Video Indexing and Retrieval

CMSC828K

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Contents

- **Part 1 : Survey**

  “Multimedia Database Management Systems”
  Guojun Lu

  Chapter 7. Video Indexing and Retrieval

- **Part 2 : Example**

  Automatic Video Indexing via Object Motion Analysis
  Jonathan D. Courtney
  Texas Instruments

Introduction

- **Video**
  - **A combination of text, audio, and images with a time dimension**
- **Indexing and retrieval methods**
  - **Metadata-based method**
  - **Text-based method**
  - **Audio-based method**
  - **Content-based method**
    - **Video : A collection of independent images or frames**
    - **Video : A sequence of groups of similar frames (shot-based)**
  - **Integrated approach**

Shot-Based Video …

- **Video shot : logical unit or segment**
  - **Same scene**
  - **Single camera motion**
  - **A distinct event or an action**
  - **A single indexable event**
- **Query**
  - **Which video?**
  - **What part of video?**
- **Steps**
  - **Segment the video into shots**
  - **Index each shots**
  - **Apply a similarity measurement between queries and video shots Retrieve shots with high similarities**

Shot Detections (Segmentation)

- **Segmentation**
  - A process of dividing a video sequence into shots
- **Key issue**
  - Establishing suitable difference metrics
  - Techniques for applying them
- **Transition**
  - Camera break
  - Dissolve, wipe, fade-in, fade-out

Basic Video Segment Techniques

- **Sum of pixel-to-pixel differences**
- **Color histogram difference**
  - **To be tolerant with object motion**
  - $SD_i = \Sigma_j |H_i(j) - H_{i+1}(j)|$ where i : frame number, j : gray level
- **Modification of color histogram**
  - $SD_i = \Sigma_j ((H_i(j) - H_{i+1}(j))^2 / H_{i+1}(j))$
  - χ^2 **test**
- **Selection of appropriate threshold - Critical**
  - **e.g.) The mean of the frame-to-frame difference + small tolerance value**

Detecting Gradual Change

- **Fade-in, fade-out, dissolve, wipe, …**
- **Twin-comparison technique**
  - **T_b : Normal camera breaks**
    T_s : Potential frames of gradual change
  - **If T_b < diff shot boundary**
    T_s < diff < T_b accumulate differences
    diff < T_s nothing
  - **If the accumulated value is greater than T_b, a gradual change is detected.**
- **Detection techniques based on wavelet transformation**
- **Very hard to detect!**

False Shot Detection

- **Camera panning, tilting, and zooming**
  - **Motion analysis techniques**
  - **Camera movements**
    - **Optical flow computed by block matching method**
- **Illumination change**
  - **Normalization of color images before carrying out shot detection**

1. $R_i' = R_i / \mathrm{Sqrt}(\Sigma^N R_i^2)$, $G_i' = \ldots$, $B_i' = \ldots$
2. Chromaticity
   1) $r_i' = R_i' / (R_i' + G_i' + B_i')$
   2) $g_i' = R_i' / (R_i' + G_i' + B_i')$
3. A combined histogram for r and g : CHI (Chromaticity histogram image)
4. Reduce it to 16x16
5. 2D DCT
6. Pick only 36 significant DCT values
7. Distances are calculated based on these values

Other Shot Detection

- **Motion removal**
  - Ideally, frame-to-frame distance should be
    - Close to zero with very little variation within a shot
    - Significantly larger than within-values between shots
  - However, within a shot
    - Object motion, camera motion, other changes
    - Filter to remove the effects of camera/object motion
- **Based on edge detection**
- **Advanced cameras**
  - Recording extra information such as position, time, orientation, …

Segmentation of Compressed Video

- **Based on MPEG compressed video**
  - **DCT coefficients**
  - **Motion information**
  - **E.g. # of bidirectional coded macro blocks in B frame, it is very likely shot boundary occurs around the B frame**
- **Based on VQ compressed video**

Video Indexing and Retrieval

- **Shot detection is preprocessing for indexing**

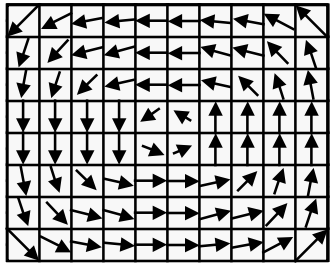
- **R (representative) frames**
  - **One or more key frames for each shot**
  - **Retrieval is based on these frames**
- **Other information**
  - **Motion, objects, metadata, annotation**

Based on R frames

- An r frame captures the main content of the shot
- Image retrieval : color, shape, texture, …
- Choosing r frames
  - How many?
    1. One per shot
    2. The number of r frames according to their length
    3. One per subshot/scene
  - How to select?
    1. First frame of segment
    2. An average frame
    3. The frame whose histogram is closest to the average histogram
    4. Large background + all foregrounds superimposed
  - First frame + frame with large distance

Based on Motion Information

- **R frame base ignores temporal or motion information**
- **Motion information is derived from optical flow or motion vectors**
- **Parameters for indexing**
  - **Content :** talking head vs car crash
  - **Uniformity :** smoothness as a function of time
  - **Panning :** horizontal camera movement
  - **Tilting :** vertical camera movement



- Camera motion
  - –Pan, tilt, zoom, swing, (horizontal/vertical) shift

Based on Objects

- Content based representation
- If one could find a way to distinguish individual objects throughout he sequence, …
- In a still image, object segmentation is difficult
  In a video sequence, we can group pixels that move together into an object.

- MPEG-4 object-based coding
  - How to represent
  - NOT how to segment and detect

Based on Others

- **Metadata**
  - **DVD-SI : DVD service information**
    Title, video type, directors
- **Annotation**
  1. **Manually**
  2. **Associated transcripts or subtitles**
  3. **Speech recognition on sound track**
- **Integrated method**

Effective Video Representation and Abstraction

- Useful to have effective representation and abstraction tool
- How to show contents in a limited space
- Applications
  - Video browsing
  - Presentation of video results
  - Reduce network bandwidth requirements and delay
- Then how?

Representation and Abstraction

- **Topical or subject classification**
  - **News : (local, international, finance, sport, weather)**
- **Motion icon (micon) or video icon**
  - **Easy shot boundary representation**
  - **Operations : browsing, slicing, extraction a subicon**
- **Video streamer**
- **Clipmap**
  - **A window containing a collection of 3D micons**
- **Hierarchical video browser**

Representation and Abstraction

- **Storyboard**
  - A collection of representative frames
- **Mosaicking**
  - An algorithm to combine information from a number of frames
- **Scene transition graph**
  - Node : image which represents one or more video shots
  - Edge : the content and temporal flow of video
- **Video skimming**
  - High-level video characterization, compaction, and abstraction

Automatic Video Indexing via Object Motion Analysis As an Object Tracking Example

- **Video indexing**
  - The process of identifying important frames or objects in the video data for efficient playback
  - Scene cut detection, camera motion, object motion
  - Hierarchical segmentation
- **Three steps**
  - Motion segmentation, object tracking, motion Analysis
- **Events**
  - Appearance/Disappearance
  - Deposit/Removal
  - Entrance/Exit
  - Motion/Rest

Motion Segmentation

- **Segmented Image C_n**
  - C_n = ccomps($T_h \bullet k$)

    Th : binary image resulting from thresholding $|I_n - I_0|$

    $T_h \bullet k$: morphological close operation on T_h
  - Reference frame I_0

- **Strong assumptions may fail when**
  - Sudden lighting
  - Gradual lighting
  - Change of viewpoint
  - Objects in reference frame

Imperfectness of Segmentation

- **All the possible problems**
  - **True objects will disappear temporarily**
  - **False objects**
  - **Separate objects will temporarily join together**
  - **Single objects will split into multiple regions**

Object Tracking

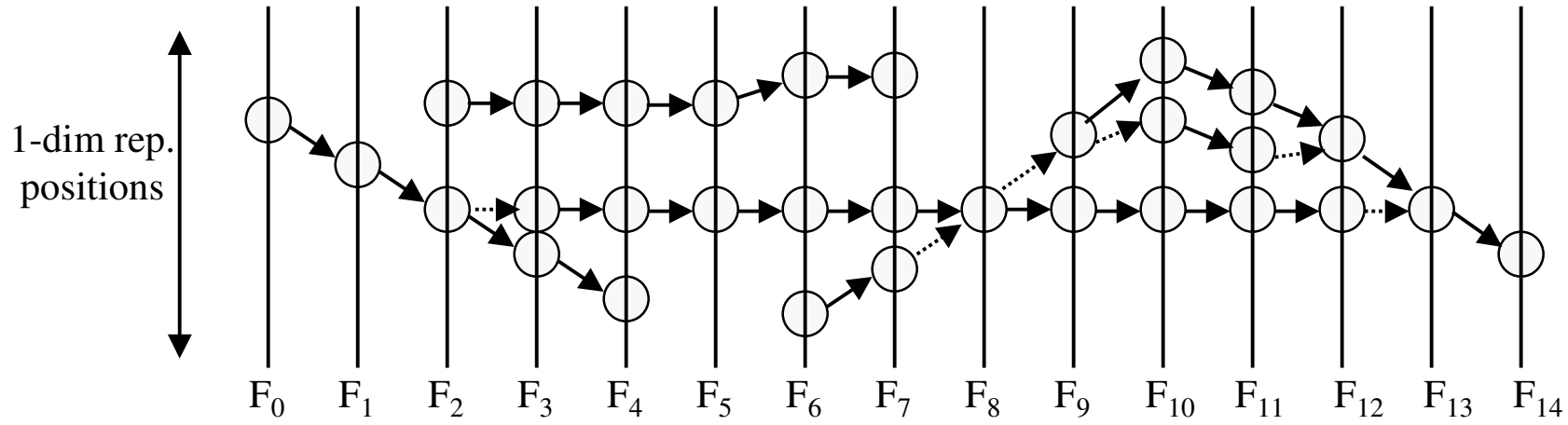
- **Terminology**
  - **Sequence - ordered set of N frames**
    $S = \{F_0, F_1, \ldots F_{N-1}\}$: F_i is i-th frame
  - **Clip $C = (S, f, s, l)$: F_f,F_l - first and last valid frame, F_s - start frame**
  - **Frame F : image I annotated with a timestamp t, $F_n = (I_n, t_n)$**
  - **Image I : r x c array of pixel**
  - **Timestamp records the date and the time**
- **V-object**
  - **Extracted by motion segmentation comparing a frame to a reference frame**
  - **Label, centroid, bounding box, shape mask**
  - **$V_n = \{ V_n^p; p = 1, \ldots P \}$**

Object Tracking

- **Tracking procedure**
  - **Iterate (forward) step 1-3 for frames 0, 1, …, N-2** $\mu_n^p = \mu_n^p + \nu_n^p(t_{n+1}-t_n)$
  1. **For each V-object, predict its position in next frame**
  2. **For each V-object, determine the V-object in the next frame with centroid nearest to the prediction**
  3. **For every pair, estimate forward velocity**
  4. **Do 1-3 in backward**
  - **For all frames**
  5. **Determine primary links for mutual nearest neighbor**
  6. **Determine secondary links from forward step**
  7. **Determine secondary links from backward step**

Object Tracking

- **Following graph is produced**
  - **Node - V-objects**
  - **Primary links (mutually nearest)**
  - **Secondary links (others)**



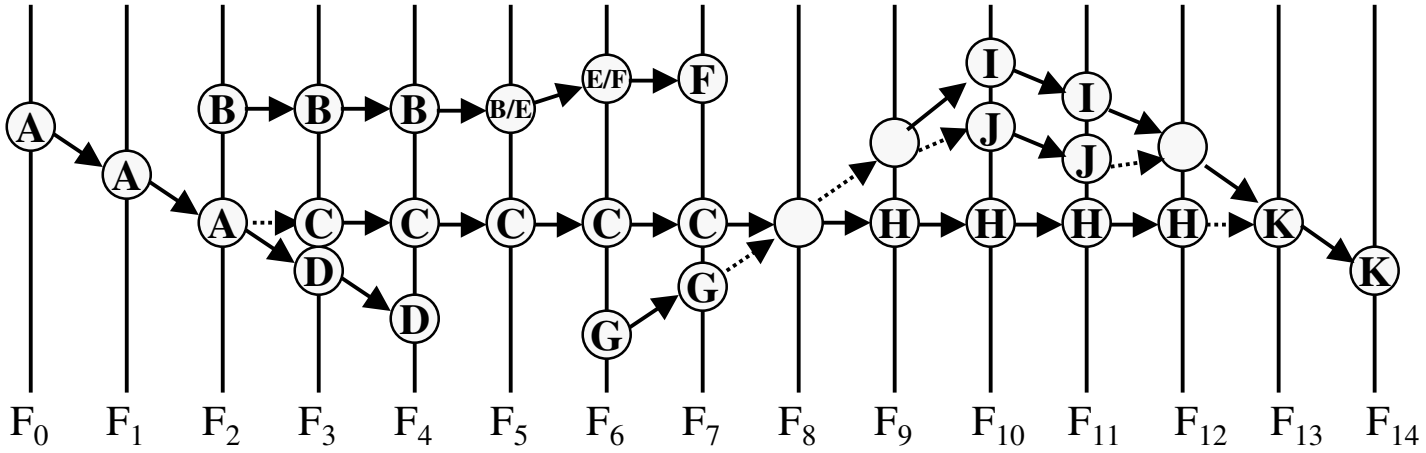
Motion Analysis
V-object Grouping

- **Group V-objects with difference levels**
  - **Stem, *M***
  - **Branch, *B***
  - **Trail, *L***
  - **Track, *K***
  - **Trace, *E***
- $E \supseteq K \supseteq L \supseteq B \supseteq M$
- **Each level implies a feature of the blob**

V-object Grouping - Stem

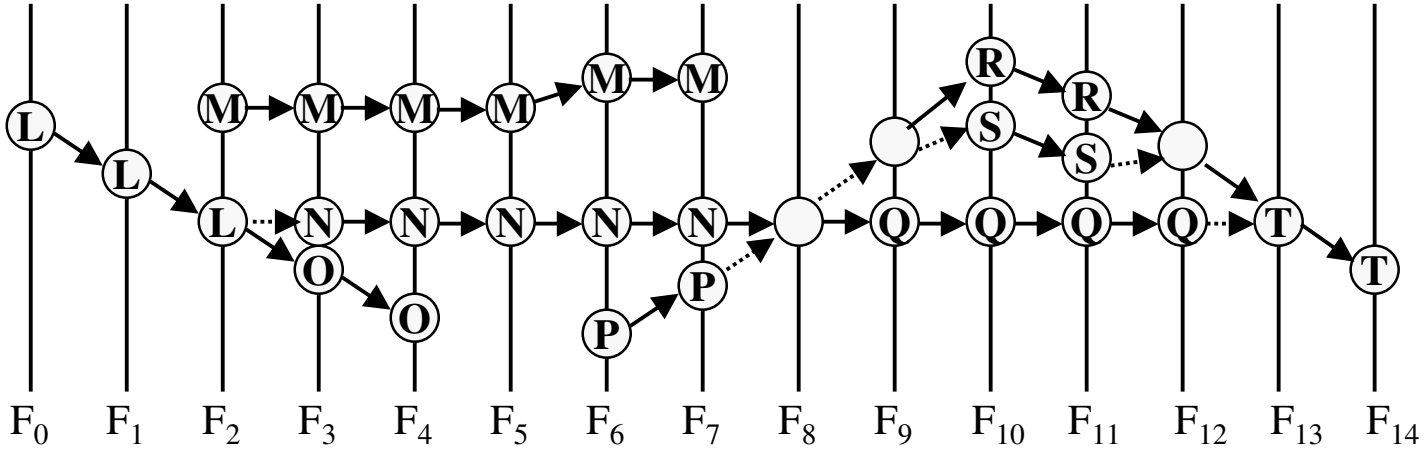
- **Maximal size path of two or more V-objects with no secondary links**
- ***M* = {V_i : *i* = 1, 2, … N_M}**
  - **outdegree(V_i) = 1 for 1 ≤ *i* < N_M**
  - **indegree(V_i) = 1 for 1<*i* ≤ N_M**
  - **either $\mu 1 = \mu 2 = \ldots = \mu_{N_M}$**
    or $\mu 1 \neq \mu 2 \neq \ldots \neq \mu_{N_M}$
- **Stationary/moving**

V-objects with constant/no movement without any change



V-object Grouping - Branch

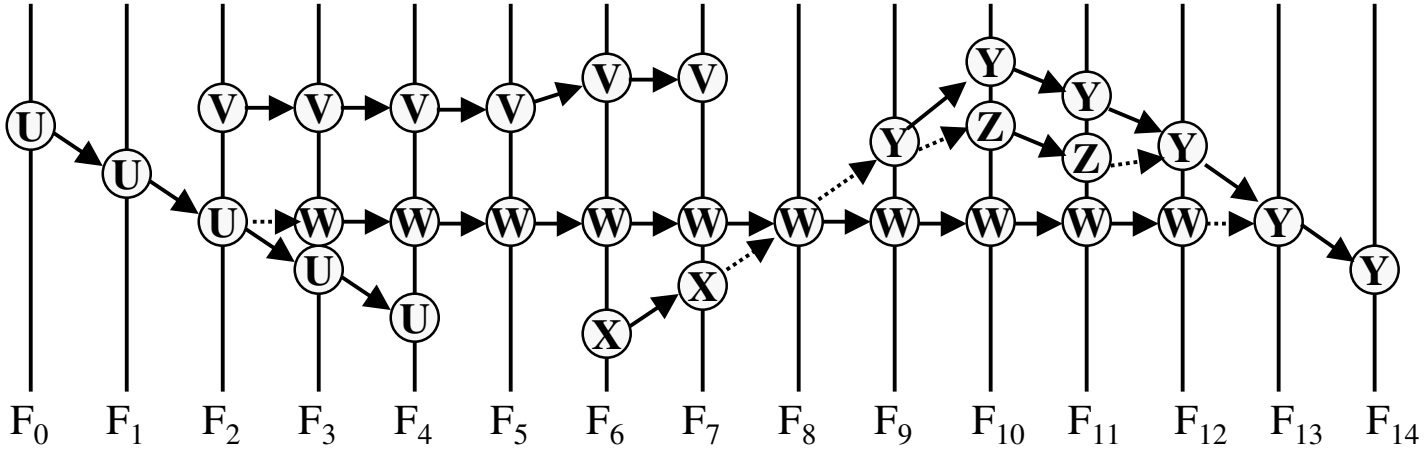
- **Maximal size path containing no secondary links and composed with only one path**
- ***B* = {V_i : *i* = 1, 2, …, N_B}**
  - **outdegree(V_i) = 1 for 1 ≤ *i* < N_B**
  - **indegree(V_i) = 1 for 1<*i* ≤ N_B**
- **Stationary(one stem) / moving(otherwise)**



V-objects without change

V-object Grouping - Trail

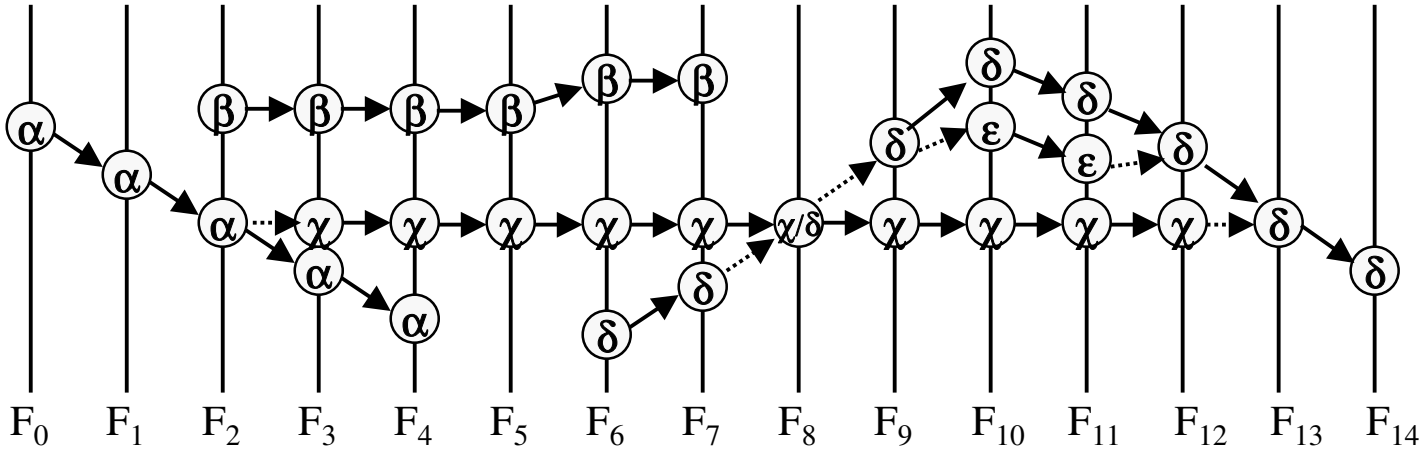
- *L*
- **Maximal-size path without secondary links**
- **Stationary/moving/unknown**



V-objects with main movement

V-object Grouping - Track

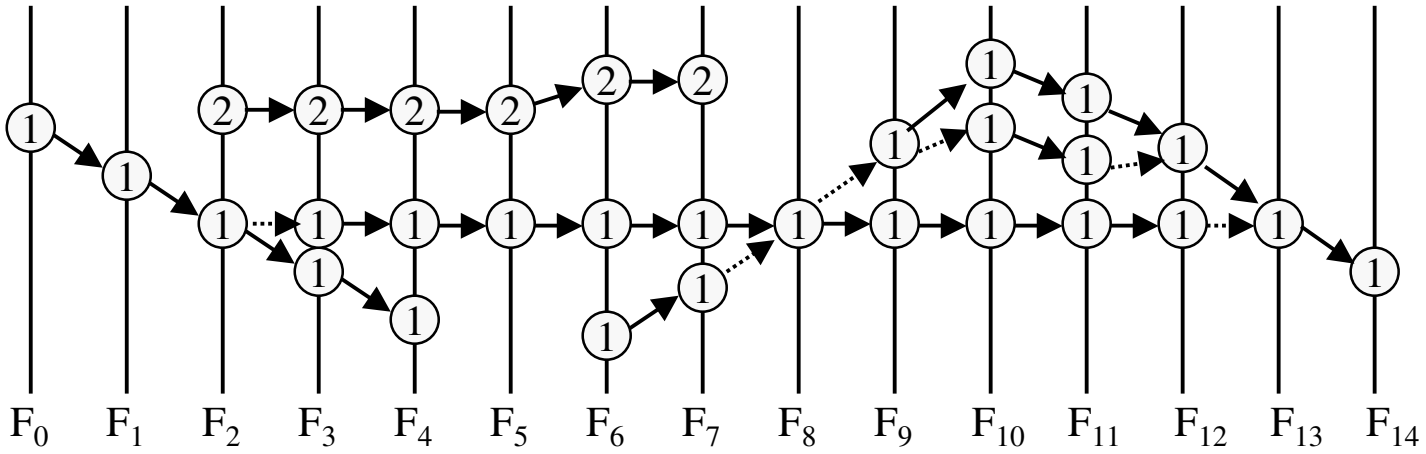
- $K = \{L_1, G_1, \ldots, L_{N_{K-1}}, G_{N_{K-1}}, L_{N_K}\}$
  - L_i : trail
  - G_i : connecting dipath with constant velocity through $H = \{V^l_i, G_i, V^1_{i+1}\}$ where V^l_i is the last object of L_i and V^1_{i+1} is the first object of L_{i+1}
- Stationary/moving/unknown



V-objects with movement guessing occluded part

V-object Grouping - Trace

- ***E***
- **Maximal size connected digraph of V-objects**



Group of V-objects overlapped

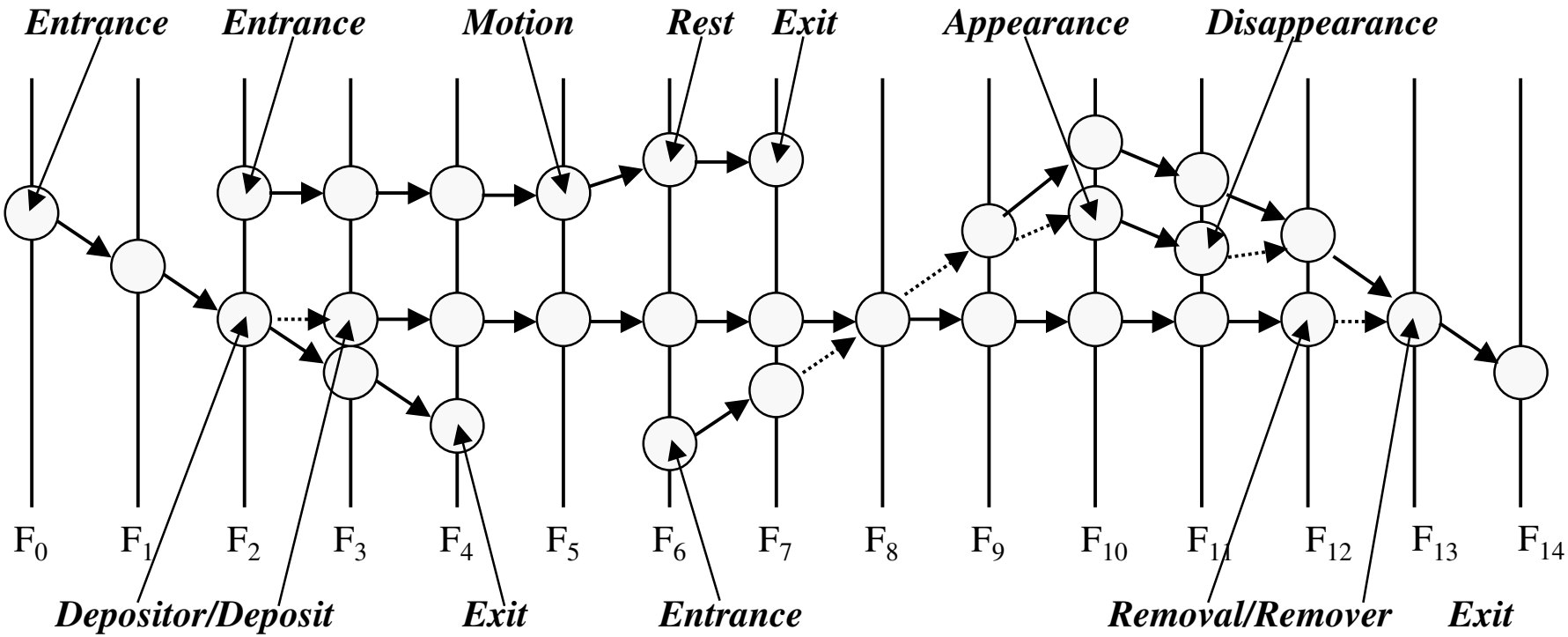
Events

- **Appearance** - an object emerges in the scene
- **Disappearance** - an object disappears from the scene
- **Entrance** - moving object enters the scene
- **Exit** - moving objects exits from the scene
- **Deposit** - an inanimate object is added to the scene
- **Removal** - an inanimate object is removed from the scene
- **Motion** - an object at rest begins to move
- **Rest** - a moving object comes to a stop
- **(Depositor)** - a moving object adds an inanimate object to the scene
- **(Remover)** - a moving object removes an inanimate object from the scene

Annotating V-objects

	V-object motion state		
	Moving	Stationary	Unknown
Appearance	1. Head of track 2. Indegree(V) > 0	1. Head of track 2. Indegree(V) = 0	
Disappearance	1. Tail of track 2. Outdegree(V) > 0	1. Tail of track 2. Outdegree(V) = 0	
Entrance	1. Head of track 2. Indegree(V) = 0		1. Head of track 2. Indegree(V) = 0
Exit	1. Tail of track 2. Outdegree(V) = 0		1. Tail of track 2. Outdegree(V) = 0
Deposit		1. Head of track 2. Indegree(V) = 1	
Removal		1. Tail of track 2. Outdegree(V) = 1	
(Depositor)	Adjacent to V-object with deposit tag		
(Remover)	Adjacent from V-object with removal tag		
Motion	1. Tail of stationary stem 2. Head of moving stem		
Rest	1. Tail of moving stem 2. Head of stationary stem		

Example of Annotation



Query

- **Y = (C, *T*, *V*, *R*, *E*)**
  - **C : a video clip**
  - **$T = (t_i, t_j)$: a time interval within the clip**
  - ***V* : V-object in the clip**
  - ***R* : a spatial region in the field of view**
  - ***E* : an object motion event**

- **Processing a query**
  - **Keeps truncating domain with query parameters**

Experimental Result

- 3 videos, 900 frames, 18 objects, 44 events
-

Video 1	Video 2	Video 3
Inventory or Security monitoring 300 frs, 10fr/sec 5 objects, 10 events entrance/exit, deposit/removal	retail customer monitoring 285 frames, 10 fr/sec 4 objects, 14 events all eight events 3 foreground objects in ref. frame Most complicated	parking lot traffic monitoring 315 frames, 3fr/sec 9 objects, 20 events most noisy

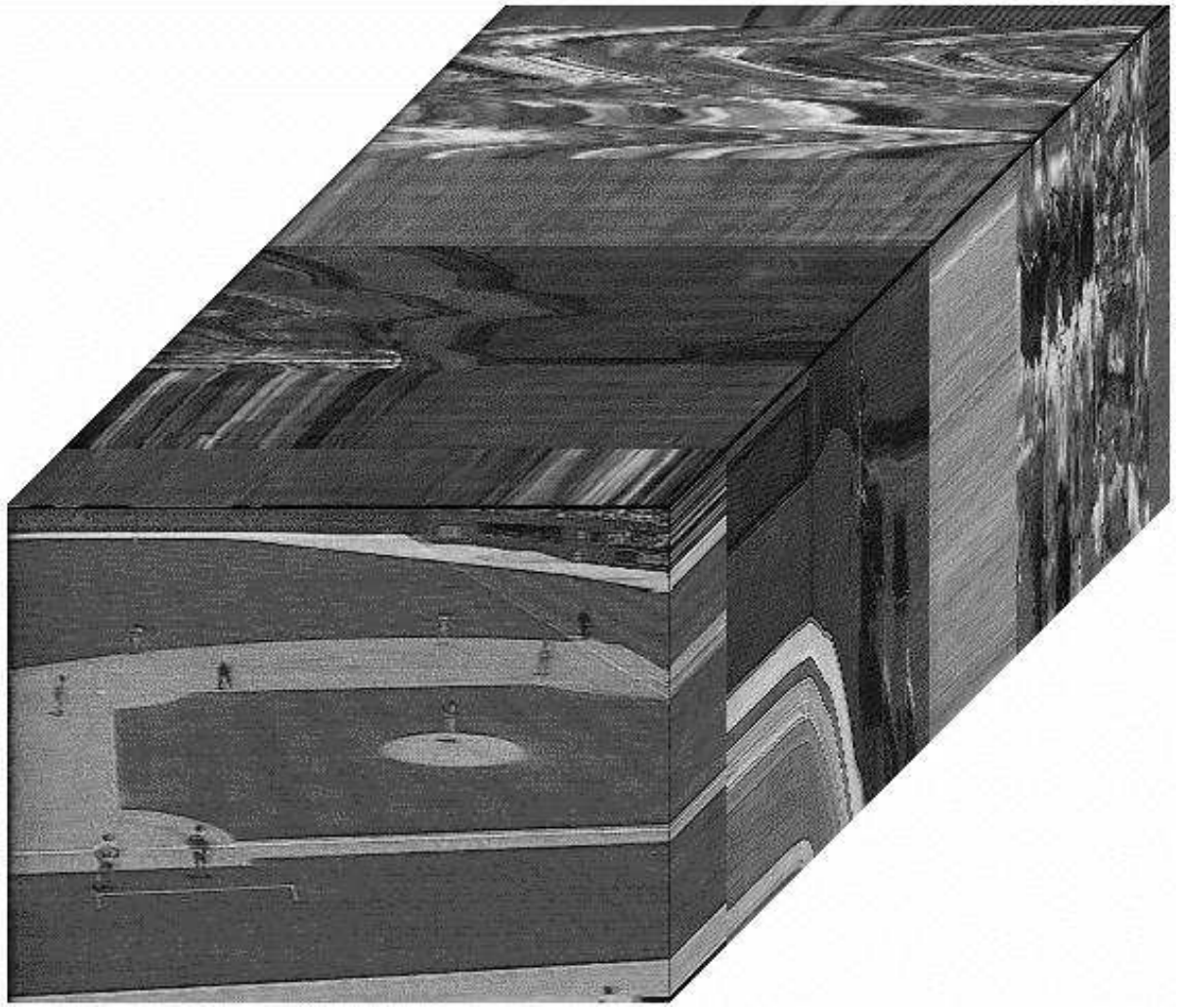
- 1 false negative, 10 false positive
- Conservative

Errors come from

- Noise in the sequence
- Assumption of constant trajectories of occluded objects
- No means to track objects through occlusion by fixed scene objects

Mosaicking

Story board, Video Multiplexing

- Show 20 minutes of video in 6 seconds
- Loop all shots as thumbnails at same time
- Let the user focus on the interesting shots

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