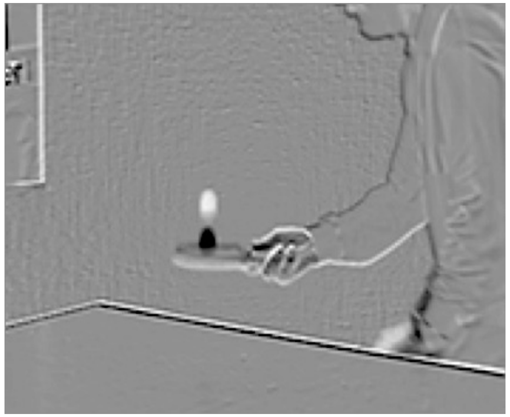
Shot segmentation



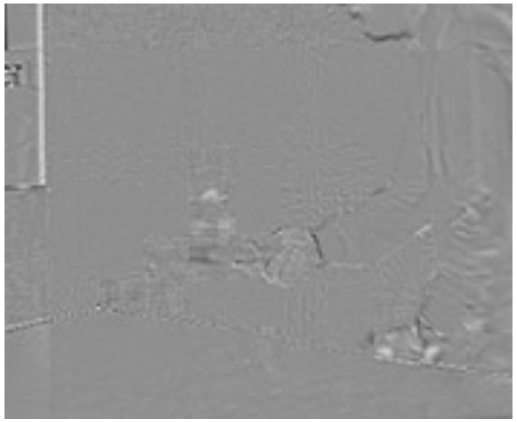
I(t-1)



I(t)



FD(t)



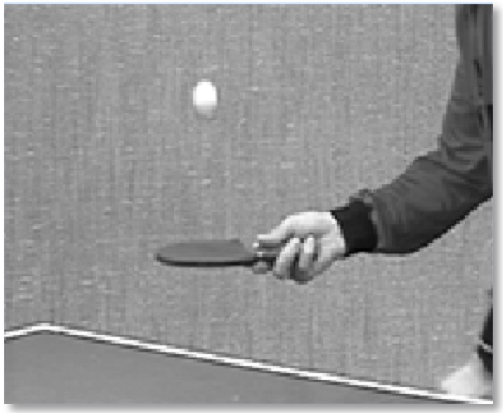
DFD(t)

2D Motion analysis

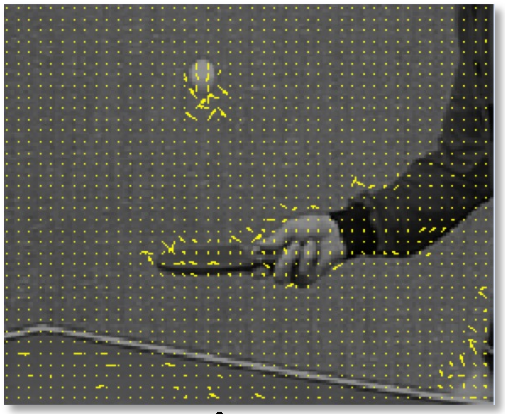
- In practice, the optical flow has to be estimated and may differ from the ideal one.

- If $\hat{\vec{D}}(\vec{r})$ denotes the estimated optical flow, the reference image to which the optical flow is applied is called the motion compensated image.

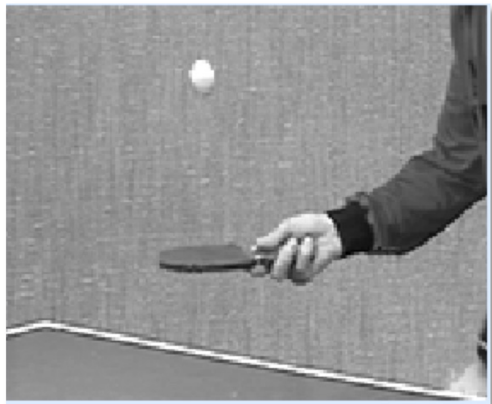
$$I^{MC}(\vec{r},t)=I(\vec{r}-\hat{\vec{D}}(\vec{r}),t-\Delta t)$$



$I(\vec{r},t-\Delta t)$



$\hat{\vec{D}}(\vec{r})$

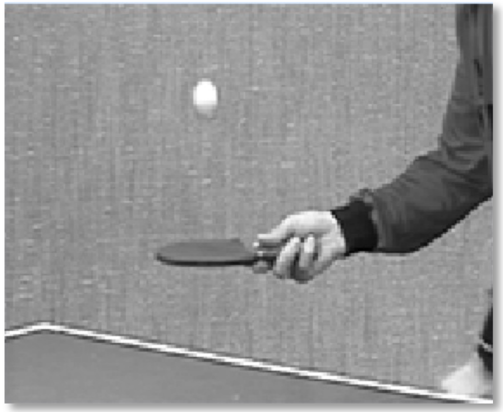


$I^{MC}(\vec{r},t)$

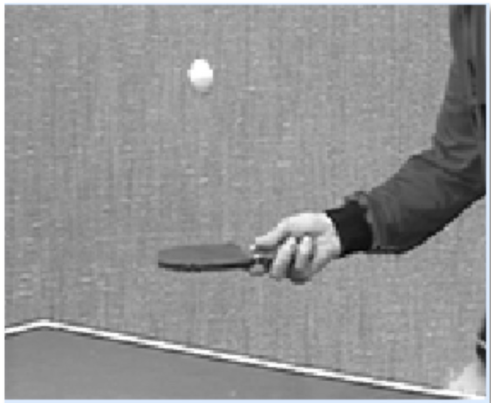
2D Motion analysis

The difference between the motion compensated frame and the real current image is called the **Displaced Frame Difference** (DFD).

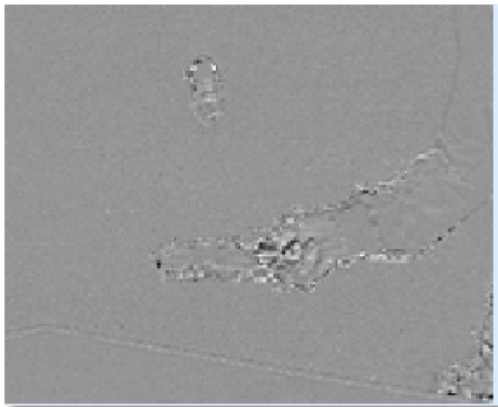
$$DFD(\vec{r},\hat{\vec{D}}(\vec{r}))=I(\vec{r},t)-I(\vec{r}-\hat{\vec{D}}(\vec{r}),t-\Delta t)$$



$I(\vec{r},t-\Delta t)$



$I^{MC}(\vec{r},t)$



$DFD(\vec{r},\hat{\vec{D}}(\vec{r}))$

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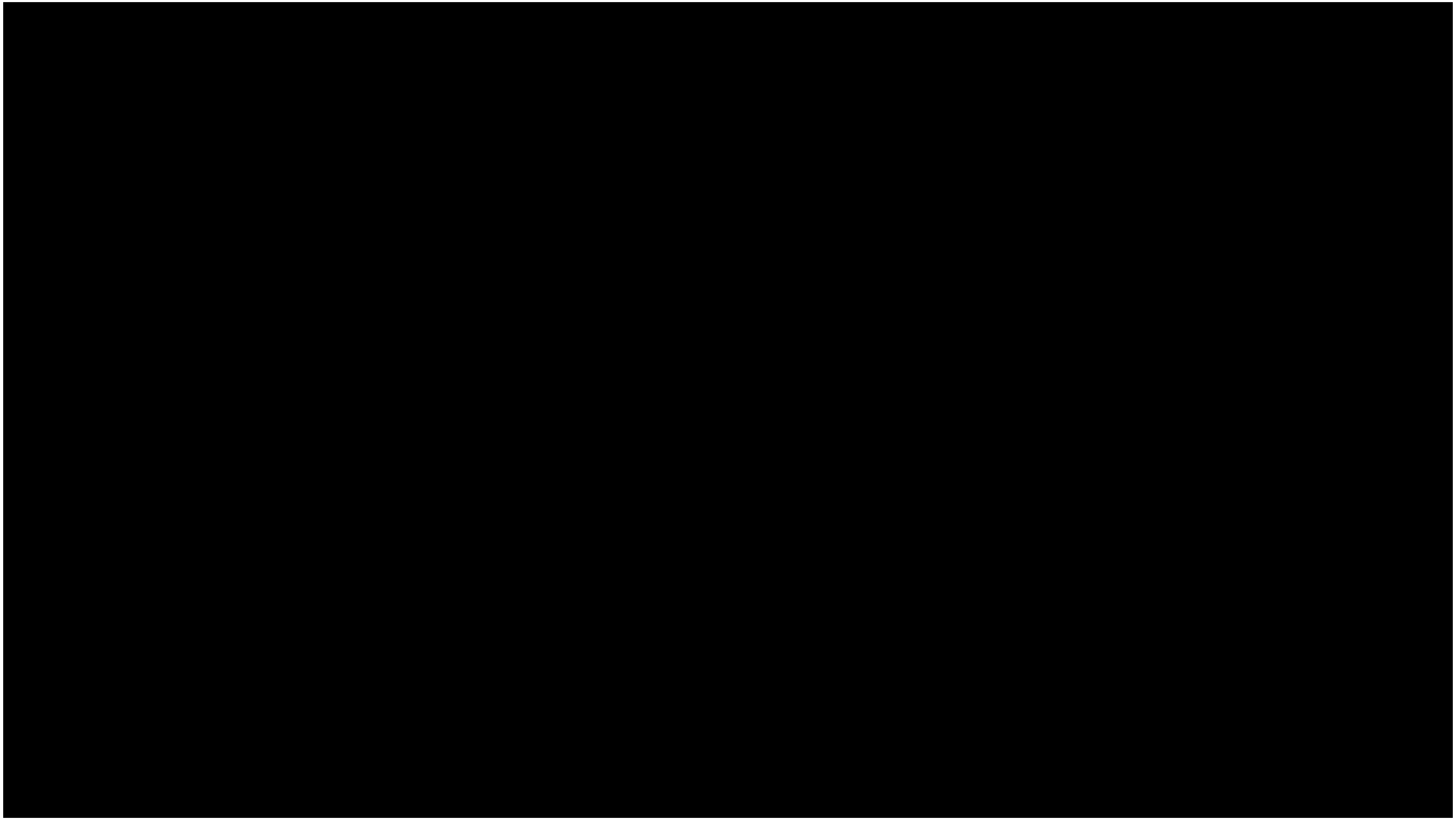
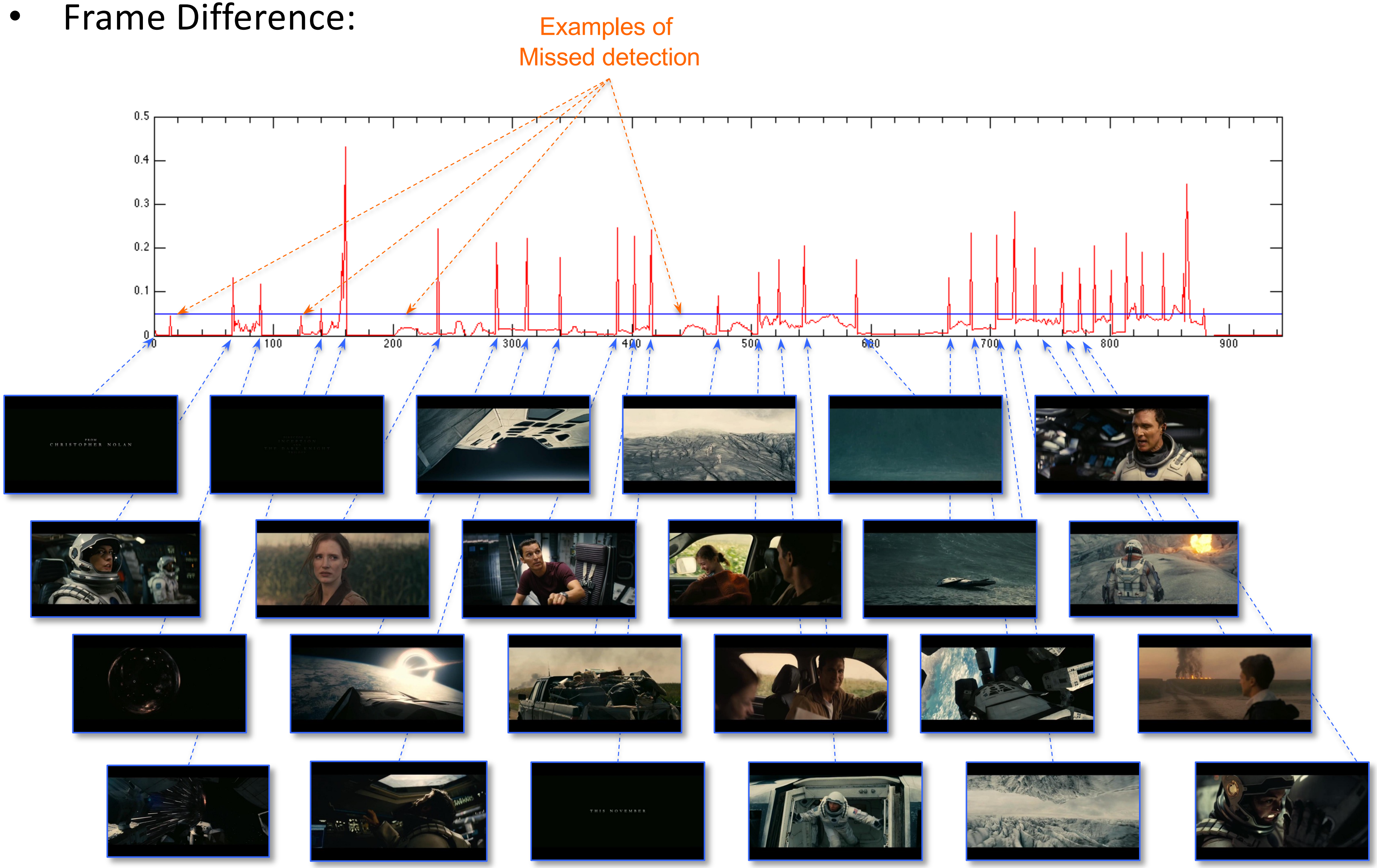
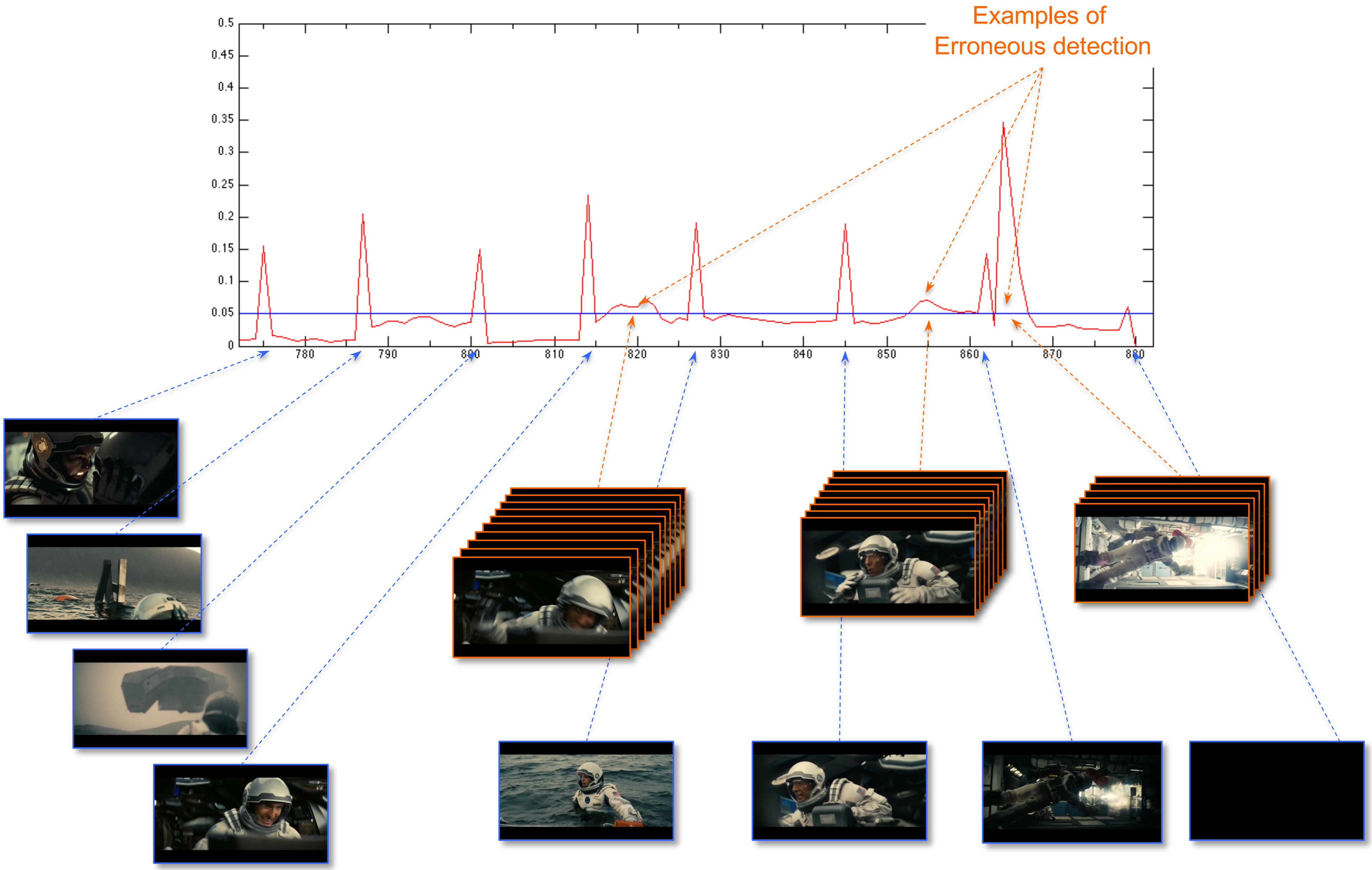


Shot segmentation (II)

- Frame Difference:

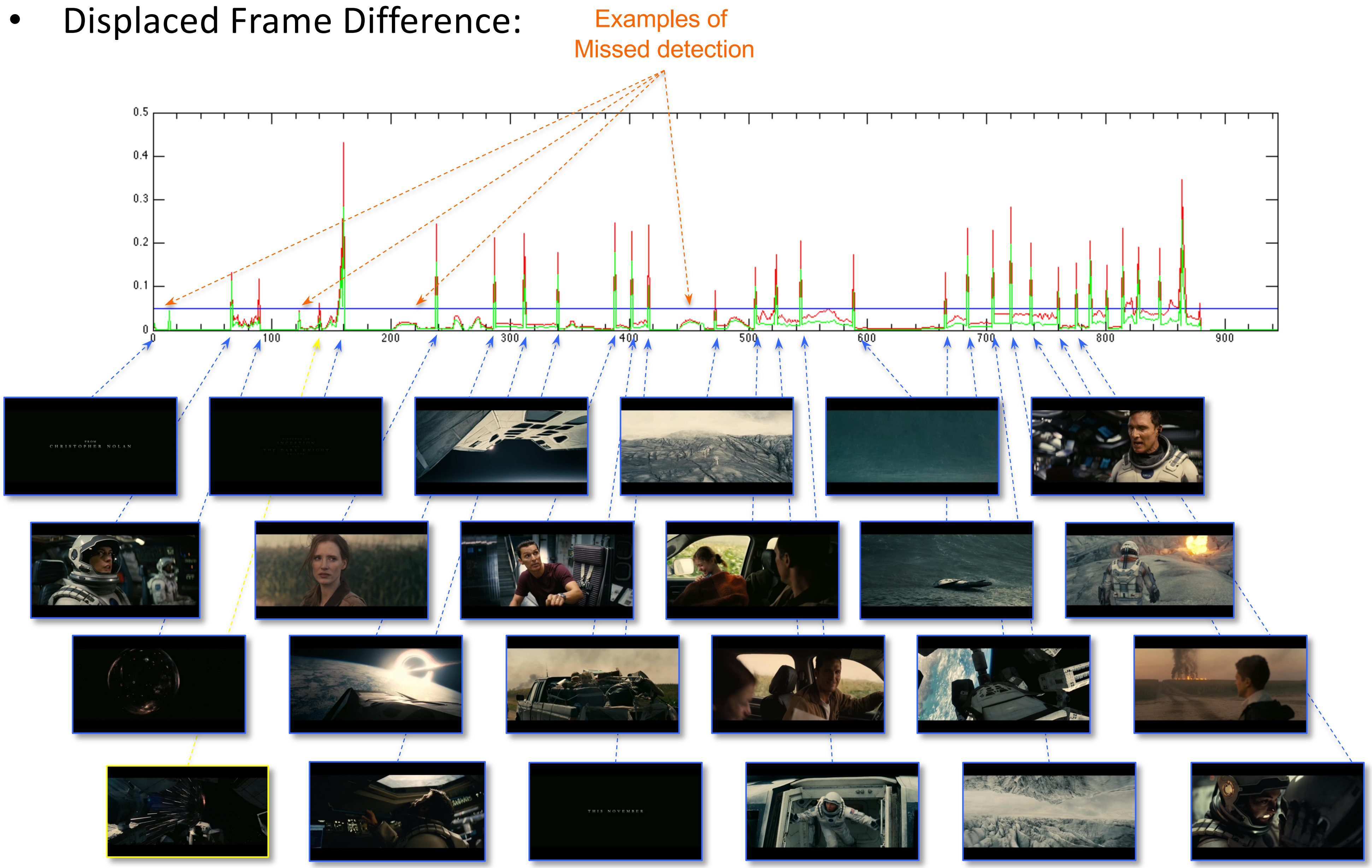


Shot segmentation (III)

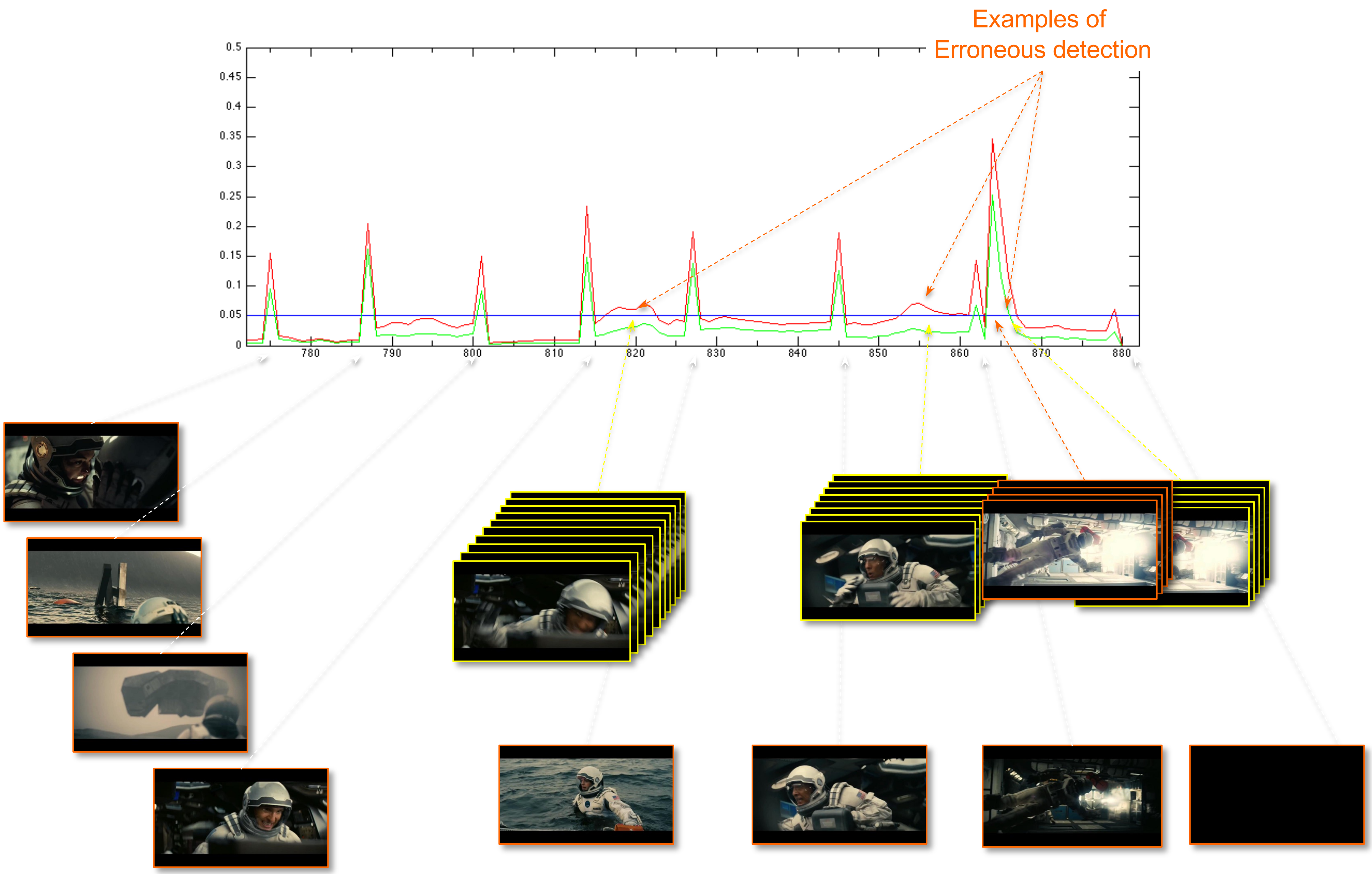


Shot segmentation (IV)

- Displaced Frame Difference:



Shot segmentation (V)



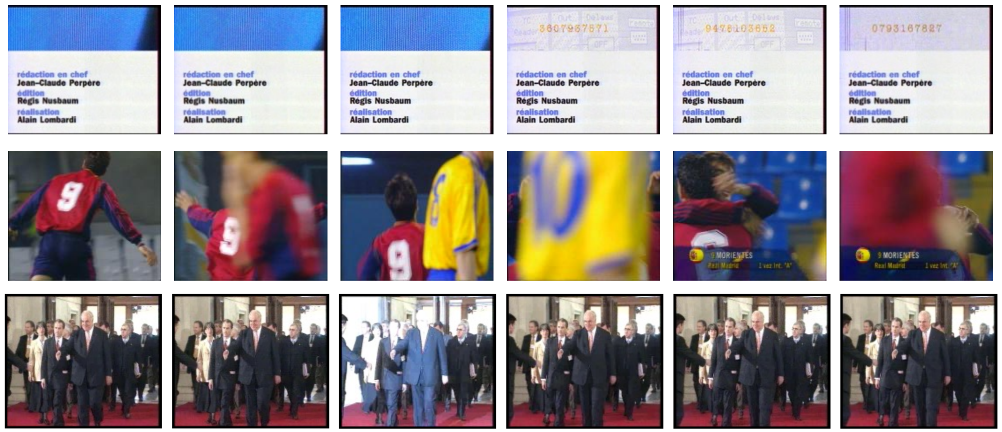
Shot segmentation (VI)

The DFD comparison allows predicting the current image with the information of the previous image leading to a more robust estimation of the shot transition. However, some transitions are difficult to handle (dissolve and fade, for instance)

- Examples of **subtle shot transitions**.

These changes correspond to shot transitions

- Examples of **internal transitions or motion**.



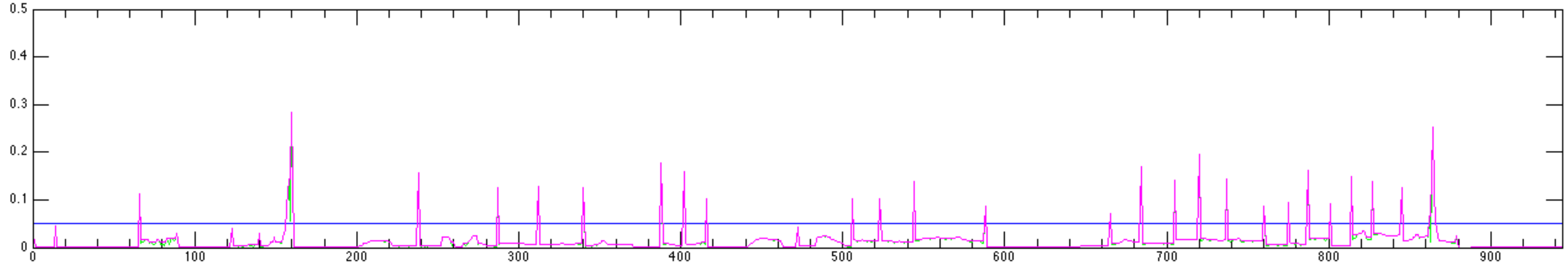
These changes *do* *not* correspond to shot transitions

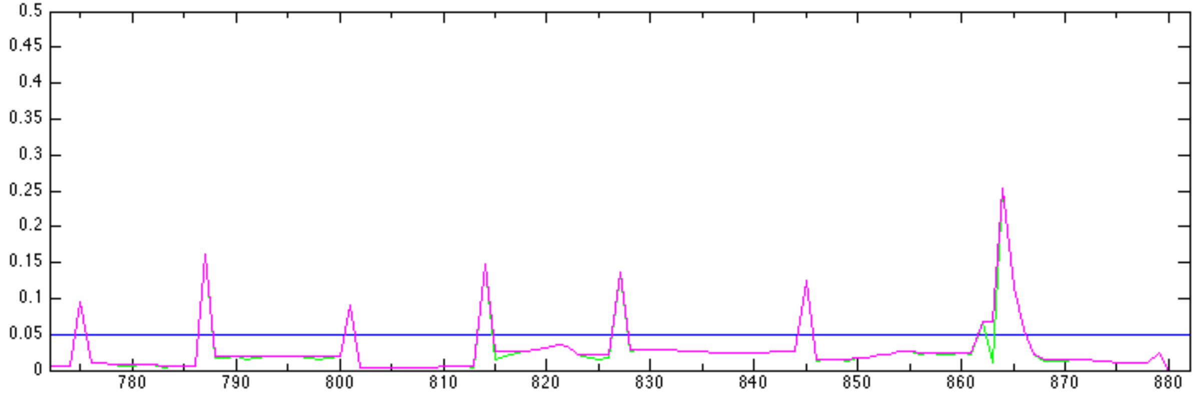
Shot segmentation (VII)

- Direct binarization may not be very robust in practice -> **Segmentation pb**

- **Simplification**:
  - Remove minima that are not long enough to correspond to a shot: closing with a structuring element corresponding to the shortest expected shot:

$$f(t) = \varphi_w(DFD(t))$$

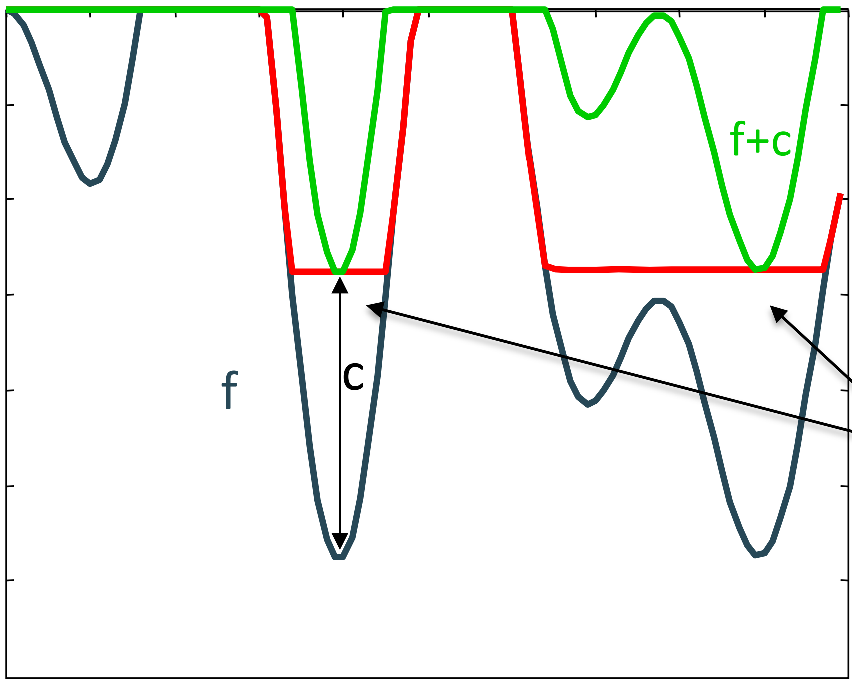




Shot segmentation (VIII)

Basic segmentation steps

- **Decision**:
  - Instead of binarization, marker detection and then watershed (or region growing)
  - Selection of meaningful minima: Negative contrast filter



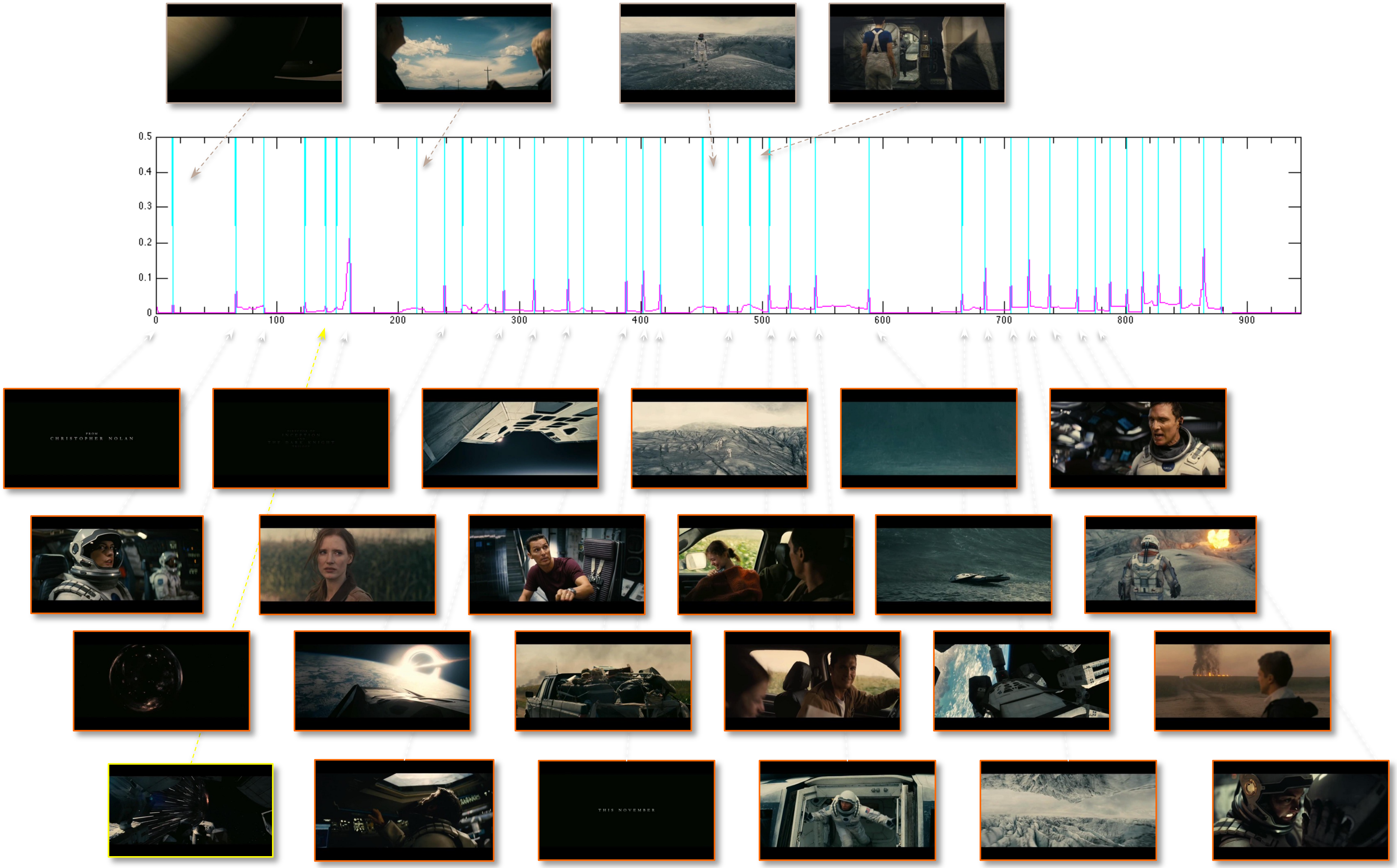
$$\varphi^{rec}(f, f+c) = f+c$$

Shot segmentation (IX)

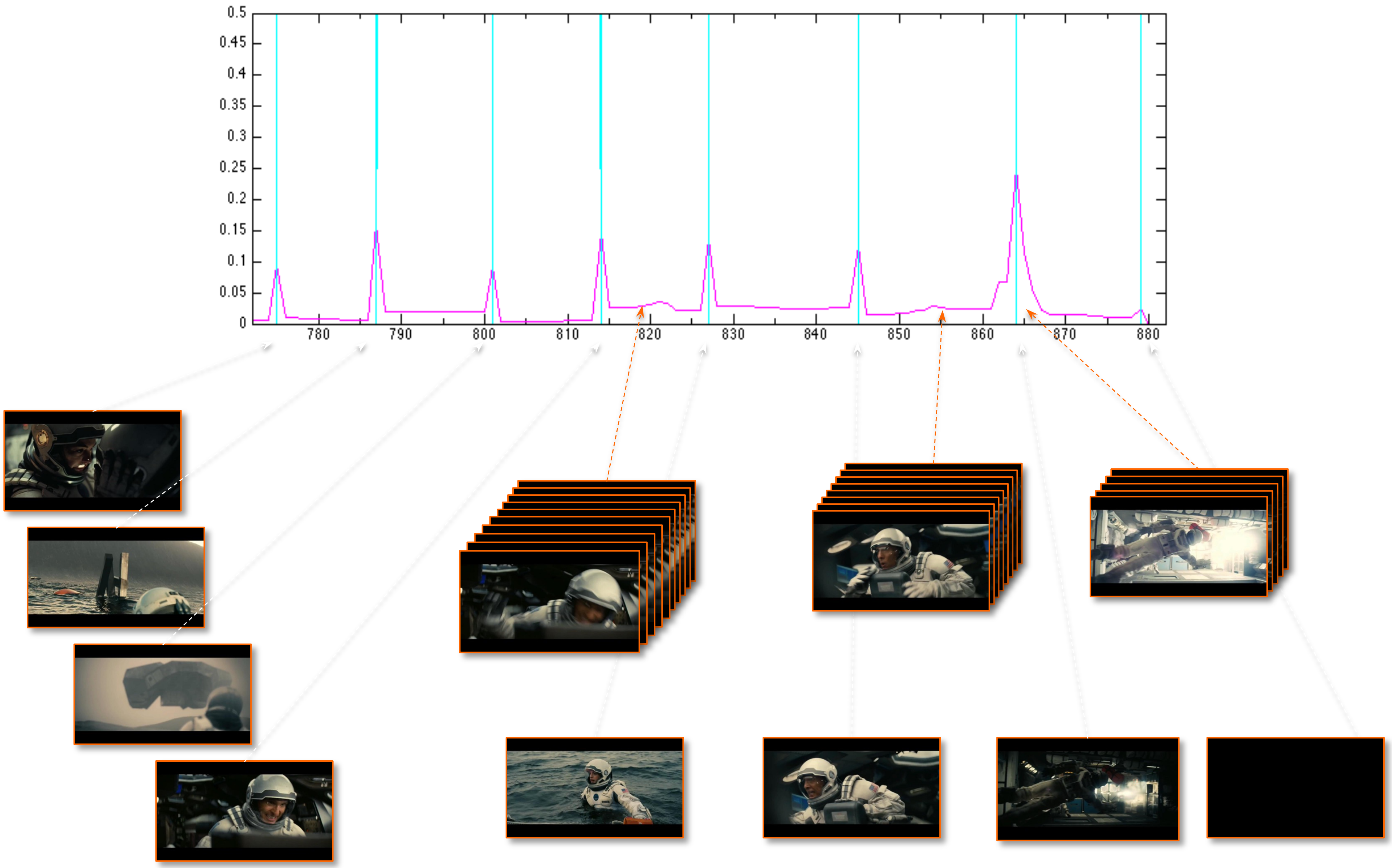
Temporal segmentation: Decision

- **Watershed**: Flooding start by the markers

Shot segmentation (X)



Shot segmentation (XI)



Shot segmentation (XIII)

- End-to-end Fully Convolutional Neural Network

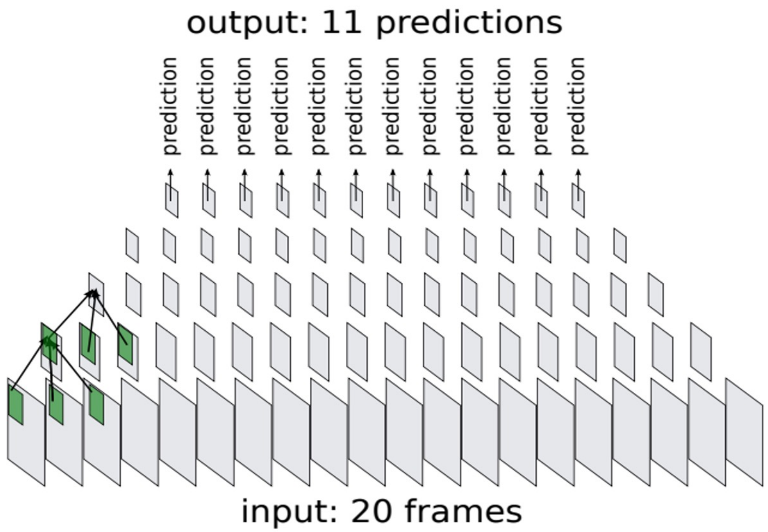


Figure 2: Our network architecture. Each frame-prediction is based on a context of 10 frames. By using a model that is fully convolutional in time, we can increase the input size and thus make *e.g.* 11 predictions by analyzing 20 frames or 91 predictions by analyzing 100 frames, etc., thus minimizing redundant computation.

M. Gigly, Ridiculously Fast Shot Boundary Detection with Fully Convolutional Neural Networks. CBMI 2018