11-2005

# Motion-based approach for BBC rushes structuring and characterization

Chong-wah NGO
*Singapore Management University*, cwngo@smu.edu.sg

Zailiang PAN

# Motion-based Approach for BBC Rushes Structuring and Characterization

*Chong-Wah Ngo, Zailiang Pan*

Department of Computer Science
City University of Hong Kong

# BBC Rushes

- *Rushes*
  - Unedited videos
  - Similar to home videos, but with better capturing skills and visual quality

- *Always….*
  - *Pan* to have another view of scene
  - *Zoom-and-hold* to freeze the impression
  - *Search* for something
  - Long take without camera motion
  - Pan to have panoramic view

# BBC Rushes

- Intentional
  - Another view of scene
  - Impression
  - Something
  - Long take, panoramic view
- Intermediate
  - *Pan* to have….
  - *Zoom-and-hold* to freeze ….
  - *Search* for …..
  - A series of search, pan, zoom
- Shaking

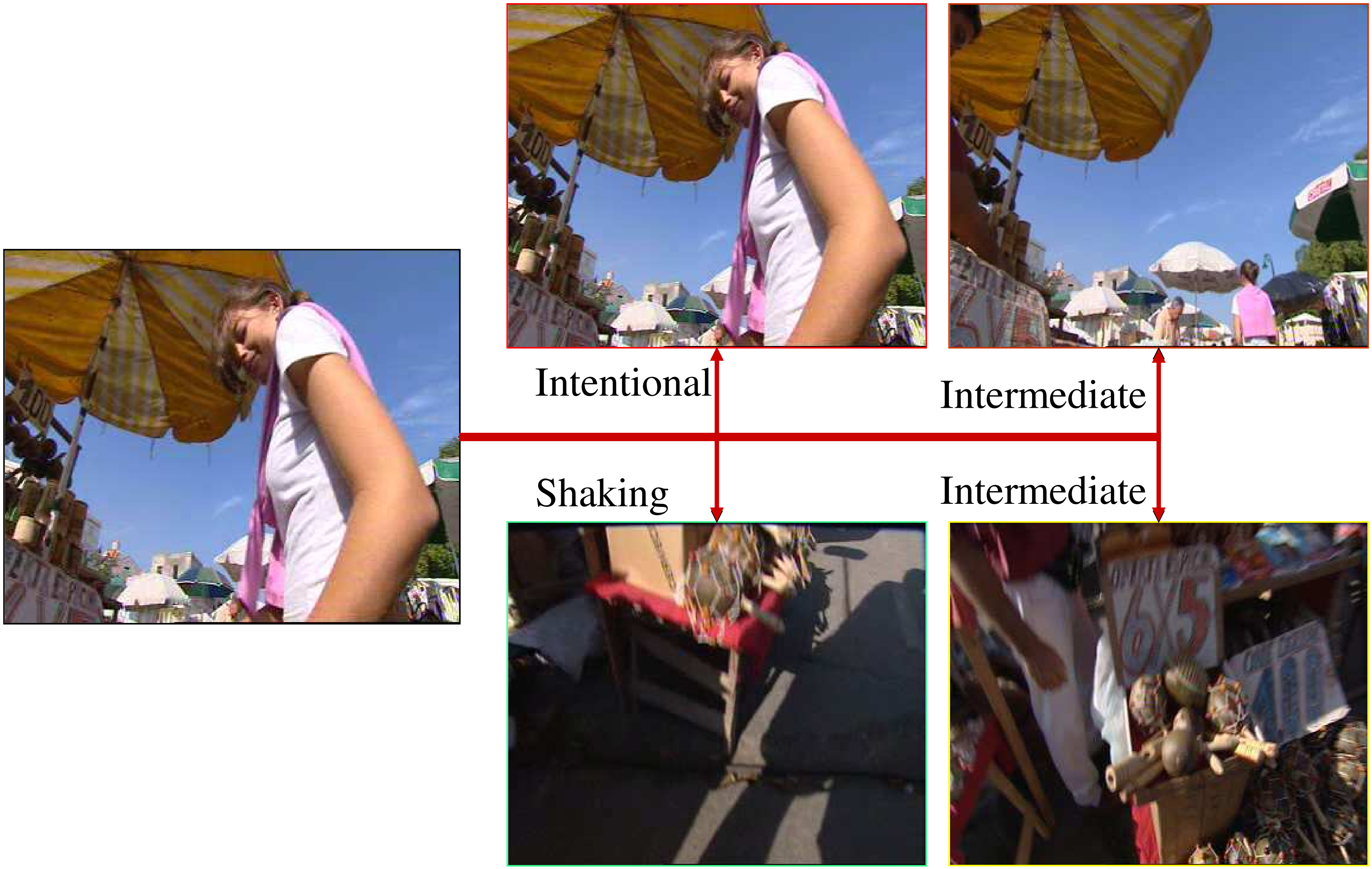
# Our Intuition…

- Detecting intentions are useful for search, browsing and summarization
- Intermediate motions are not really meaningful for most tasks
- Shaking clips can be either useful or not useful

# Objective

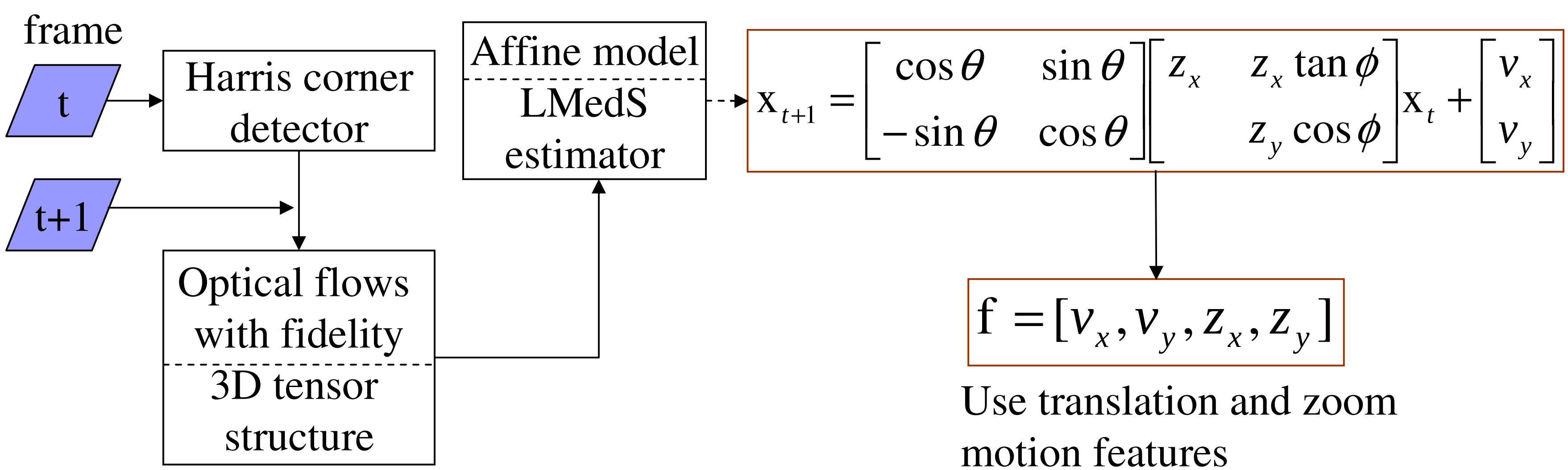
- To structure-and-characterize (or characterized-and-structure) video content, we propose
  - Finite State Machine (FSM)
  - Support Vector Machine (SVM)
  - Hidden Markov Model (HMM)

| | | *FSM* | *SVM* | *HMM* |
|---|---|---|---|---|
| I | Intentional | √ | √ | √ |
| II | Intermediate | √ | √ | √ |
| III | Shaking | √ | √ | √ |


Intentional
Intermediate
Shaking
Intermediate

# Global Motion Estimation

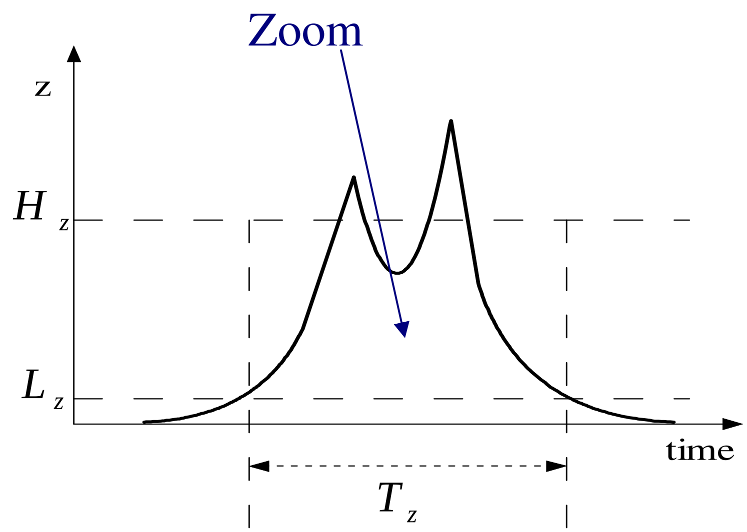
- The motion-driven FSM, SVM and HMM are all based on the inter-frame global motion estimation. Considering the generalization and complexity, we choose to use the ***affine motion model***.



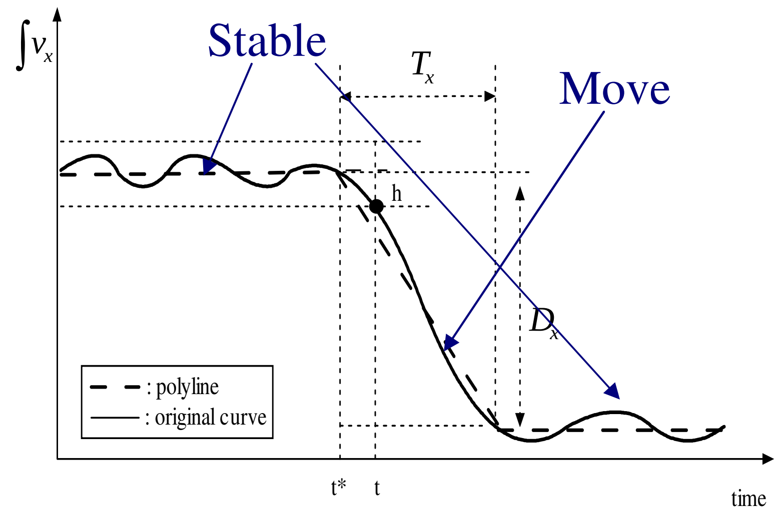

Use translation and zoom motion features

# FSM—Partition

**Zoom partition**: The techniques of hysteresis thresholding are used for the zoom motion feature. Two thresholds are used: higher one for locating the position; lower one for the zoom partition ***Z***.

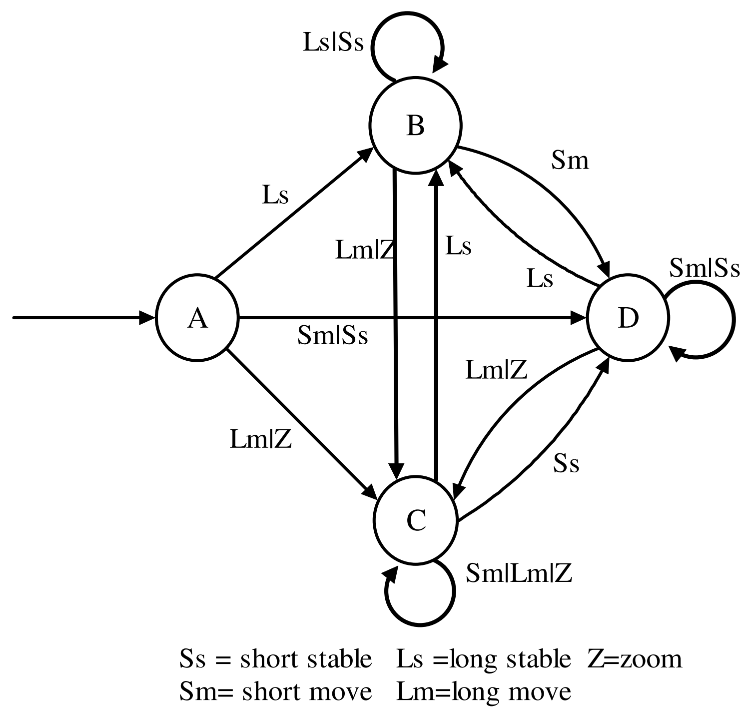



**Static and move partition**: A polyline is fitted to the camera trajectory using Kalman filter. Based on the properties of the lines, camera trajectory are partitioned into long stable ***Ls***, short stable ***Ss***, long move ***Lm*** and short move ***Sm***.



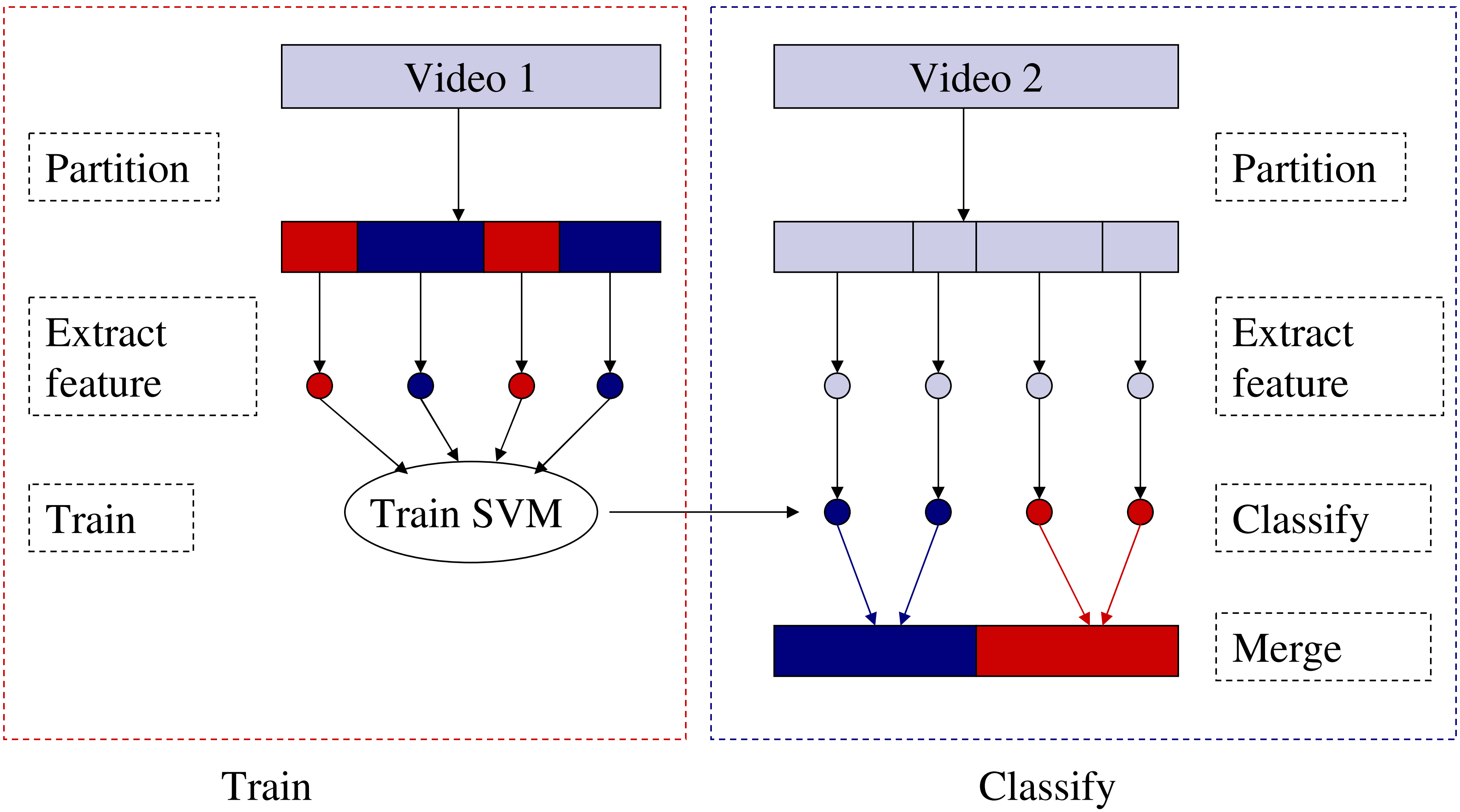
# FSM—Classification

- A 4-state FSM is employed to refine the partition and characterize video.
  - A: initial state.
  - B: intentional motion.
  - C: intermediate and shaky motions. They are further separated by the rate of camera direction changes.
  - D: temporarily undetermined short segments.




Z. Pan and C.-W. Ngo, "Structuring home video by snippet detection and pattern parsing," in *ACM SIGMM Int'l Workshop on MIR*, 2004.

# Flowchart of SVM



# SVM Implementation

- Partition: video is divided into segments of equal fixed duration.
- Feature extraction: 9 features from motion are extracted for each video segment. They are:

Speed:
$$M_x = \operatorname*{mean}_{i=1}^{N}(|v_i^x|), \quad M_y = \operatorname*{mean}_{i=1}^{N}(|v_i^y|)$$

Zoom:
$$Z_x = \operatorname*{mean}_{i=1}^{N}(|z_i^x|), \quad Z_y = \operatorname*{mean}_{i=1}^{N}(|z_i^y|)$$

Acceleration:
$$D_x = \operatorname*{mean}_{i=1}^{N-1}(|v_{i+1}^x - v_i^x|), \quad D_y = \operatorname*{mean}_{i=1}^{N-1}(|v_{i+1}^y - v_i^y|$$

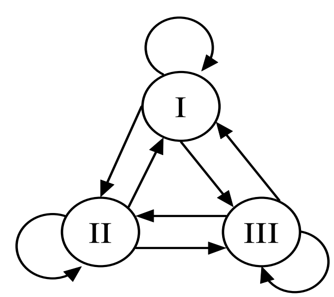
Acceleration variance:
$$V_x = \operatorname*{var}_{i=1}^{N-1}(|v_{i+1}^x - v_i^x|), \quad V_y = \operatorname*{var}_{i=1}^{N-1}(|v_{i+1}^y - v_i^y|)$$

Motion change:
$$S = \operatorname*{mean}_{i=1}^{N-1}(|\mathbf{v}_{i+1}||\mathbf{v}_i| - \mathbf{v}_{i+1} \cdot \mathbf{v}_i)$$

***Motion change*** feature actually is $|\mathbf{v}_{i+1}||\mathbf{v}_i|(1 - \cos\theta)$, which considers both the angle change and motion magnitude.

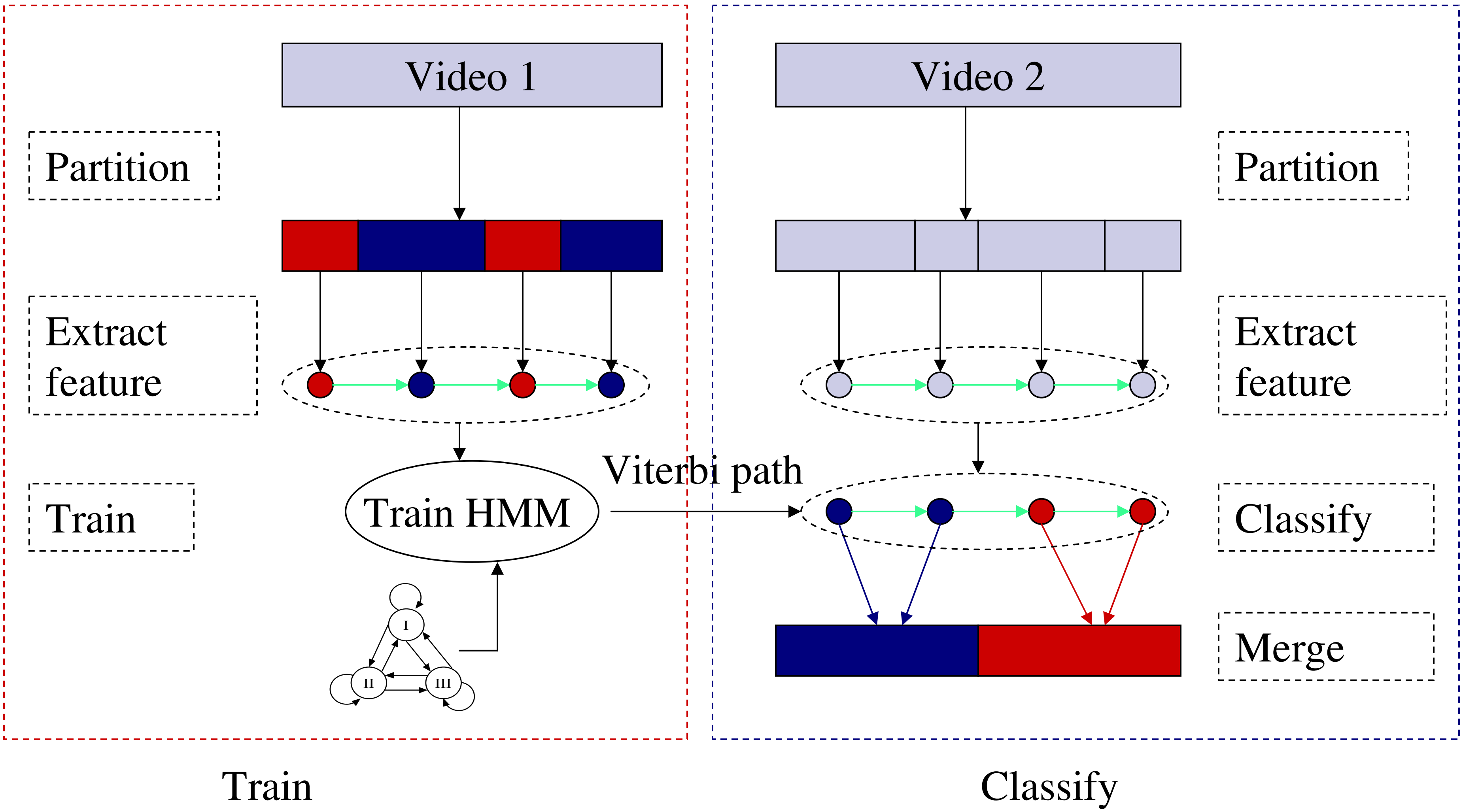
# HMM-based Approach

- Motivation: ***First order decision*** (look at one sample and make decision at a time) may not be sufficient, ***Second order decision*** (look at multiple samples to make decision) should be better in principle.
- **Hidden Markov Model (HMM)** is then used as second order decision for video structuring and characterization.
  - HMM State transition à video structuring
  - HMM State prediction à video characterizing
- **3-state** hidden Markov model is used to represent respectively the intentional, intermediate and shaky motions.




HMM

# Flowchart of HMM



# MHMM & SHMM

- We investigate two kinds of HMM, called ***MHMM*** and ***SHMM***. The difference is,
  - MHMM (*m*otion-based):

    Partition: Video is divided into segments of equal fixed duration.

    Feature: Extract 9 features from motion.
  - SHMM (*s*hot-based):

    Partition: Video is divided into shots by cut detector.

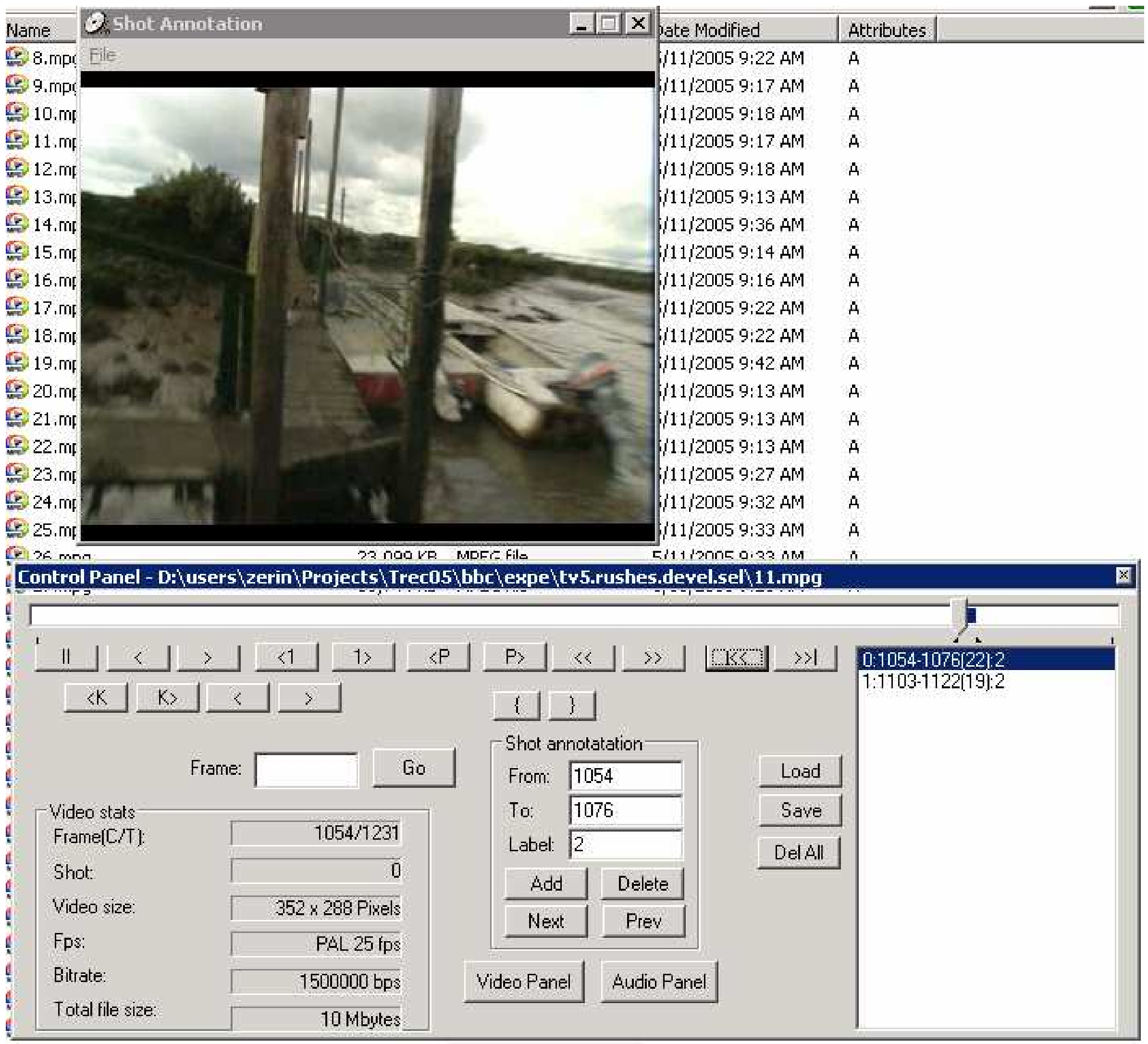
    Feature: Extract shot duration

  - *Note*: We use SHMM as baseline
    - Intuition: Short shots correspond to shaking/intermediate motion

# Experiments – Data Set and Training

- 60 videos (337K frames) from the development set
- Manually annotate sub-shots and their characteristics
- 768 shots and 1135 sub-shots
- 30 videos for training and 30 videos for testing.

# Annotation Tool



# Approaches

| | Segment Unit | Feature Number | Feature Types | Training | Decision |
|---|---|---|---|---|---|
| FSM | Sub-shot | 4 | Motion | No | 1st |
| SVM | Equal duration | 9 | Motion | Yes | 1st |
| MHMM | Equal duration | 9 | Motion | Yes | 2nd |
| SHMM | Cut | 1 | Time | Yes | 2nd |

1st : look at one sample and make decision at a time

2nd: look at multiple samples to make decision

# Experiment – Structuring

- Sub-shot boundary detection
- A sub-shot boundary is counted as correct as long as we can find a matched ground-truth boundary within 1 second.

| | Training | | Testing | |
|---|---|---|---|---|
| | Recall | Prec. | Recall | Prec. |
| FSM | 0.614 | 0.282 | 0.593 | 0.279 |
| SVM | **0.769** | 0.281 | **0.763** | 0.289 |
| MHMM | 0.461 | **0.419** | 0.395 | **0.379** |
| SHMM | 0.060 | 0.355 | 0.056 | 0.322 |

Results of structuring BBC rushes

# Experiment – Characterization

- Sub-shot classification
- Use frame as basic unit for evaluation

| | Intentional | | Intermediate | | Shaky | |
|---|---|---|---|---|---|---|
| | Recall | Prec. | Recall | Prec. | Recall | Prec. |
| FSM | 0.815 | 0.981 | **0.802** | 0.118 | 0.011 | 0.050 |
| SVM | 0.827 | **0.990** | 0.701 | **0.162** | **0.715** | 0.239 |
| MHMM | **0.927** | 0.970 | 0.329 | 0.137 | 0.311 | **0.339** |

Results of characterizing BBC rushes (training videos)

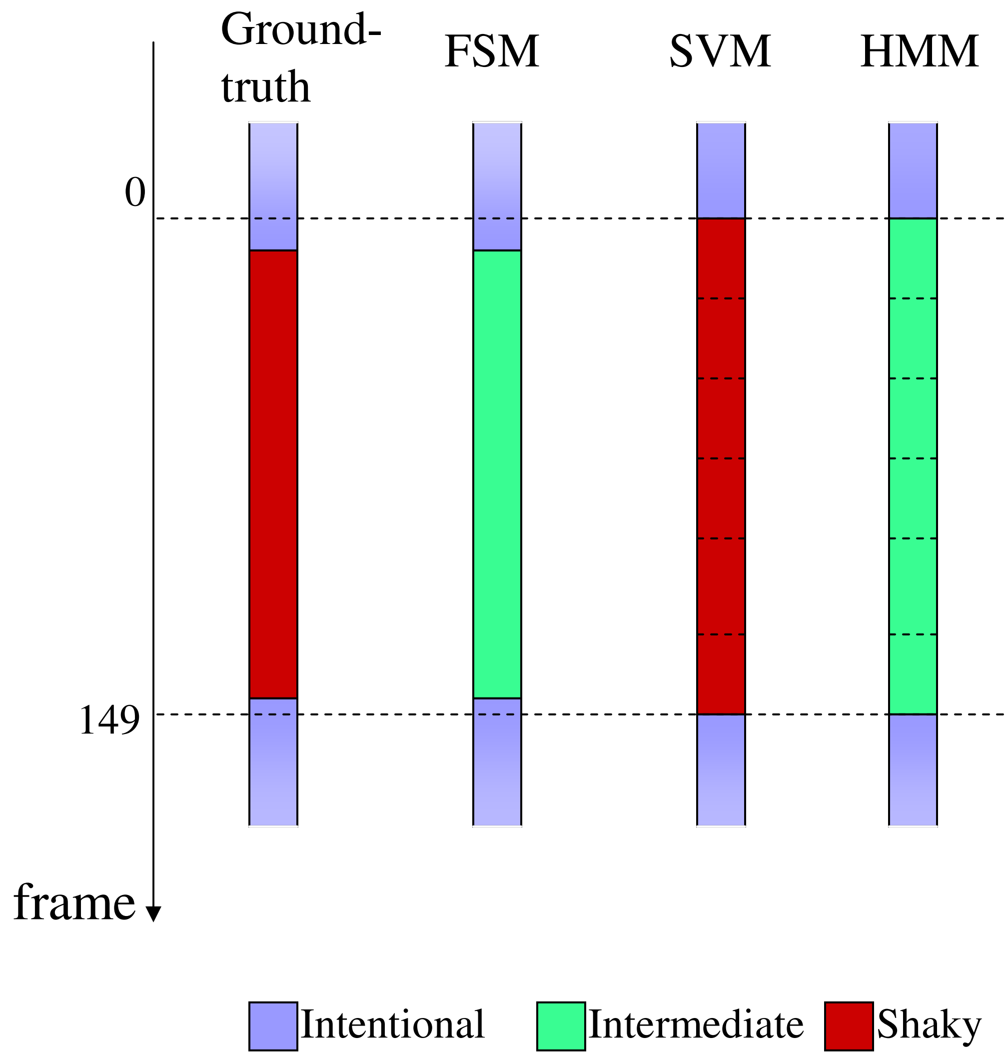
# Experiment – Characterization Cont'

- 30 testing videos

| | Intentional | | Intermediate | | Shaky | |
|---|---|---|---|---|---|---|
| | Recall | Prec. | Recall | Prec. | Recall | Prec. |
| FSM | 0.756 | 0.968 | **0.844** | 0.128 | 0.000 | 0.000 |
| SVM | 0.778 | **0.975** | 0.456 | 0.120 | **0.362** | **0.182** |
| MHMM | **0.909** | 0.929 | 0.375 | **0.196** | 0.043 | 0.067 |

Results of characterizing BBC rushes (testing videos)

# Example



Ground-truth
FSM
SVM
HMM
0
149
frame
Intentional
Intermediate
Shaky

# Summary

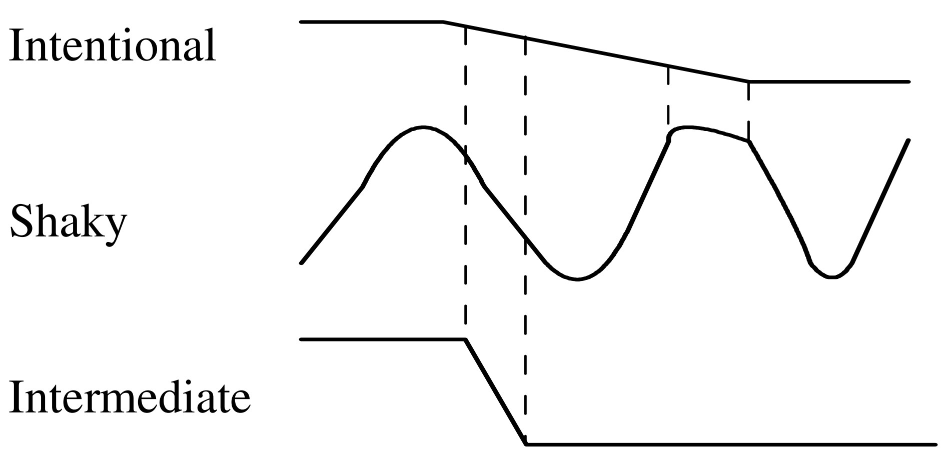
- For structuring, SVM gives the best recall (above 75%), followed by FSM (about 60%); the performances of MHMM and SHMM are poor.
- For characterization:
  - HMM performs best for extracting intentional motion
  - FSM performs best for intermediate motion detection
  - On average, SVM is best for three characteristics.
- Several problems remain difficult and challenging

# FSM—Limitation

- For FSM, the following issues should be considered.
  - The threshold is difficult to set empirically to distinguish between intentional and intermediate. For example, “panorama view” or “pan to search”?
  - The use of rate of directional changes as features for separating shaky and intermediate motions is poor.

# SVM—Limitation

- For SVM, the following sorts of segments are ambiguous by just looking at small time frame:
  - A panoramic or "pan to search"?
  - "Pan to search" or one part of a shaky?
  - A relative stable part of a shaky or intentional?



# MHMM—Limitation

- More works can be done in HMM:
  - Only one state is not enough to represent the intentional, intermediate or shaky characteristic, e.g.
    - “Intermediate” may have two sub-state: “pan to search” and “zoom-and-hold”
    - “Shaky” may have sub-states such as “shake left”, “shake right”, “shake up” , “ shake down”.
  - State “intentional: is over trained since sequences has more intentional than intermediate/shaky segments. Over-trained “intentional” state compresses the detection of other two types, especially shaky.

# More on Characteristic of BBC Rushes…

I. **Intentional**

II. **Intermediate Motion**

III. **Shaky Motion**

IV. **Blur**

- motion blur, defocusing blur

V. **Illumination Change**

# Challenge in Motion Estimation

- Camera motion estimation is difficult for cases like blur, illumination and large foreground objects

Blur

Illumination

Foreground object

# Future Work

- Detecting segments with blur and sharp/inconsistent illumination changes –
  - facilitate browse/search/summarization
  - Motion estimation can be an easier task
- Consider variants of SVM and HMM models for more accurate structuring and characterization.