Distributed Vision Processing in Smart Camera Networks

CVPR-07
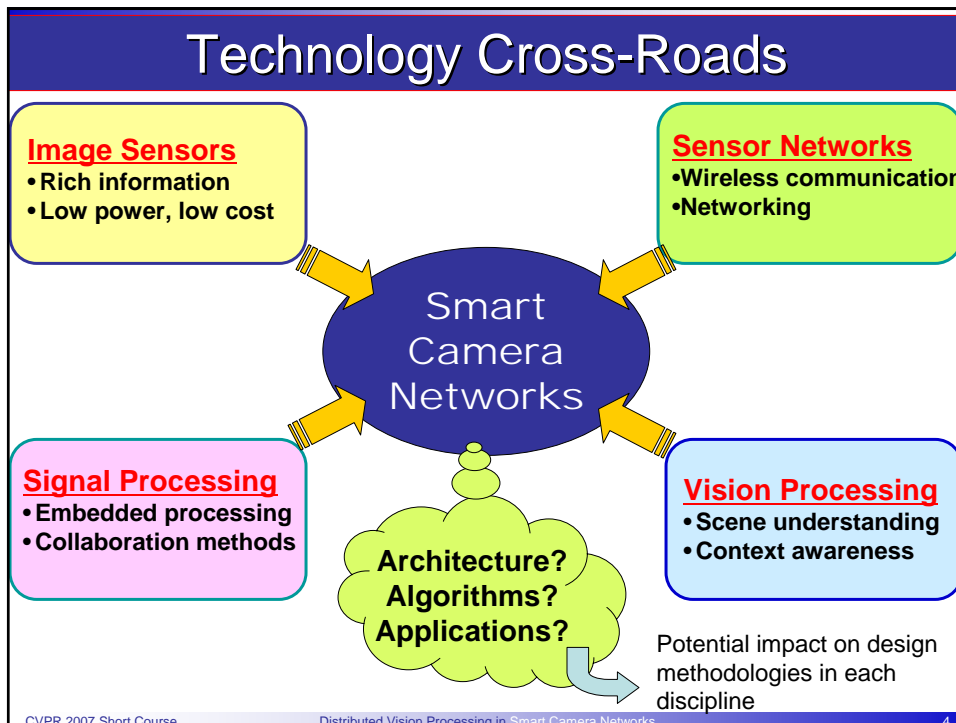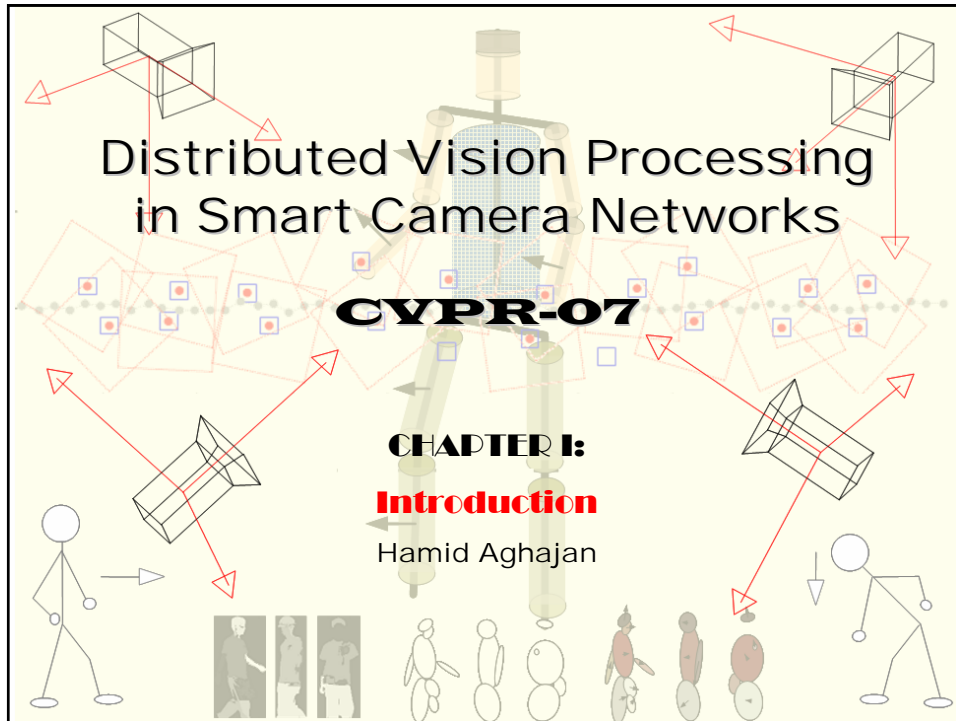
Hamid Aghajan, Stanford University, USA
François Berry, Univ. Blaise Pascal, France
Horst Bischof, TU Graz, Austria
Richard Kleihorst, NXP Research, Netherlands
Bernhard Rinner, Klagenfurt University, Austria
Wayne Wolf, Princeton University, USA

March 18, 2007
Minneapolis, USA

Course Website – http://wsnl.stanford.edu/cvpr07/index.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**

Distributed Vision Processing in Smart Camera Networks

CVPR-07

CHAPTER I:

Introduction

Hamid Aghajan

Technology Cross-Roads

Image Sensors
- Rich information
- Low power, low cost

Sensor Networks
- Wireless communication
- Networking

Smart Camera Networks

Signal Processing
- Embedded processing
- Collaboration methods

Vision Processing
- Scene understanding
- Context awareness

Architecture?
Algorithms?
Applications?

Potential impact on design methodologies in each discipline

2

Sensor Networks Perspective

❖ Opportunities for novel applications:

➢ Make *complex interpretation* of environment and events

➢ Learn *phenomena* and *behavior,* not just measure effect

➢ Incorporate *context awareness* into the application

➢ Allow network to *interact* with the environment

- Change of paradigm:
  High-bandwidth sensors (vision)

Vision Processing Perspective

❖ Novel approach to vision processing:

➢ Use the additional available dimension: space
  ➢ Data fusion across views, time, and feature levels

➢ Design based on effective use of all available information (opportunistic fusion)

➢ Utilize multiple views to:
  ➢ Overcome ambiguities
  ➢ Achieve robustness
  ➢ Allow for low complexity algorithms

➢ Use communication to exchange descriptions - not raw data
  ➢ In-node processing

- Change of paradigm:
  Networked vision sensors

Smart Camera Networks

New Paradigm

High-bandwidth data
⇩
In-node processing
⇩
Low-bandwidth communication
⇩
Collaborative interpretation
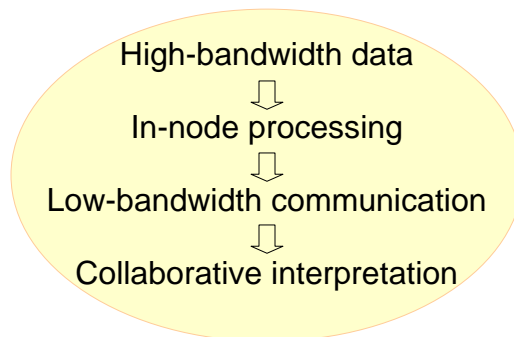
Smart Camera Networks

❖ Rich design space utilizing concepts of:
  – Vision processing
  – Signal processing and optimization
  – Wireless communications
  – Networking
  – Sensor networks

❖ Novel smart environment applications:
  – Interpretive
  – Context aware
  – User centric

Smart Camera Networks

❖ Processing at source allows:
- Image transfer avoidance
- Descriptive reports
- Scalable networks

❖ Design opportunities:
- Processing architectures for real-time in-node processing
- Algorithms based on opportunistic data fusion
- Novel smart environment applications
- Balance of in-node and collaborative processing:
  - Communication cost
  - Latency
  - Processing complexities
  - Levels of data fusion

Smart Camera Networks

❖ Vision sensing requires awareness of:
- Privacy issues
  - Employ in-node processing
  - Avoid image transfer
  - Applications that provide services not based on monitoring / reporting
- Bandwidth issues
  - Transmit processed information not raw data
  - Transmit based on information value for fusion / query-based
- Processing demand
  - Employ separate early vision and interpretive processing mechanisms
  - Layered processing architecture: Features, objects, relationships, models, decisions
    - Employ data exchange and collaboration across different layers

Application Potentials

Examples by: Chen Wu, Chung-Ching Chang, Huang Lee, Joshua Goshporn, Itai Katz, Kevin Gabayan

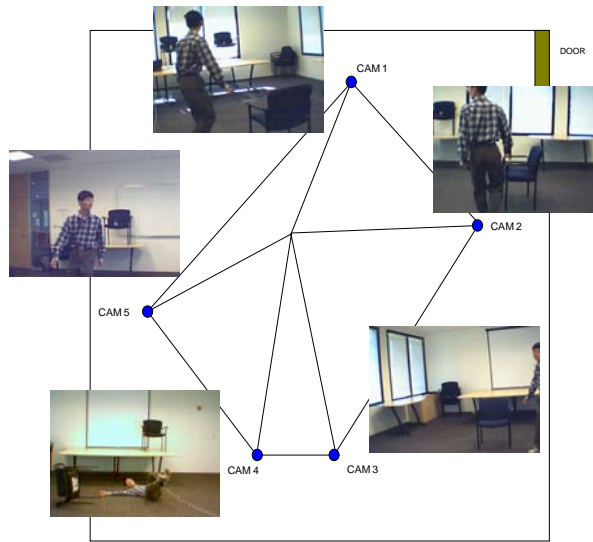Wireless Sensor Networks Lab, Stanford University

---

Application Potentials: View Selection

➢ Select best view of person of interest in real-time tracking
   ➢ Data exchange between cameras determines which one to stream visual data
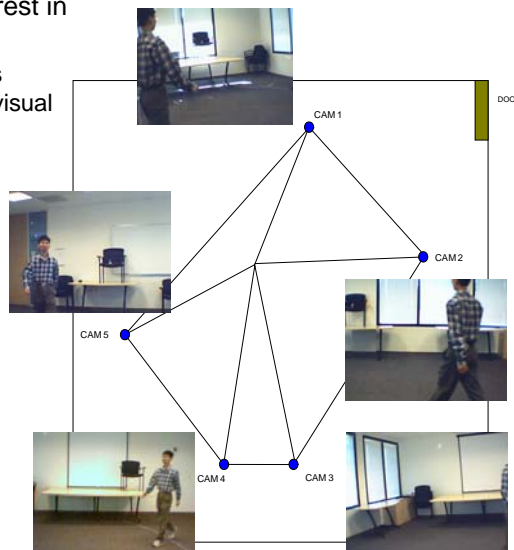
Application Potentials: Assisted Living
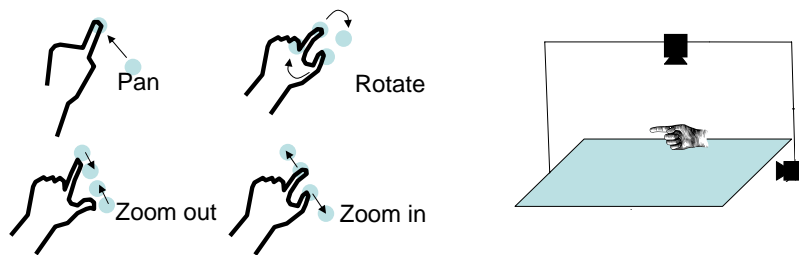
➢ Detect accidents at home

CAM 1

DOOR

CAM 2

CAM 5

CAM 4   CAM 3

Application Potentials: Multi-Finger Gesture

➢ Manipulate virtual world with free hand gesture

Pan

Rotate

Zoom out

Zoom in

Application Potentials: Face Profiling

➢ Interpolate and reconstruct face model from a few snapshots
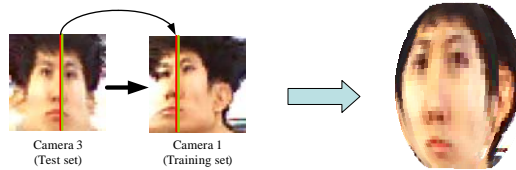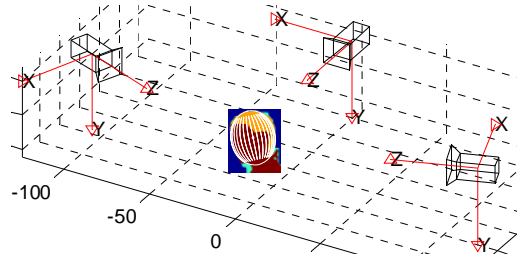
-100

-50

0

Camera 3
(Test set)

Camera 1
(Training set)

Application Potentials: 3D Model Reconstruction
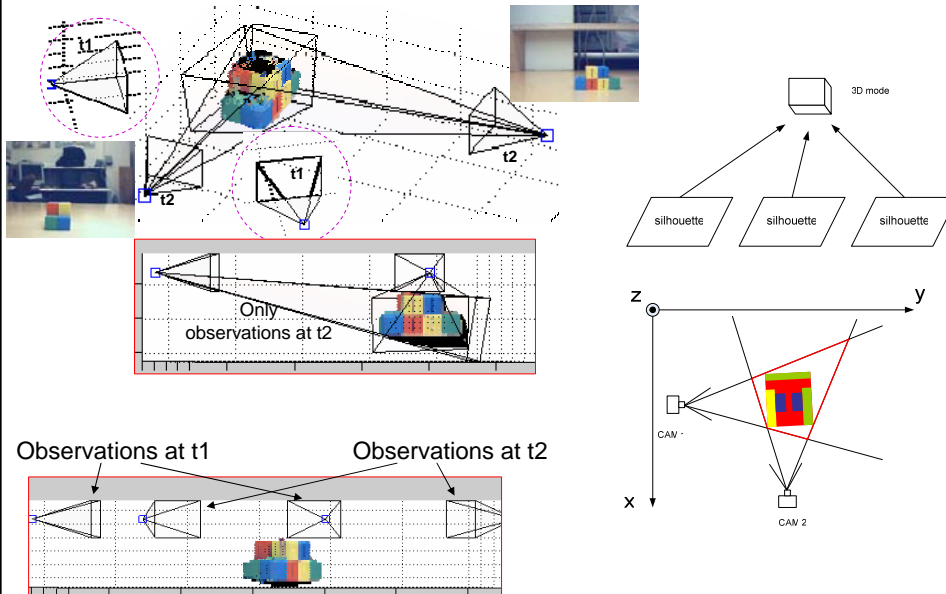
t1

t2

t1

t2

Only
observations at t2

3D mode

silhouette   silhouette   silhouette

z   y

x

CAM

CAM 2

Observations at t1   Observations at t2

8

Application Potentials: Virtual Reality

> Place people in virtual world
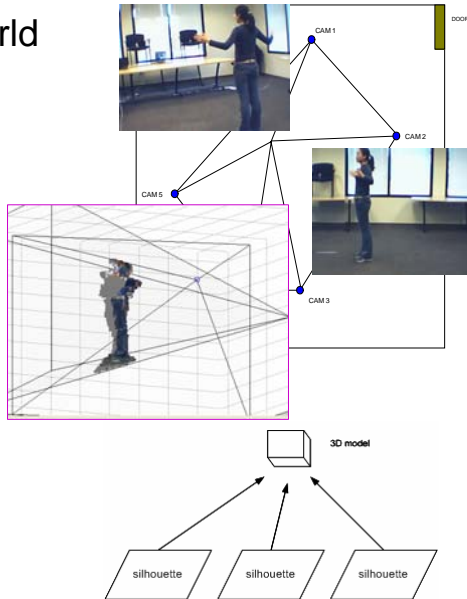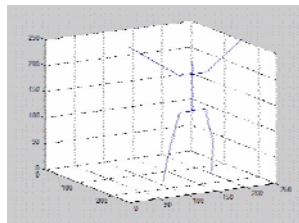
ACM/IEEE International Conference on Distributed Smart Cameras
ICDSC-07
Vienna, Austria
Sept. 25-28, 2007

First ACM / IEEE International Conference on Distributed Smart Cameras (ICDSC-07)

September 25-28, 2007
Vienna, Austria

- Smart camera architectures
- Image sensing techniques for smart cameras
- Embedded vision programming
- Fusion of vision and other sensors
- Distributed vision processing algorithms
- Distributed appearance modeling
- Collaborative feature extraction, data and decision fusion
- Architectures and protocols for camera networks
- Wireless and mobile image senor networks
- Position discovery and middleware applications
- Vision-based smart environments
- Surveillance and tracking applications
- Multi-view vision for human-computer interaction
- 3D scene analysis
- Distributed multimedia and gaming applications

www.ICDSC.org

Tutorials:

- Tsuhan Chen, CMU, USA: "Smart Camera Arrays"

- Andrea Cavallaro, Queen Mary University of London, UK: "Smart Cameras: Algorithms, Evaluation and Applications"

- Bjoern Gottfried, University of Bremen, Germany: "Ambient Intelligence and the Role of Spatial Reasoning: Smart Environments with Smart Cameras"

- More TBA

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