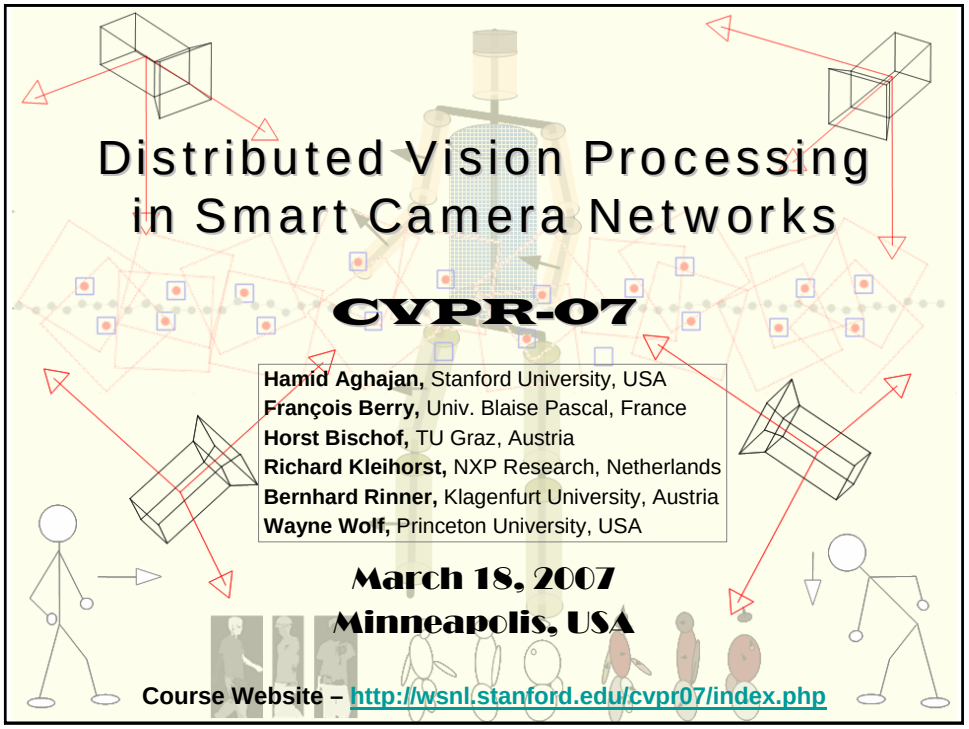
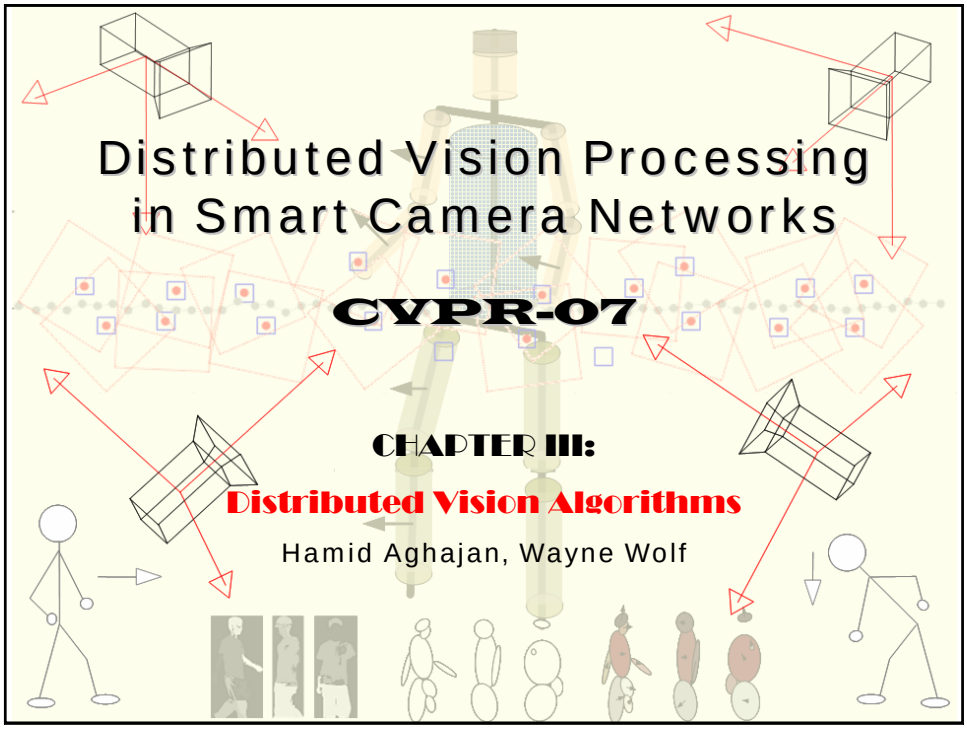


Outline



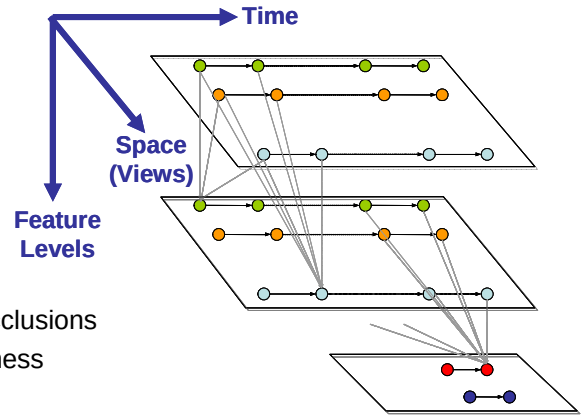
Fusion Mechanisms in Distributed Vision Networks

Contact: Hamid Aghajan

hamid <AT> WSNL.Stanford.Edu

Joint work with: Chen Wu, Chung-Ching Chang

Smart Camera Networks



Fusion Dimensions

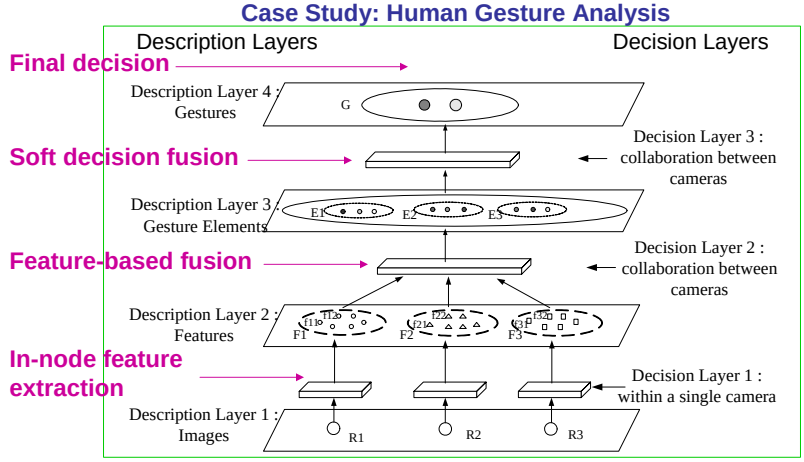
- Space (views)
  - Overcome ambiguities, occlusions
  - Enhance estimate robustness
- Time
  - Increase confidence level of estimates
  - Detection of key frames
- Feature levels
  - Exchange of features with other nodes across algorithmic layers

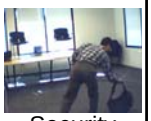
Fusion Mechanisms

- Feature fusion:
  - Use of multiple, complementary features within a camera node
- Temporal fusion:
  - Local interpolation / smoothing of estimates
  - Exchange of updates via spatial fusion
  - Spatiotemporal estimate smoothing and prediction
- Key features and key frames:
  - Information assisting other nodes
- Spatial fusion:
  - Localization, epipolar geometry, ROI and feature matching
  - Validation of estimates by checking consistency, outlier removal
  - 3D reconstruction
- Model-based fusion:
  - 3D human body reconstruction, human gesture analysis
  - Feedback to in-node feature extraction
- Decision fusion:
  - Estimates based on soft decisions
  - Adequate features in own observations
  - Cost, latency of communication

Layered Spatial Collaboration

Case Study: Human Gesture Analysis




Security


Gaming


Smart Presentation

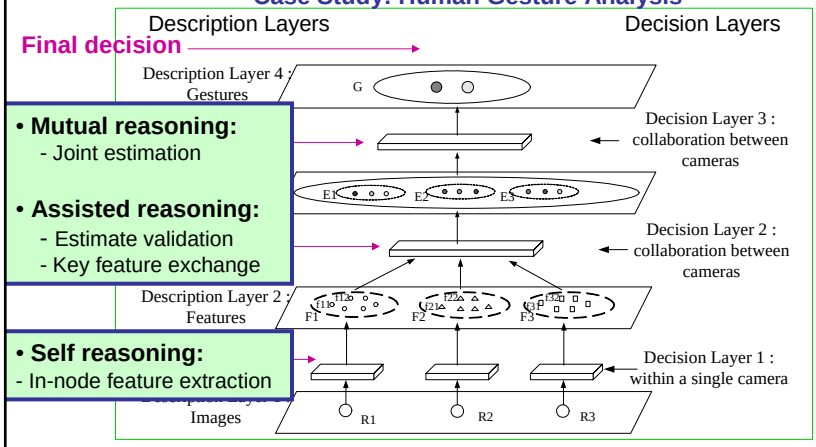

Accident Detection

Opportunistic data fusion

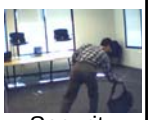
- **Fusion of features within a single camera**
- **Fusion based on collaboration among multiple cameras**

Layered Spatial Collaboration

Case Study: Human Gesture Analysis



- **Mutual reasoning:**
  - Joint estimation
- **Assisted reasoning:**
  - Estimate validation
  - Key feature exchange
- **Self reasoning:**
  - In-node feature extraction


Security


Gaming

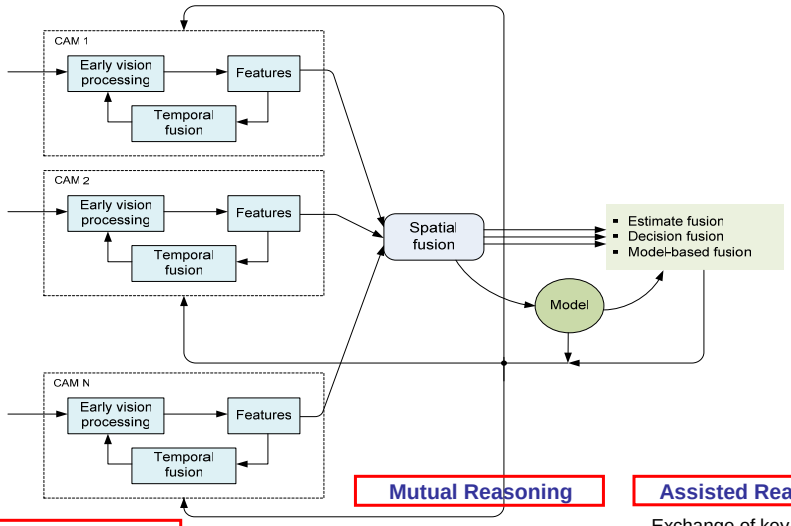

Smart Presentation


Accident Detection

Opportunistic data fusion

- **Fusion of features within a single camera**
- **Fusion based on collaboration among multiple cameras**

Fusion Mechanisms



Mutual Reasoning

Assisted Reasoning

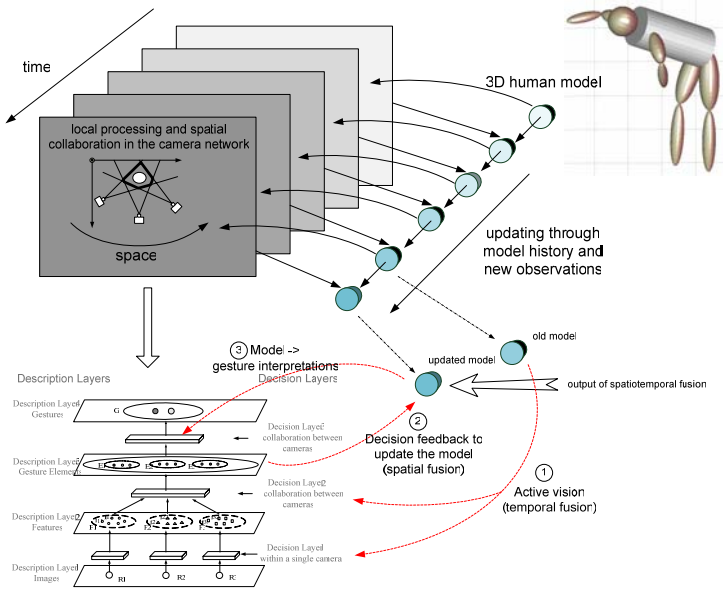
Exchange of key features

Self Reasoning

- **Feature fusion**
- **Temporal fusion**

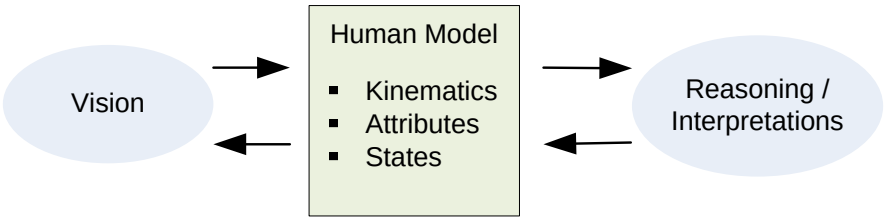
- **Spatial fusion**
- **Spatiotemporal fusion**
  - **Model-based**
  - **Active vision**
  - **Feedback**

The Big Picture



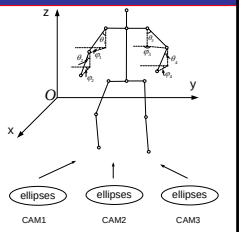
Model-based Fusion

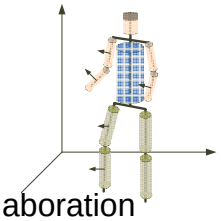
- Motivation to build a human model:
  - A concise reference for merging information from cameras
  - Offers flexibility for interpretation in different applications:
    - Various gesture interpretation applications
  - Allows recreation of body gesture in virtual domain
    - Viewing angles to body not available from any of the cameras
  - Allows employment of active vision methods:
    - Focus on what is important
    - Develop more detail in time
  - Helps address privacy concerns in various applications



Model-based Fusion

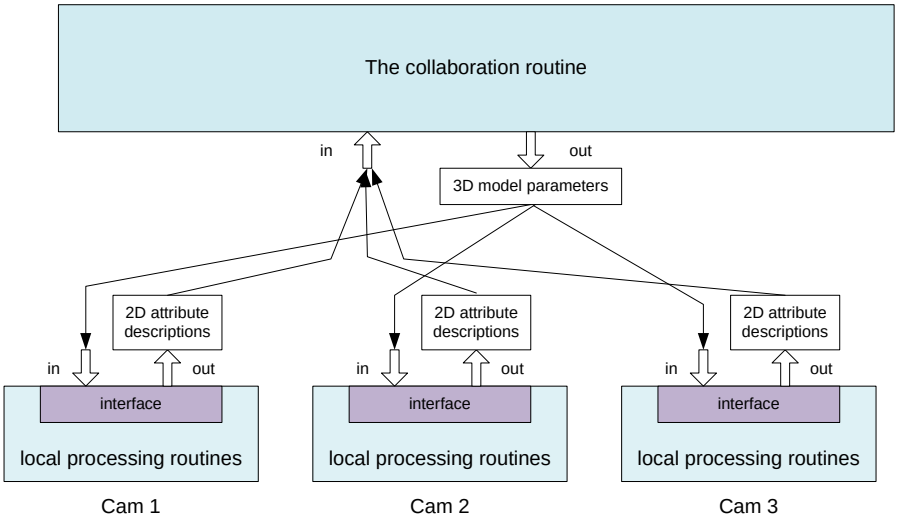
- Approach:
  - Exchange segments and attributes, combine to reconstruct a 3D model
  - Subject's information mapped and maintained in the model:
    - Geometric configuration: dimensions, lengths, angles
    - Color / texture / motion of different segments



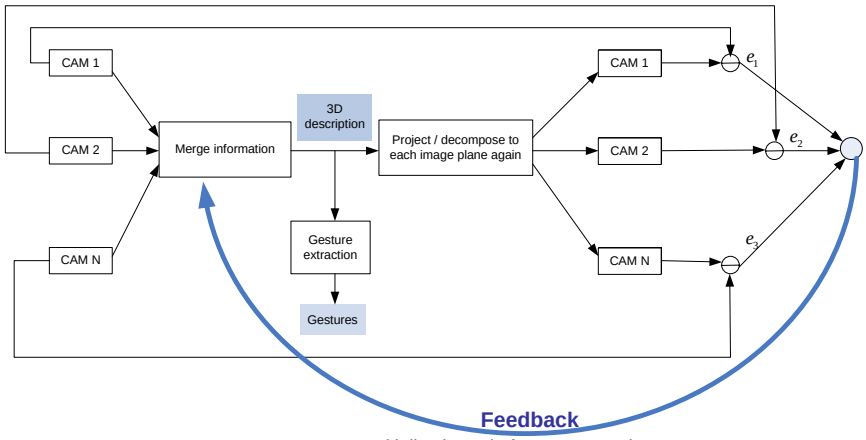


- Advantages:
  - Employ higher level of in-node processing
  - Exchange descriptions only relevant to model
  - Affordable communication for multi-camera collaboration
  - Initialization for active vision in nodes:
    - Provides color (other feature) distributions for rough segmentation
    - Helps with body part tracking (motion flow)
    - Offers hint on what is important to look for in images

Data Flow



Use of Feedback

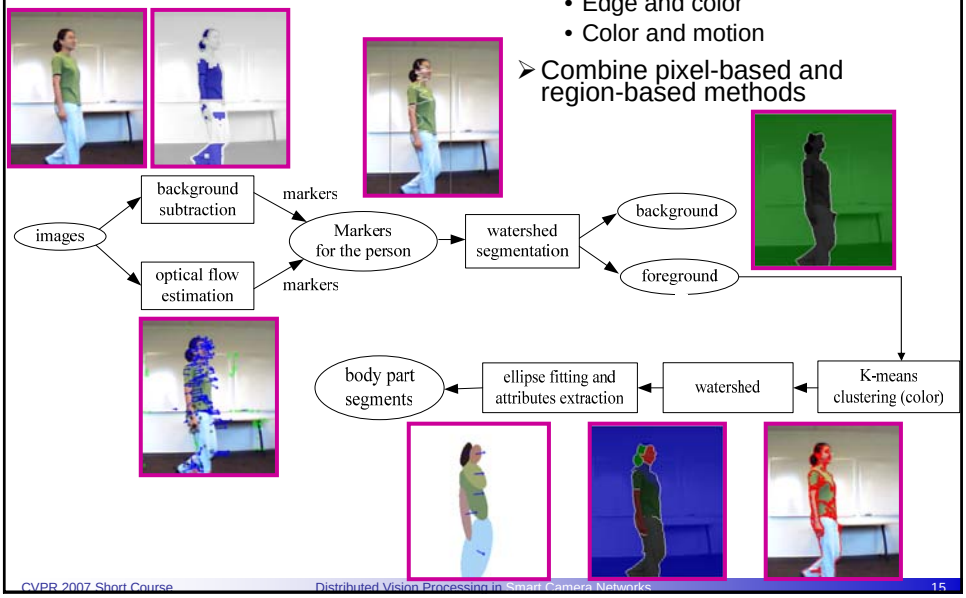


Feedback

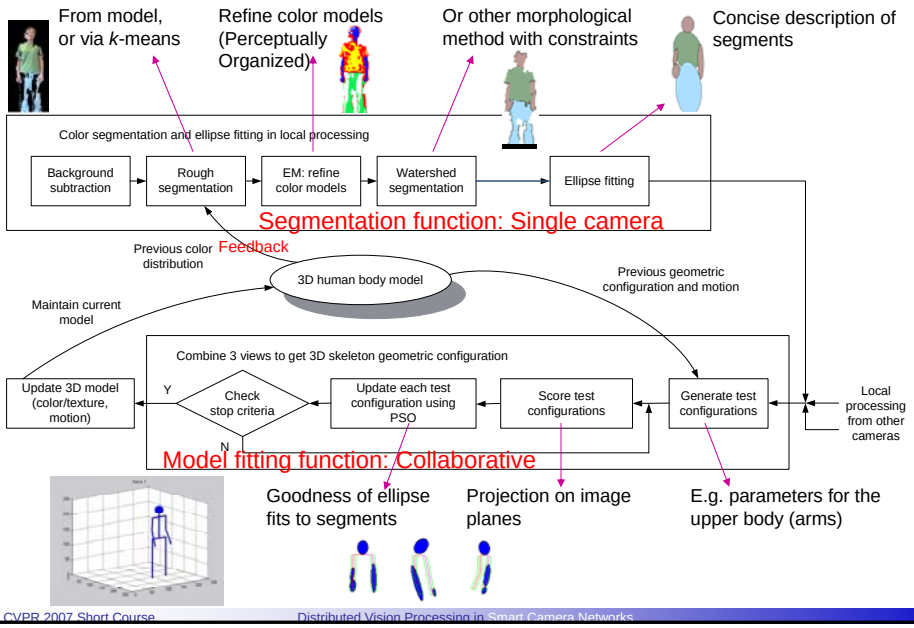
- Initialize in-node feature extraction
- Active vision (focus on what is important)

Feature Fusion: Optical Flow and Color

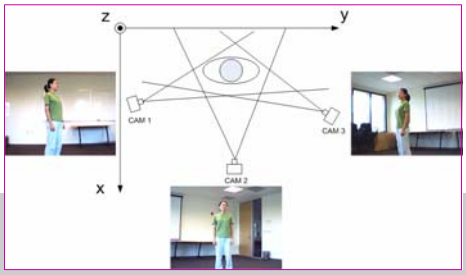
- Use of complementary features
  - Edge and color
  - Color and motion
- Combine pixel-based and region-based methods

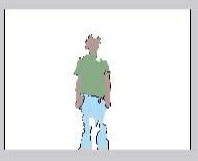


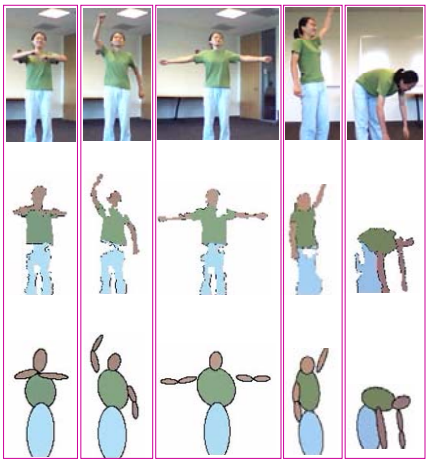
Model-based Human Posture Reconstruction



In-Node Feature Fusion for Segmentation







Collaborative Model Fitting

Frame 1

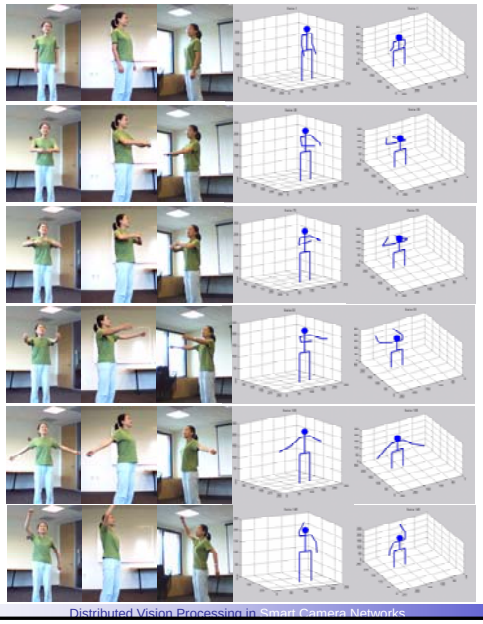
Frame 28

Frame 70

Frame 81

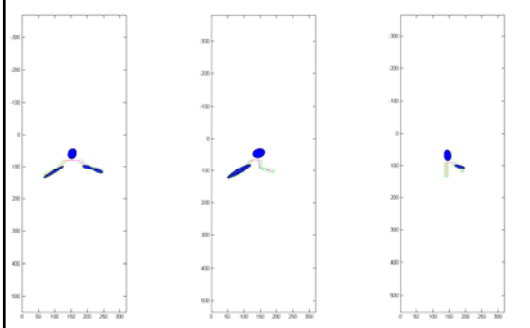
Frame 105

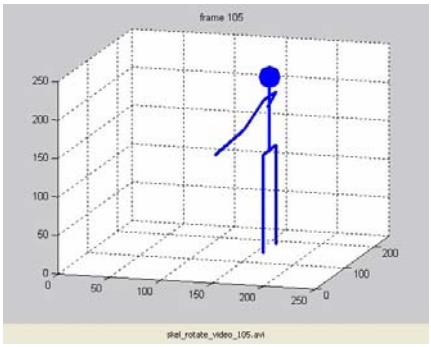
Frame 148



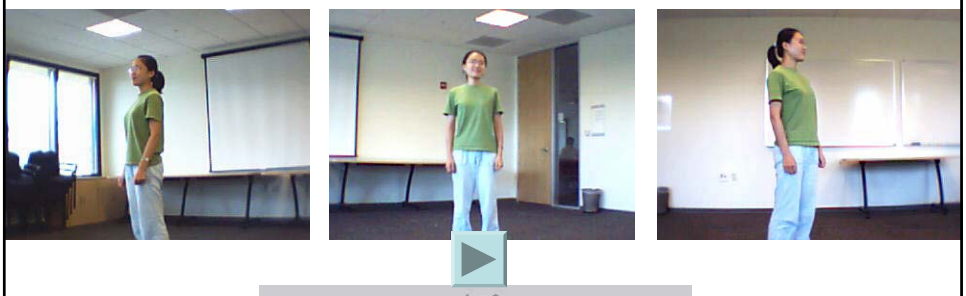
Collaborative Model Fitting

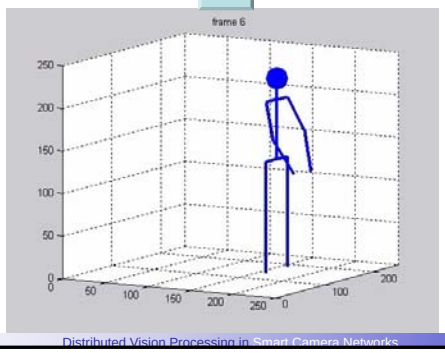
Frame 105





Collaborative Model Fitting

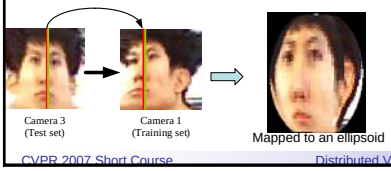


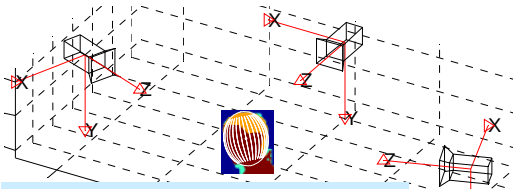


Spatial Fusion

- Geometric fusion
- Mutual reasoning
  - Joint estimation
  - Joint refinement
  - Decision fusion
- Assisted reasoning
  - Estimate validation
  - Key frame exchange

- Making correspondences
- Tracking
- Reconstruction of 3D models
- Camera network calibration
- Use of epipolar geometry to:
  - Feature matching
  - Outlier removal
  - ROI mapping between camera views

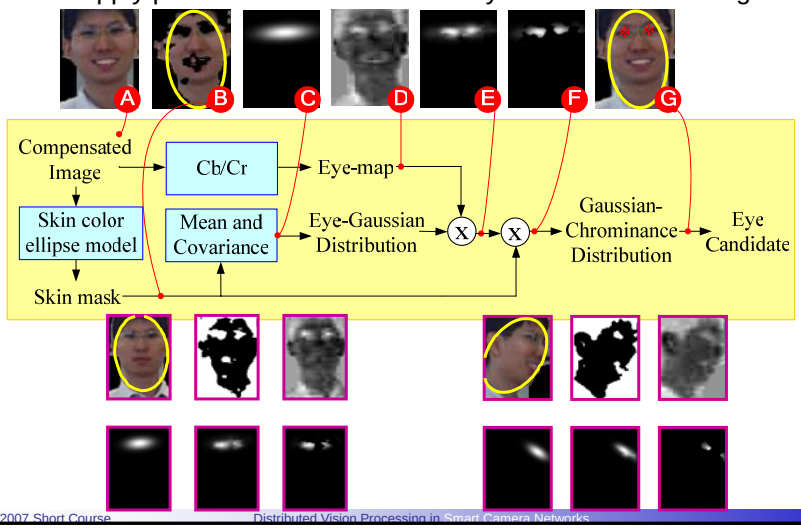




Face Orientation Estimation
- Color and geometry-based method
- Spatial / temporal validation method

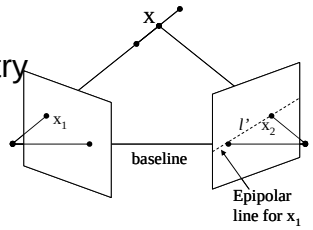
Color and Geometry Fusion

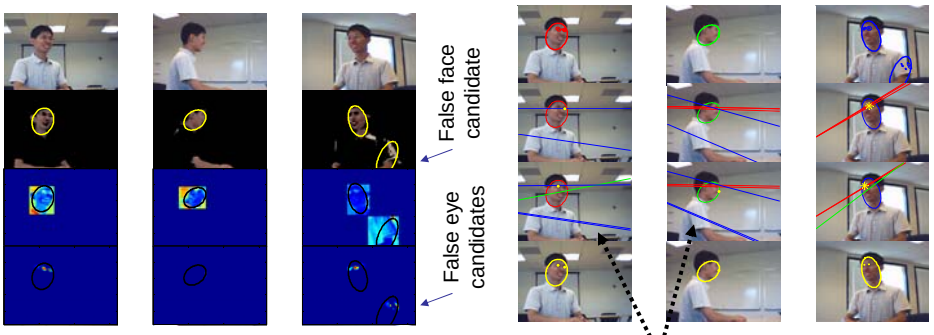
- Face orientation analysis
  - In-node feature extraction by fusion of Color and Geometry
    - Apply position constraints for the eyes when thresholding Cb/Cr



Color and Geometry Fusion

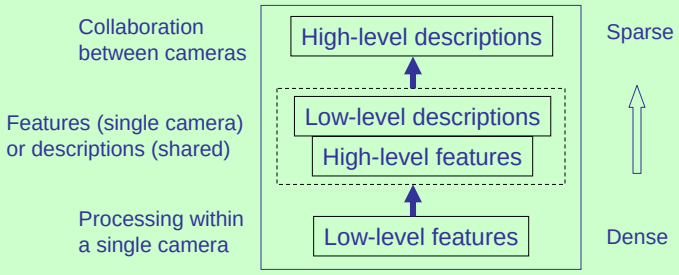
- Face orientation analysis
  - Feature matching with epipolar geometry
    - Use geometry of cameras to:
      - Match features
      - Remove false feature candidates





Feature Fusion

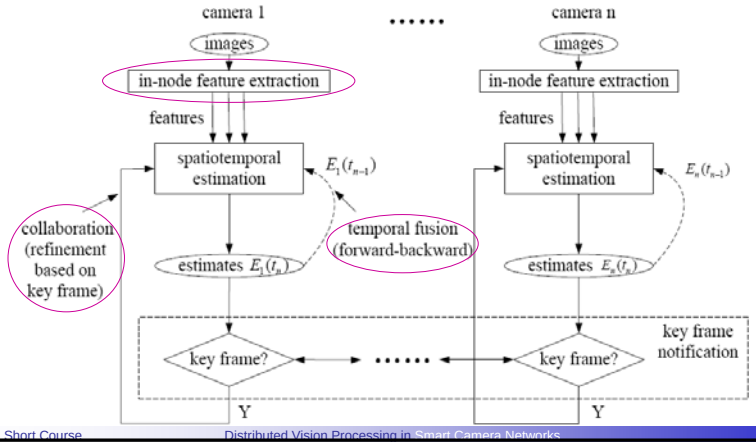
- Level of features for fusion between cameras?
  - Features are typically dense fields
    - Edge points, motion vectors
  - They are locally fused to derive descriptions (sparse)
    - Descriptions are exchanged
  - Valuable features may be exchanged as dense descriptors
    - Communication cost issues need to be considered



- Key features and key frames allow selective sharing of dense features

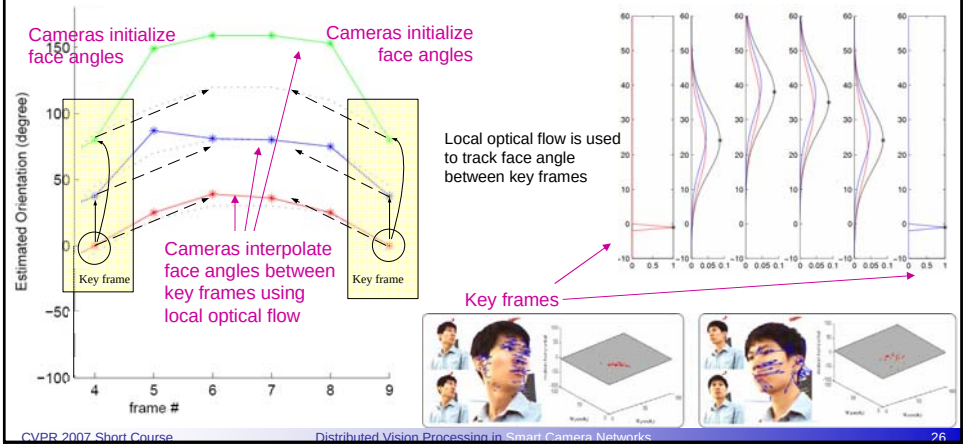
Key Frames

- Frames with high confidence estimates
  - Node with key frame observation broadcasts derived information
  - Other nodes use them to refine their local estimates



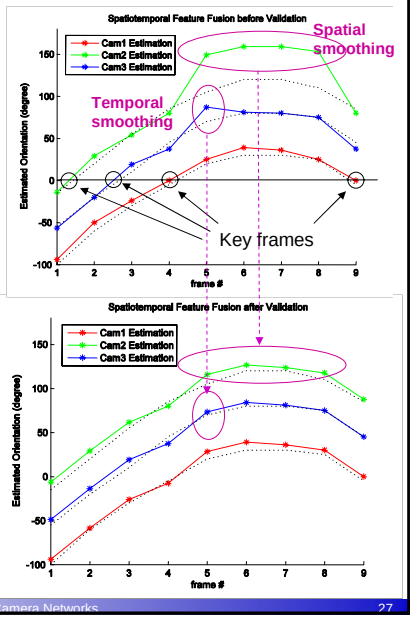
Temporal Fusion

- Use key frames to re-initialize local face angle estimate
  - Use angle estimates close to zero (frontal view)
- Aims to limit error propagation in time
  - Use optical flow to locally track angle changes between frames
  - Interpolate between two key frames to limit optical flow error propagation

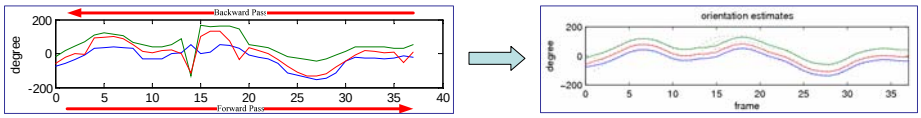


Spatial / Temporal Validation

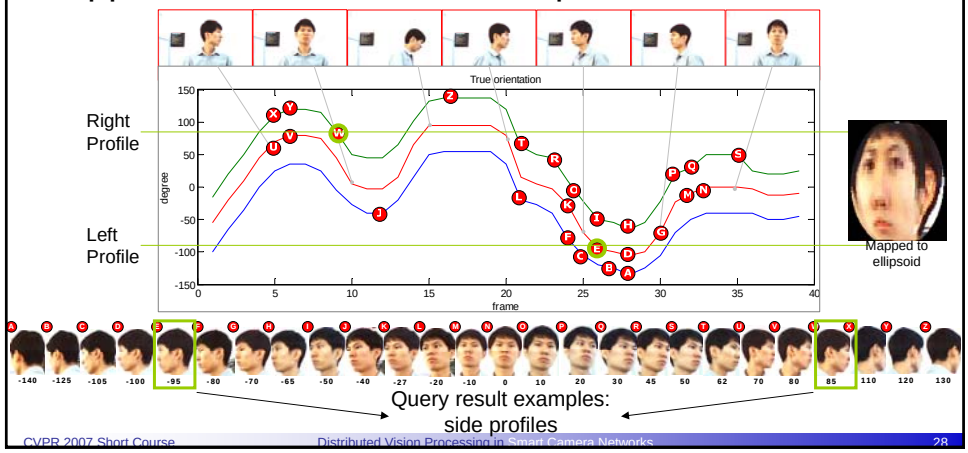
- Estimates between key frames are corrected by:
  - Temporal smoothing (one camera)
  - Outlier removal (multiple cameras)
- Can this be done more effectively?
  - ➢ Spatiotemporal filtering



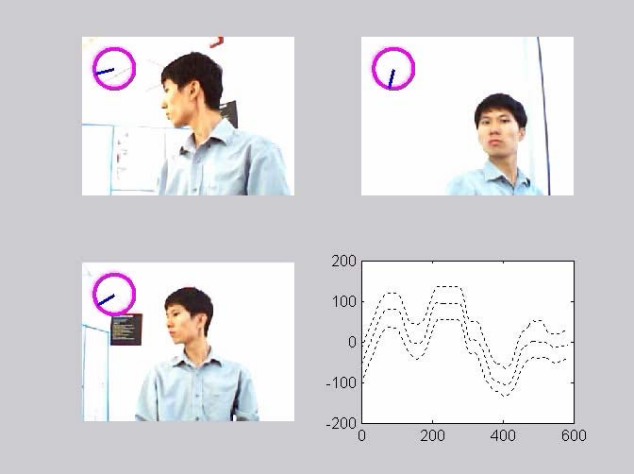
Spatiotemporal Fusion



➢ Opportunistic creation of face profile



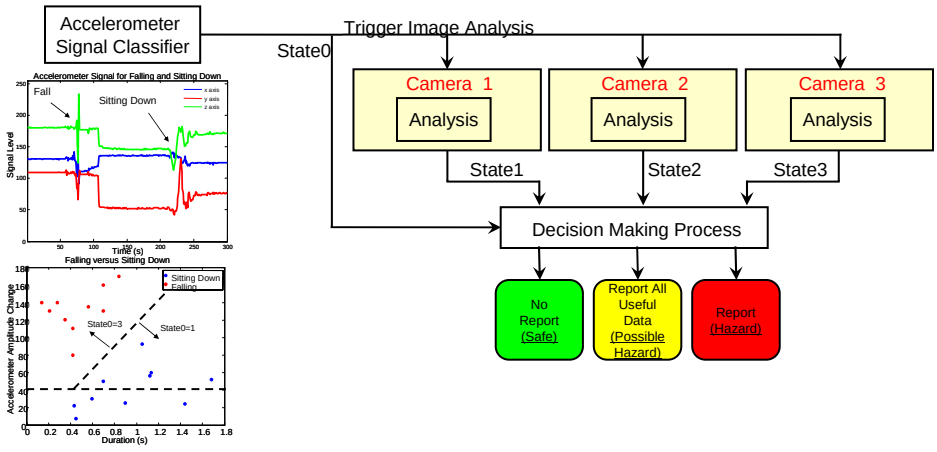
Spatiotemporal Fusion



Decision Fusion

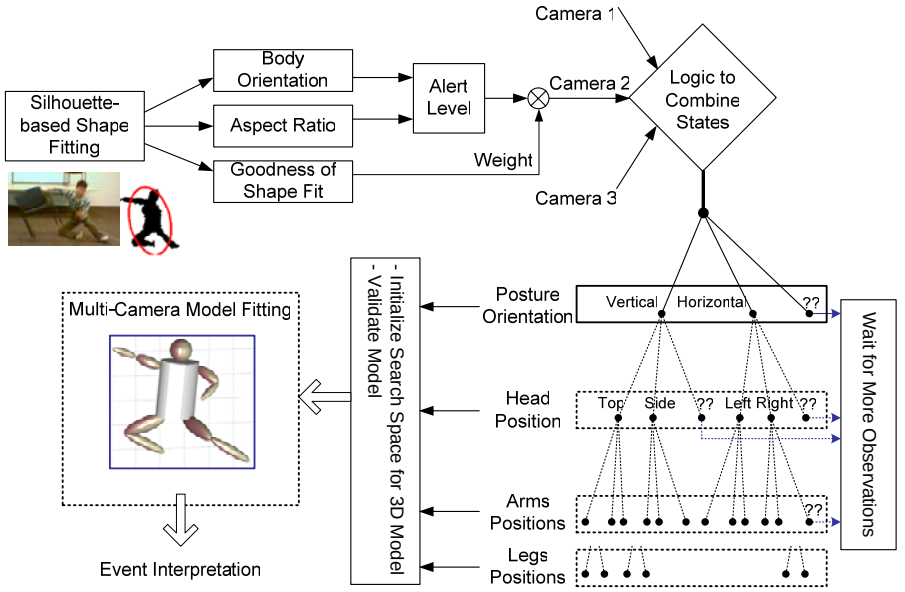
- Smart home care network for fall detection

➢ States are combined as soft decisions to create a report

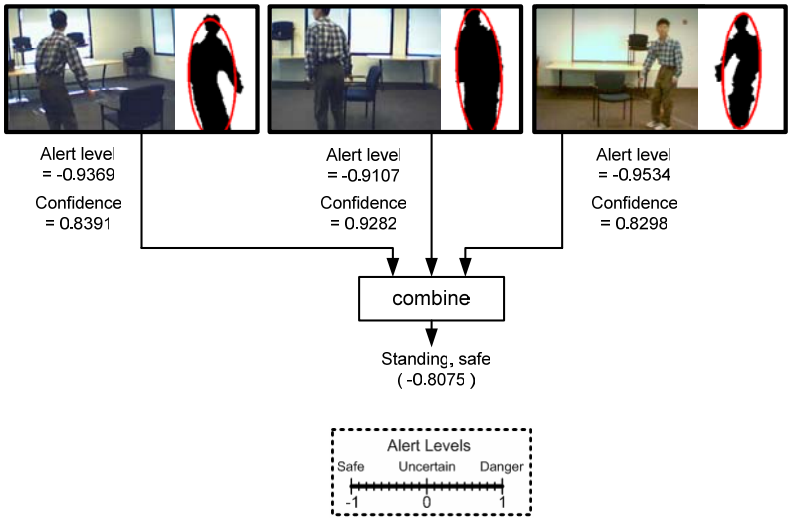


Joint work with: Arezou Keshavarz, Ali Maleki-Tabar

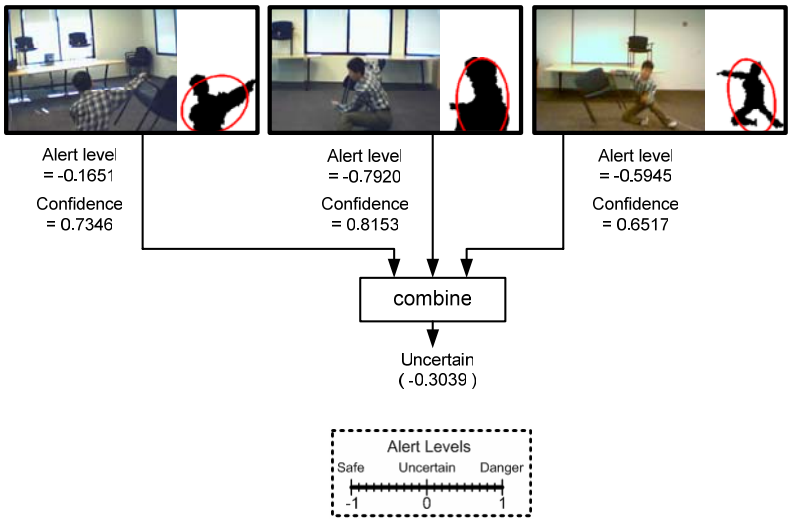
Decision Fusion



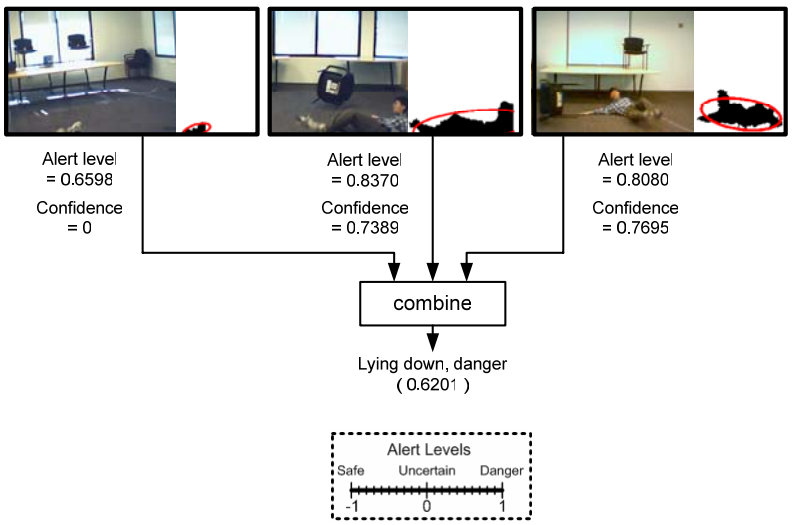
Decision Fusion



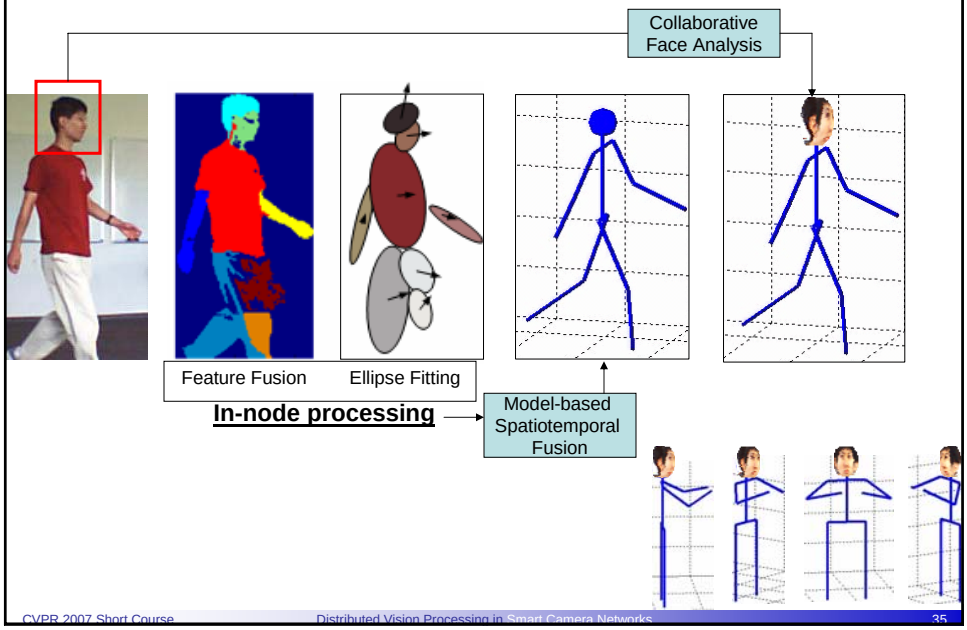
Decision Fusion



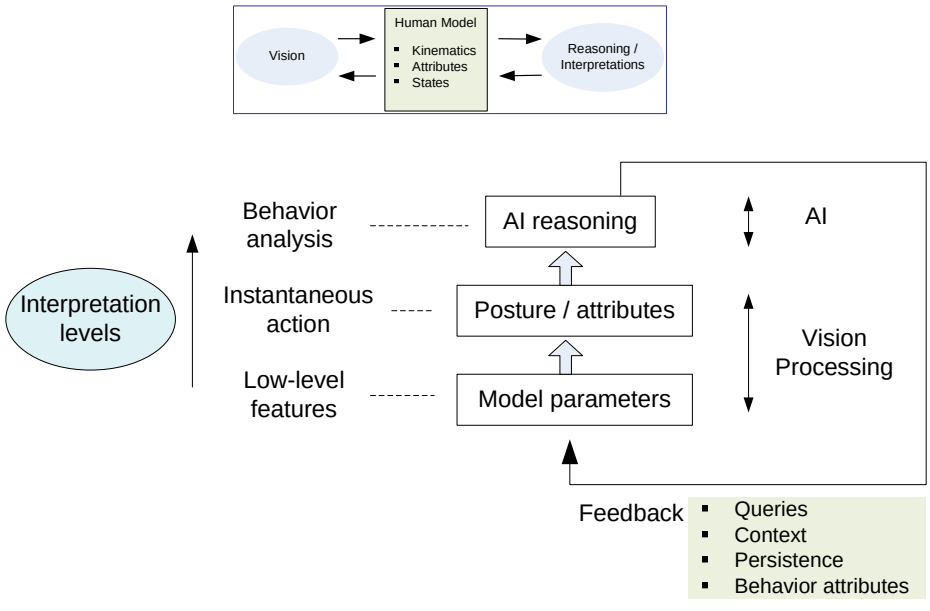
Decision Fusion



Virtual Placement



Event Interpretation



Event Interpretation

References

- C. Wu and H. Aghajan, Model-based Human Posture Estimation for Gesture Analysis in an Opportunistic Fusion Smart Camera Network, Int. Conf. on Advanced Video and Signal based Surveillance (AVSS), Sept. 2007.
- C. Chang and H. Aghajan, A LQR Spatiotemporal Fusion Technique for Face Profile Collection in Smart Camera Surveillance, Int. Conf. on Advanced Video and Signal based Surveillance (AVSS), Sept. 2007.
- C. Chang and H. Aghajan, Spatiotemporal Fusion Framework for Multi-Camera Face Orientation Analysis, Advanced Concepts for Intelligent Vision Systems (ACIVS), August 2007.
- C. Wu and H. Aghajan, Model-based Image Segmentation for Multi-View Human Gesture Analysis, Advanced Concepts for Intelligent Vision Systems (ACIVS), August 2007.
- Hamid Aghajan and Chen Wu, Layered and Collaborative Gesture Analysis in Multi-Camera Networks, Int. Conf. on Acoustics, Speech, and Signal Processing (ICASSP), April 2007.
- Chen Wu and Hamid Aghajan, Opportunistic Feature Fusion-based Segmentation for Human Gesture Analysis in Vision Networks, IEEE SPS-DARTS, March 2007.
- Chen Wu and Hamid Aghajan, Collaborative Gesture Analysis in Multi-Camera Networks, ACM SenSys Workshop on Distributed Smart Cameras (DSC), Oct. 2006.
- Chung-Ching Chang and Hamid Aghajan, Collaborative Face Orientation Detection in Wireless Image Sensor Networks, ACM SenSys Workshop on Distributed Smart Cameras (DSC), Oct. 2006.
- A. Maleki-Tabar, A. Keshavarz, H. Aghajan, “Smart Home Care Network using Sensor Fusion and Distributed Vision-Based Reasoning”, ACM Multimedia Workshop On Video Surveillance and Sensor Networks (VSSN), Oct. 2006.
- A. Keshavarz, A. Maleki-Tabar, H. Aghajan, “Distributed Vision-Based Reasoning for Smart Home Care”, ACM SenSys Workshop on Distributed Smart Cameras (DSC), Oct. 2006.

http://wsnl.stanford.edu/publications.php

Outline

I. Introduction
II. Smart Camera Architectures
    1. Wireless Smart Camera
    2. Smart Camera for Active Vision
III. Distributed Vision Algorithms
    1. Fusion Mechanisms
    2. Vision Network Algorithms
IV. Requirements and Case Studies
V. Outlook