Gesture Interaction with Virtual Humans and Social Robots

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Visigrapp 2015, Berlin

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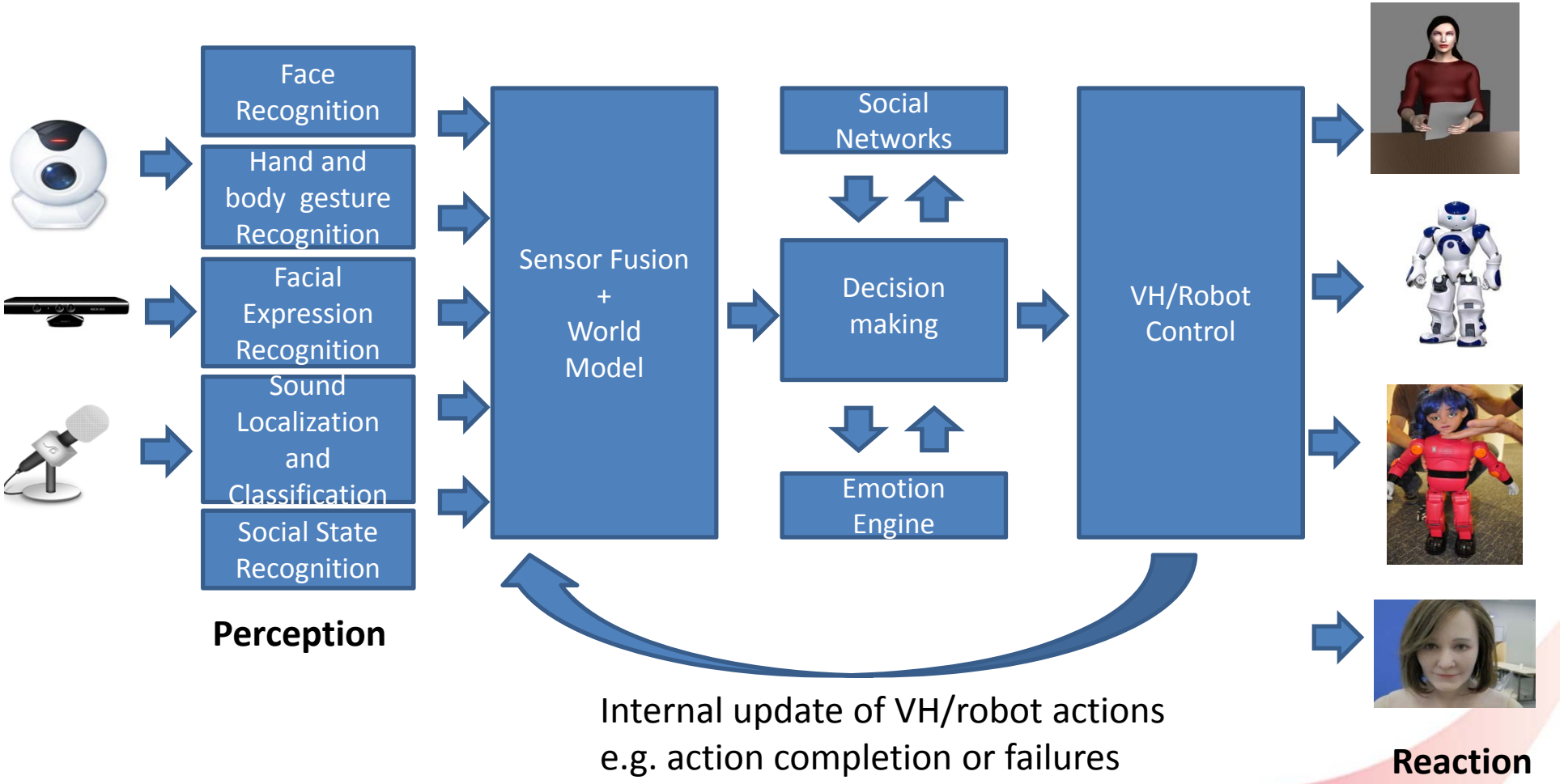
Overview

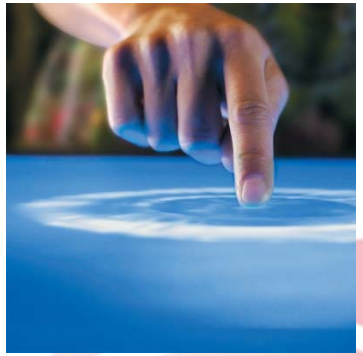

Face Recognition
Hand and body gesture Recognition
Facial Expression Recognition
Sound Localization and Classification
Social State Recognition
Perception
Sensor Fusion + World Model
Social Networks
Decision making
Emotion Engine
VH/Robot Control
Internal update of VH/robot actions
e.g. action completion or failures
Reaction

Body and Hand Gesture recognition

The Nature of Gesture

- Gestures are expressive, meaningful body motions – i.e., physical movements of the fingers, hands, arms, head, face, or body with the intent to convey information or interact with the environment.

- 3 functional roles of human gesture:
  - Semiotic – to communicate meaningful information
  - Ergotic – to manipulate environment
  - Epistemic – to discover environment through tactile experience.

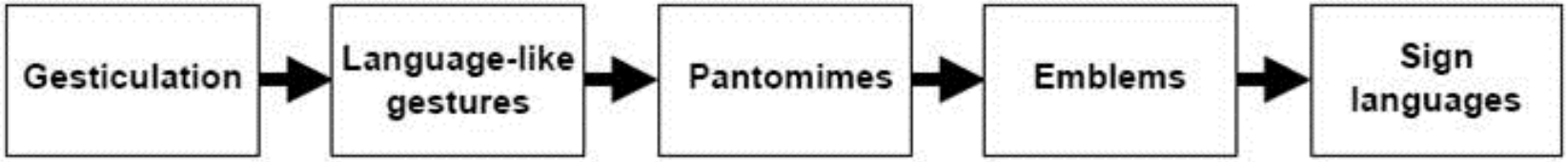


Gesture recognition

- Process by which gestures made by the user are make known to the system.
- Standard mouse and keyboard actions used for selecting items and issuing commands are gestures: trivial cases.
- While static position (posture, configuration, or pose) is not technically considered as gesture, we will include it in gestures.

Kendon's gesture continuum

- *Gesticulation* – spontaneous movements of hands and arms that accompany speech
- *Language-like gestures* – gesticulation integrated into spoken utterance, replacing particular spoken word
- *Pantomimes* – gestures that depict objects or actions, with or without accompanying speech
- *Emblems* – familiar gestures such as "V for victory"
- *Sign languages* – Linguistic systems, such as American Sign Language



As list progresses (from left to right in figure)

speech → **Language properties** → **spontaneity** → **Social regulation** →

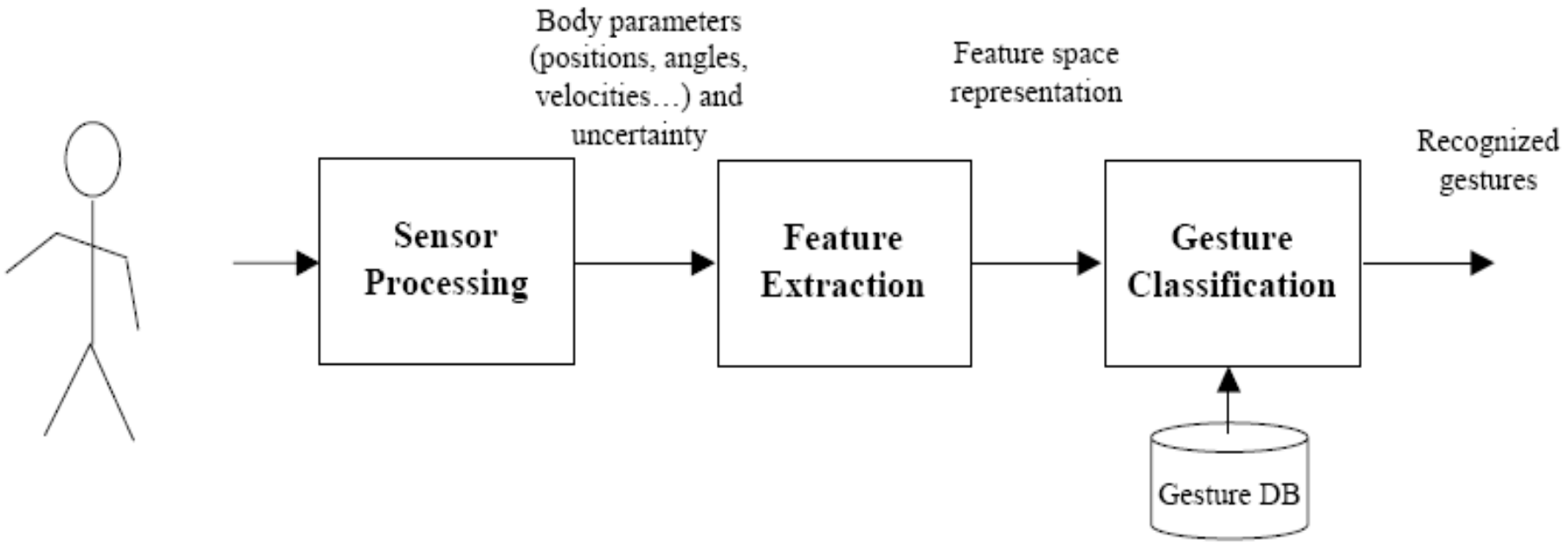
Gestures: Some Concepts

- Recognition of natural, continuous gestures requires temporally segmenting gestures.
- Automatically segmenting gestures difficult, and often ignored in current systems by requiring a starting position in time and/or space.
- Similar to this: problem of distinguishing intentional gestures from other "random" movements.
- No standard way to do gesture recognition, variety of representations and classification schemes used.

Static and Dynamic Gesture

- Gestures can be static, where user assumes certain pose or configuration, or dynamic, defined by movement.
- McNeill defines 3 phases of dynamic gesture:
  - pre-stroke, stroke, and post-stroke
- Some gestures have both static and dynamic elements, where pose is important in one or more of gesture phases; particularly relevant in sign languages.
- When gestures produced continuously, each gesture affected by gesture that preceded it, and possibly by gesture that follows it.

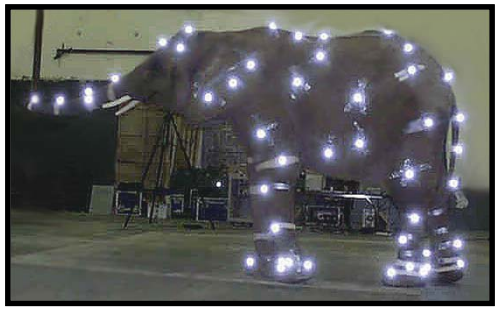
Steps of Gesture Recognition



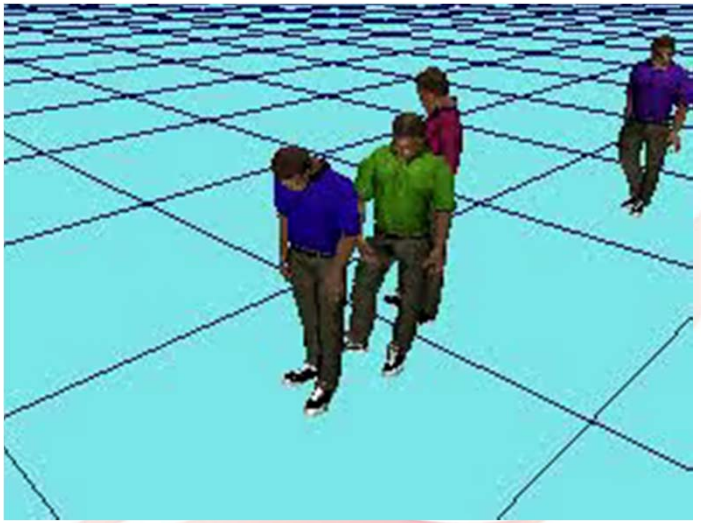
Magnetic sensors

- Source generates low frequency magnetic field detected by sensor.
- Polhemus, Ascension
- Calibration retaining motion realism
- Not very accurate
- Perturbation by magnetic fields
- Perturbation introduced by soft tissue and muscle displacement

Optical sensors (infra-red) Exemple: VICON

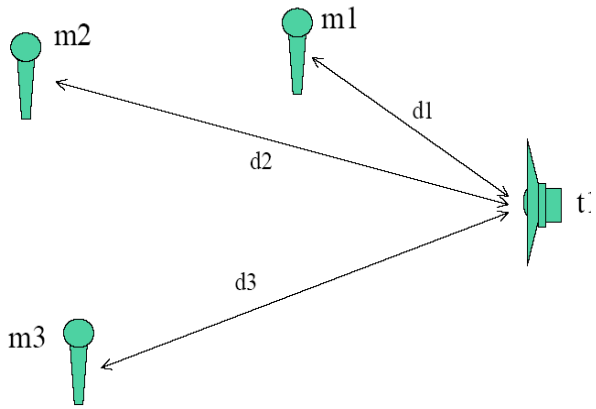


Rec



Ultrasonic sensors

3 microphones used to identify spatial position of one microphone.

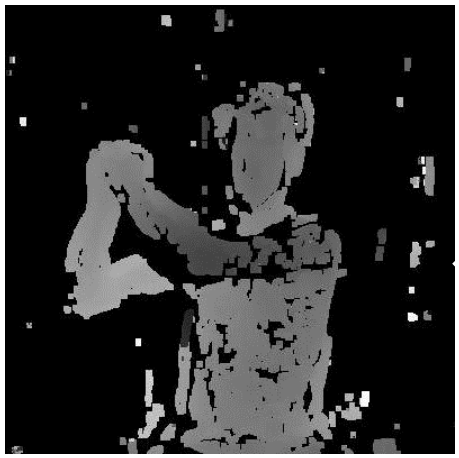


Gyroscopic system

- Sensor composed by 3 gyroscopes along orthogonal axis providing orientation information.
- Gyroscopes are subject to drift so a compass measuring 3D earth magnetic field

Sensing through video-based motion capture (R. Plaenkers, P. Fua)

Much easier in one plane (2D)



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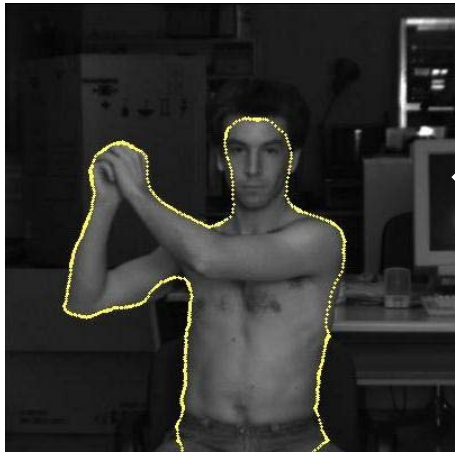
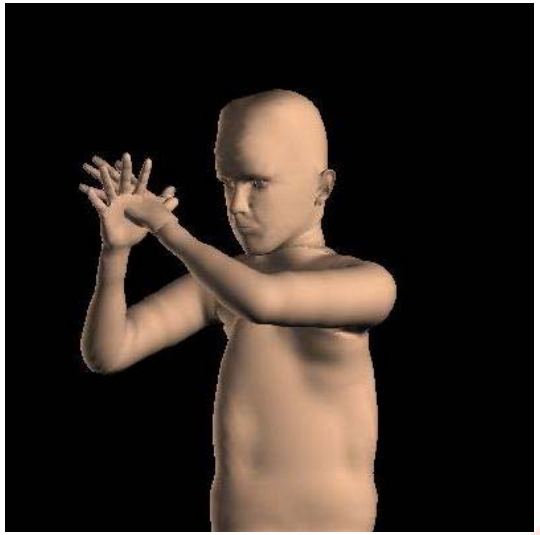




Depth cameras: Kinect

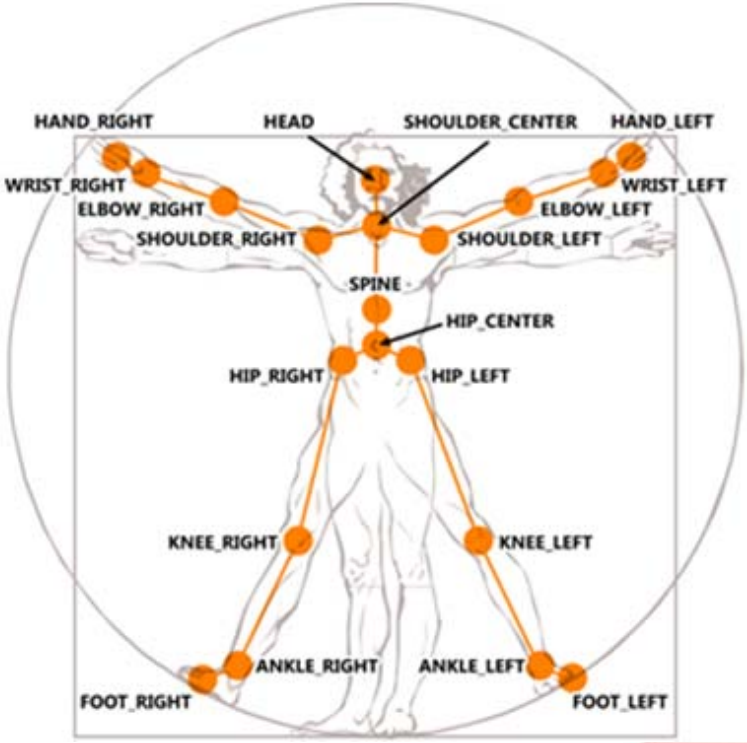
- Depth sensor: infrared laser projector combined with monochrome CMOS sensor, which captures video data in 3D under any ambient light conditions
- Kinect: motion sensing input device by Microsoft for the Xbox 360 video game console and Windows PCs.

Sensor Solution

Kinect

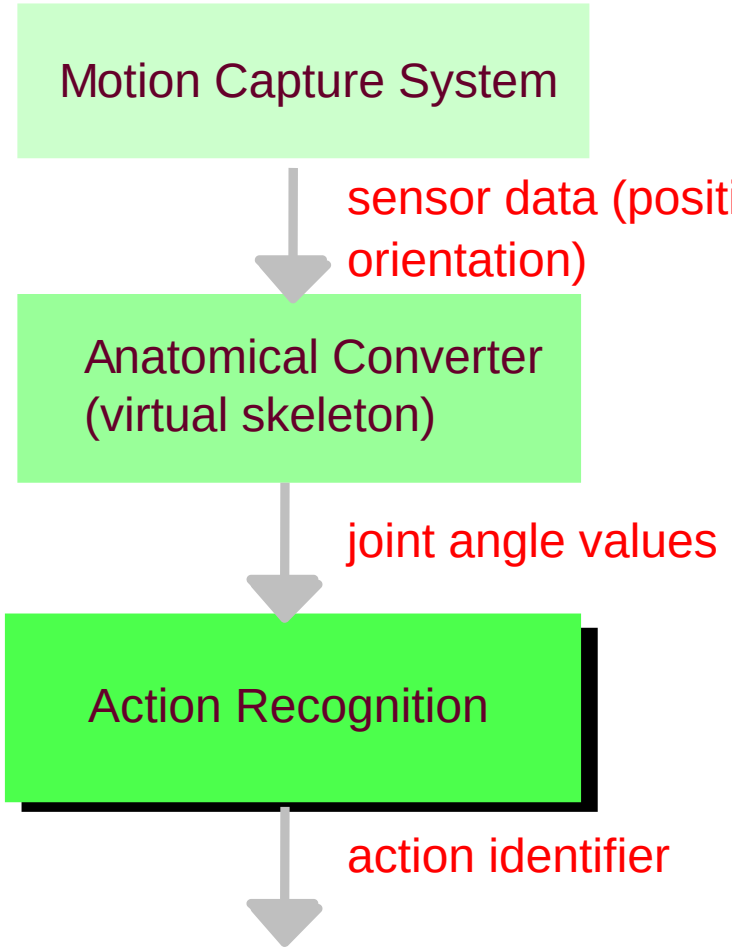
RGB Image

Depth Image



Skeletons

Body Action Recognition

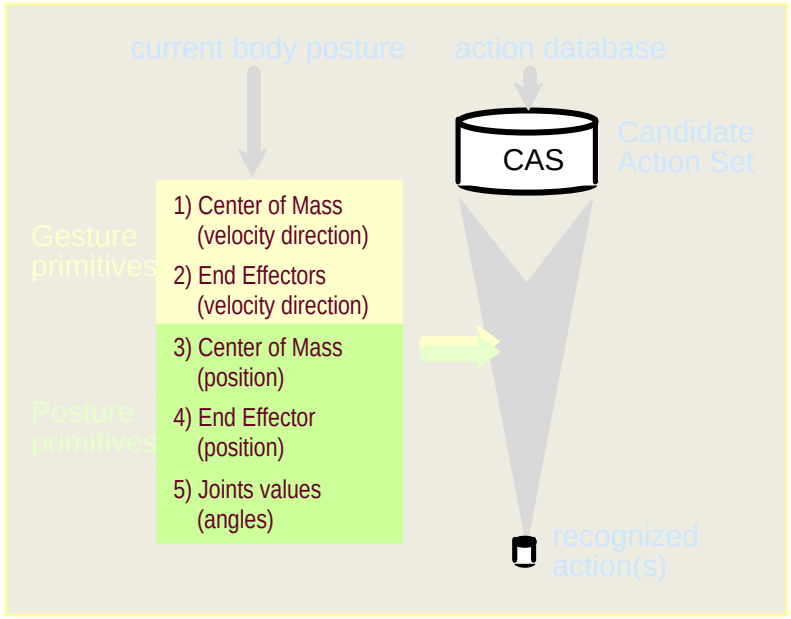


- Independence of Motion Capture System
- Action recognition solely based on virtual skeleton configuration.

Body Actions

- Action Primitives
  - posture primitives = (position, CoM) or (EEs,position) or (Joints, angles)
  - gesture primitives = (CoM, velocity direction) or (EE, velocity direction)
- ACTION = Boolean Expression of Action Primitives

- e.g. walking =((spine, forward) AND (left foot, forward)) OR (spine, forward) AND (right foot, forward))



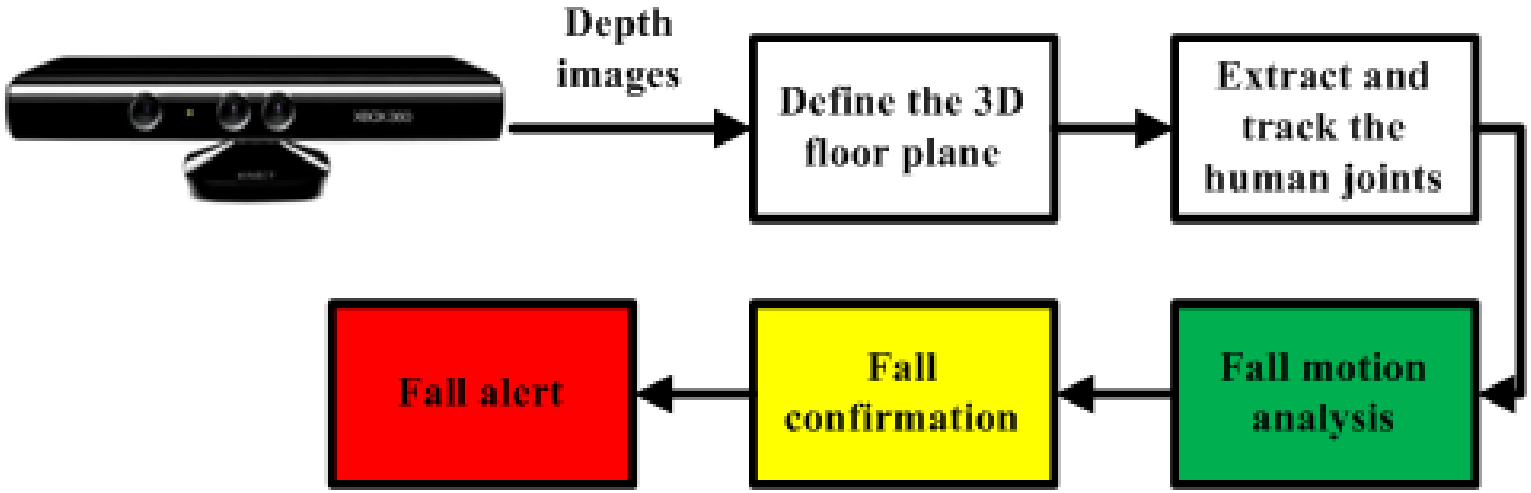
Body Action Recognition

Augmented Reality

S. Balcisoy, R. Torre, M. Ponder, P. Fua, D. Thalmann, **Augmented Reality for Real and Virtual Humans**, *Proc. CGI 2000*, IEEE Computer Society Press, pp.303-308.

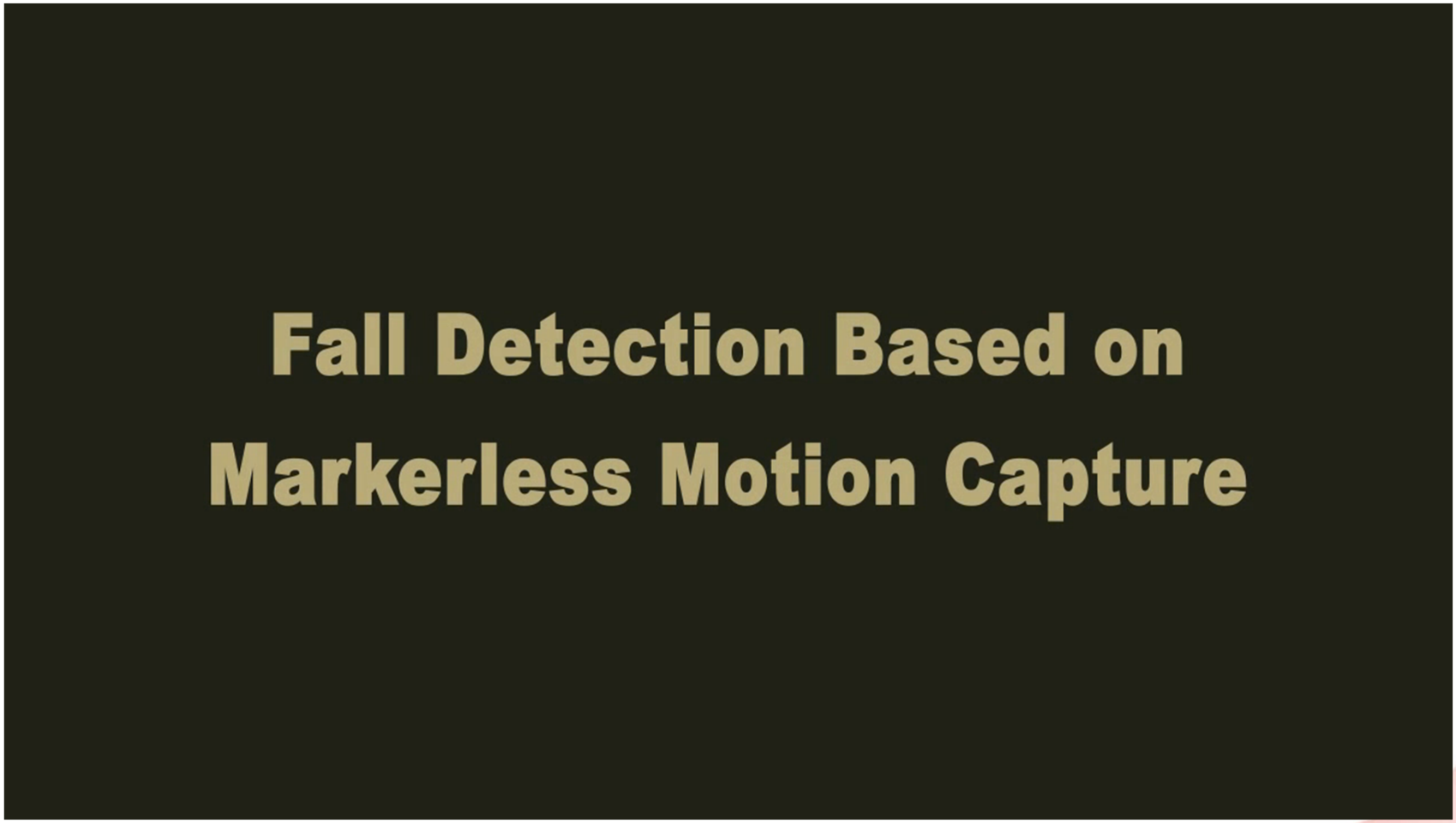
Fall Detection

- Robust fall detection system based on marker-less motion capture.
- Novelty: independent of illumination condition, and the person does not require to wear any markers.

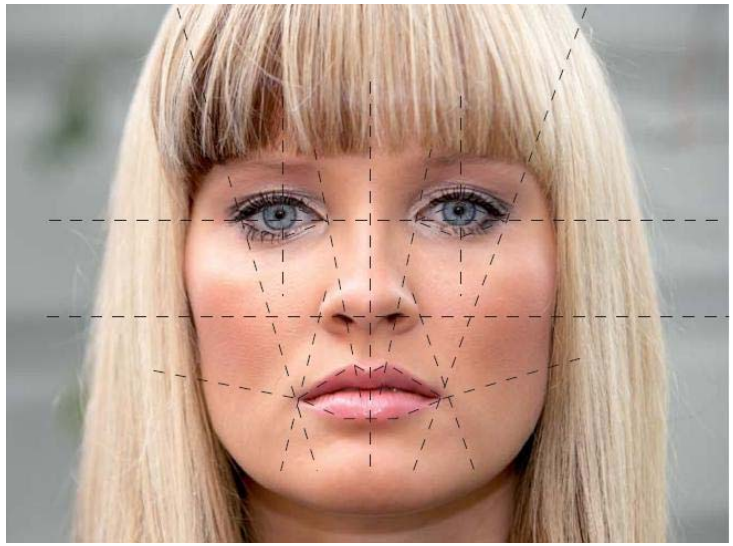


Z.P. Bian, L.P. Chau, and N. Magnenat-Thalmann, "**A depth video approach for fall detection based on human joints height and falling velocity**," in International Conference on Computer Animation and Social Agents, May 2012.
Z.P. Bian, L.P. Chau, and N. Magnenat-Thalmann, "**Fall detection based on skeleton extraction**," in Proceedings of the 11th ACM SIG-GRAPH International Conference on Virtual-Reality Continuum and its Applications in Industry. New York, NY, USA: ACM, 2012, pp. 91–94.

Demo: Fall Detection



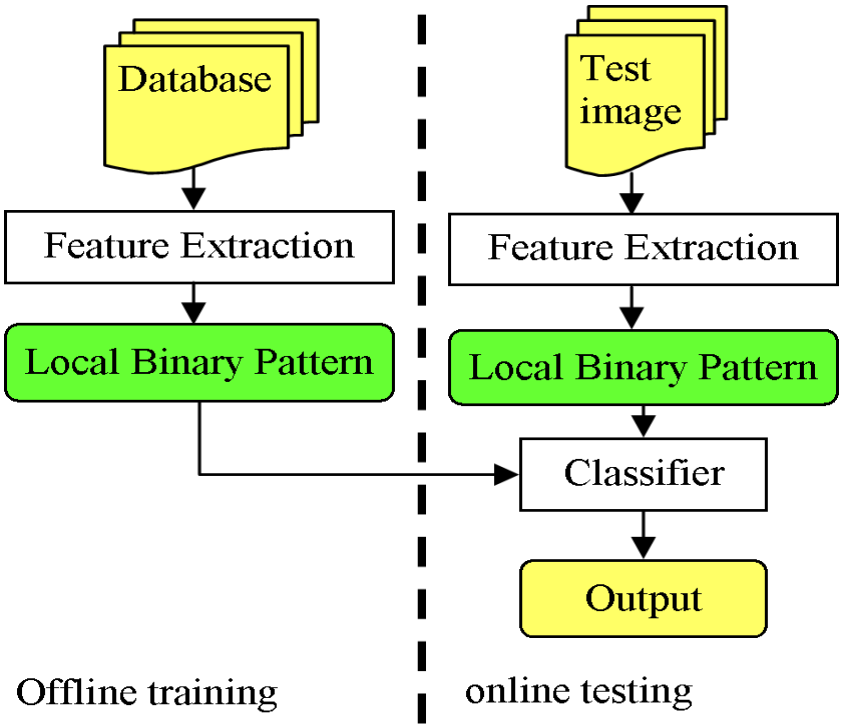
Face Recognition



- Automatically identifying a person from a digital image or a video source
- Typical ways to do this: comparing selected facial features from image and facial database.
- Recognition algorithms: two main approaches:
  - **geometric**, looks at distinguishing features,
  - **photometric**, statistical approach that distils an image into values and compares them with templates to eliminate variances.
- **3D face recognition**; uses 3D sensors to capture information about shape of a face
- **Skin texture analysis**: captures and uses visual details of skin

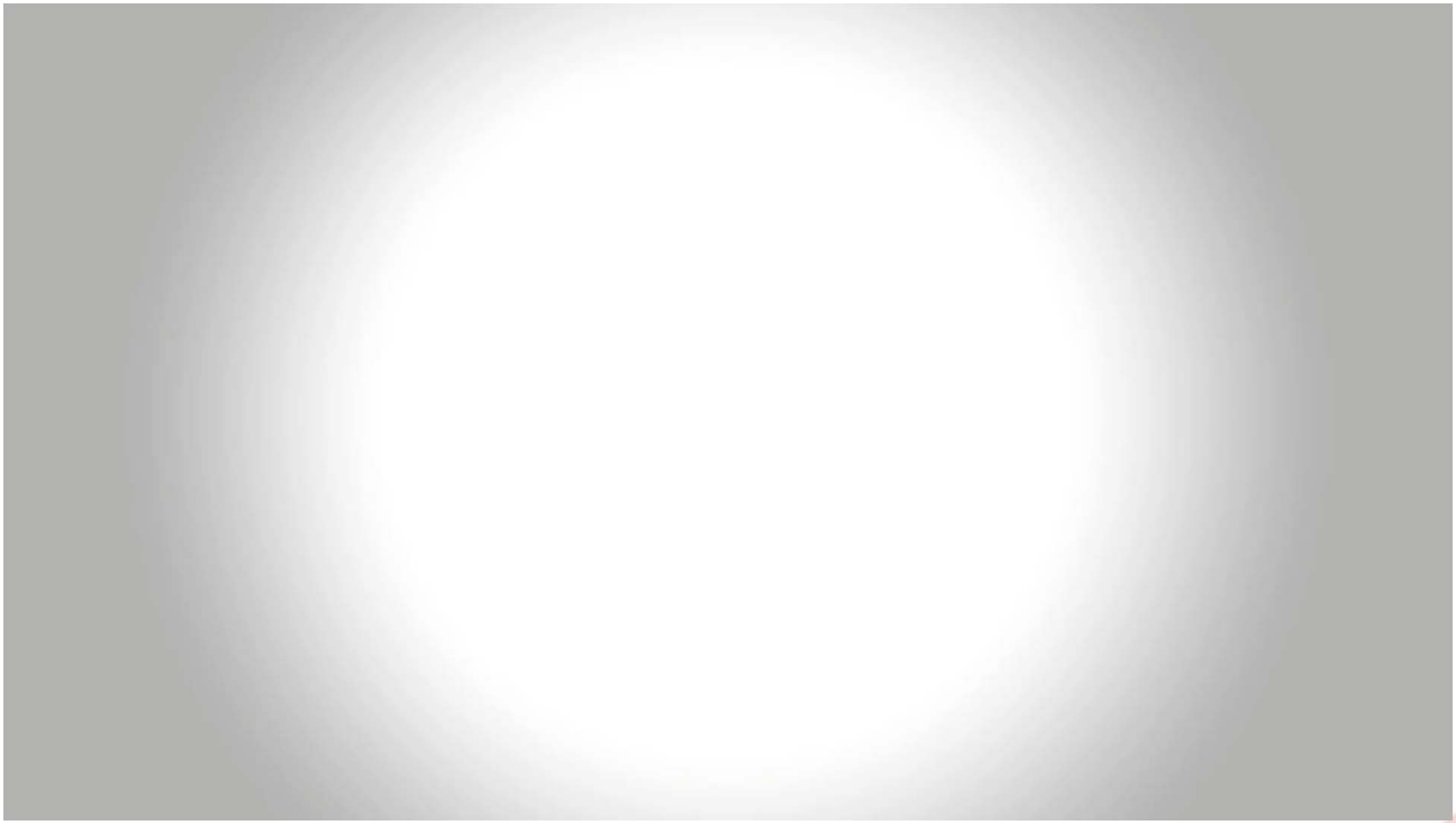
Face Recognition using the Kinect

- Novelty: Utilize Local Binary Patterns feature, extremely fast
- Training: 20 seconds
- Recognition: real-time



1. Jianfeng Ren, et al., **Learning Binarized Pixel-Difference Pattern for Scene Recognition,** 2013 IEEE International Conference on Image Processing (ICIP)
2. Jianfeng Ren, et al. **Relaxed Local Ternary Pattern for Face Recognition**, 2013 IEEE International Conference on Image Processing (ICIP)
3. Jianfeng, Ren, Xudong Jiang, Junsong Yuan, "**Dynamic Texture Recognition Using Enhanced LBP Features**", accepted by ICASSP 2013.

Demo: Face Recognition



Body and hand gesture recognition

Hand feature extraction
(Cyber-glove)

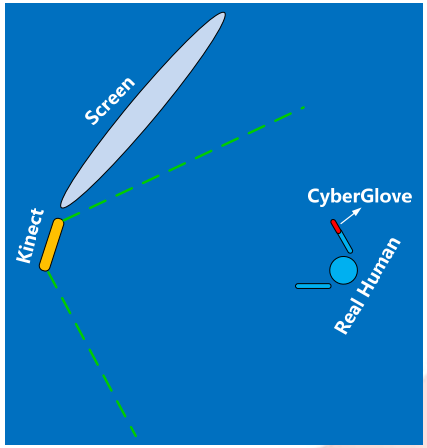
+

Upper body joints extraction
(Kinect)

→ Information fusion

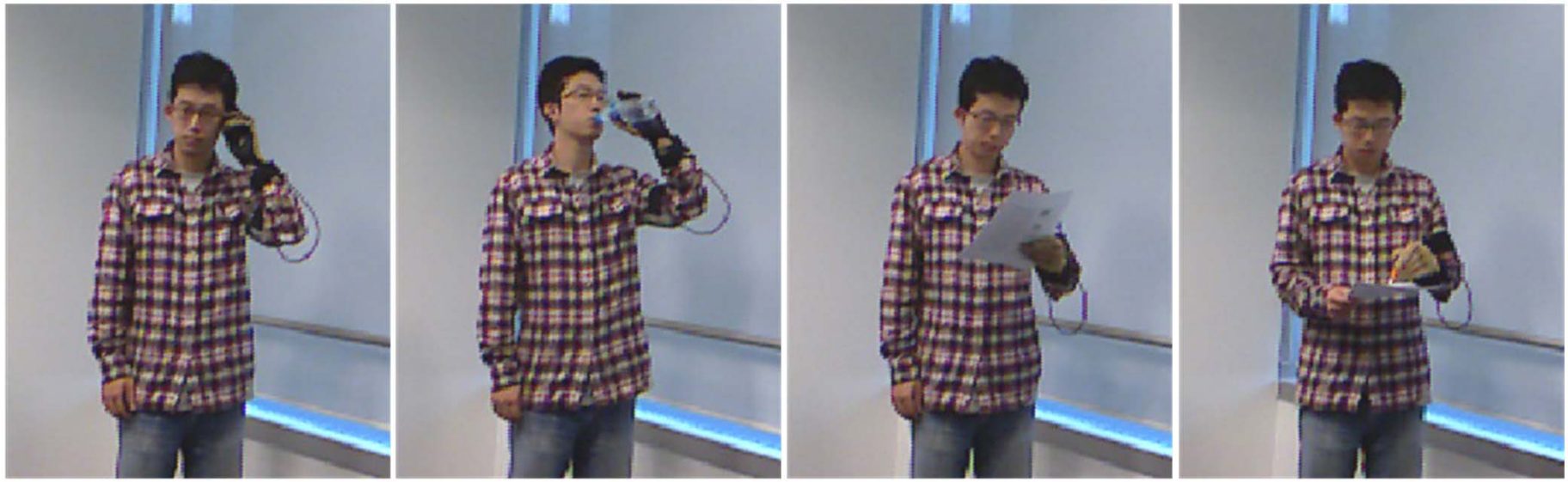
↓

Recognize upper body gesture



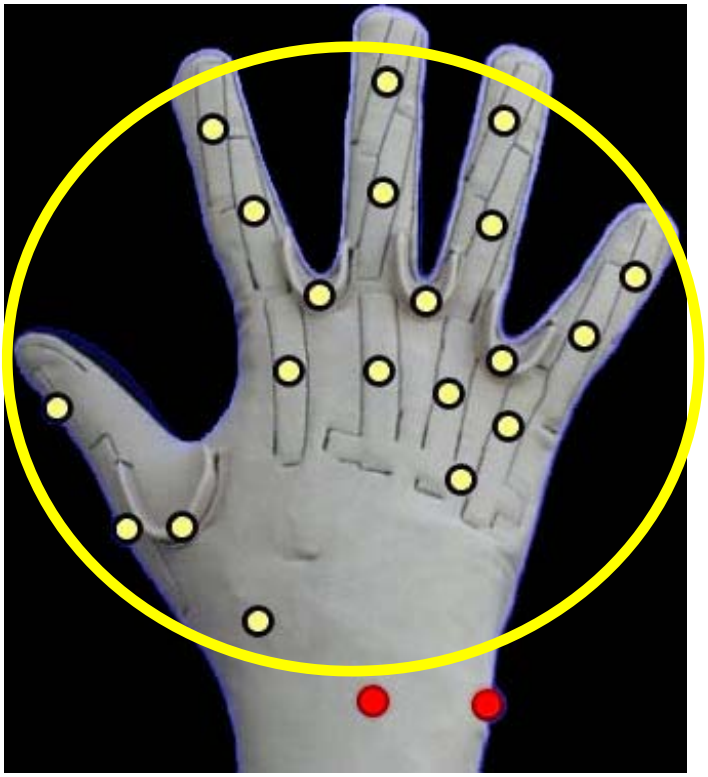
Yang Xiao; Junsong Yuan; Daniel Thalmann
Human-Virtual Human Interaction by Upper Body Gesture Understanding, Proc. ACM VRST 2013

Upper Body Gestures without Human-object Interaction



Upper Body Gestures <u>with</u> Human-object Interaction

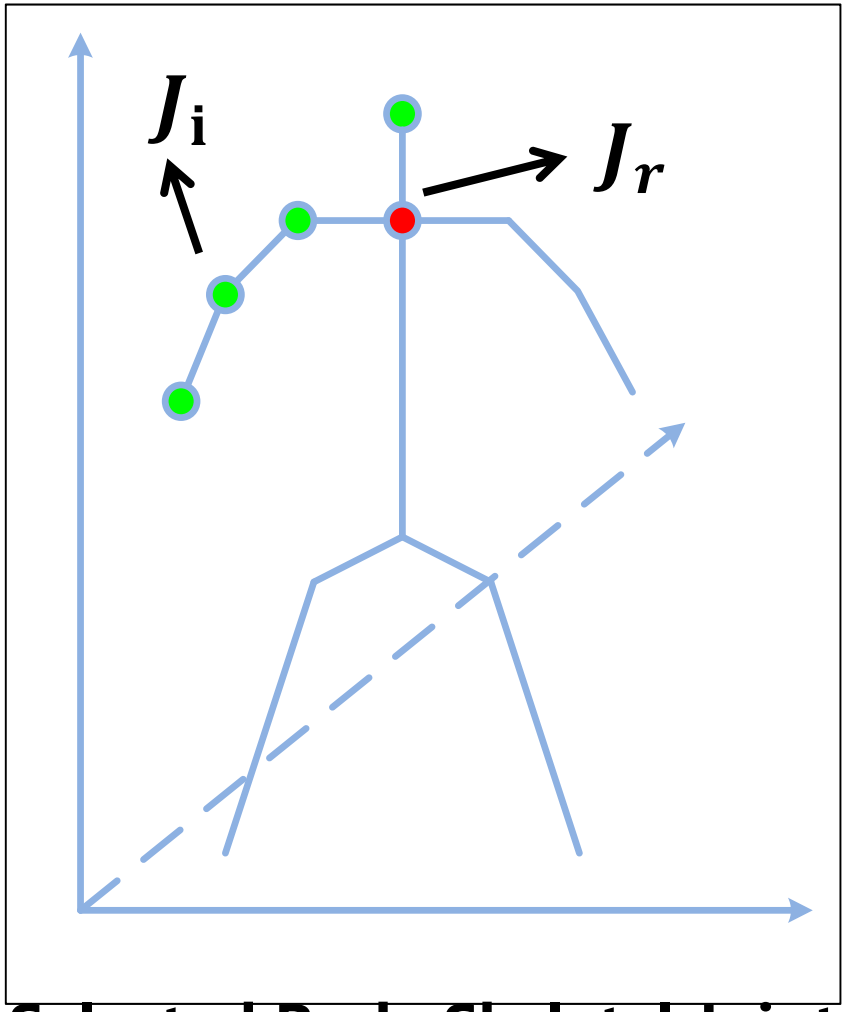
Upper Body Gesture Understanding



$$F_{hand} = (h_1, h_2, h_3 \cdots h_{19}, h_{20})$$

CyberGlove II Data Joints

Upper Body Gesture Understanding



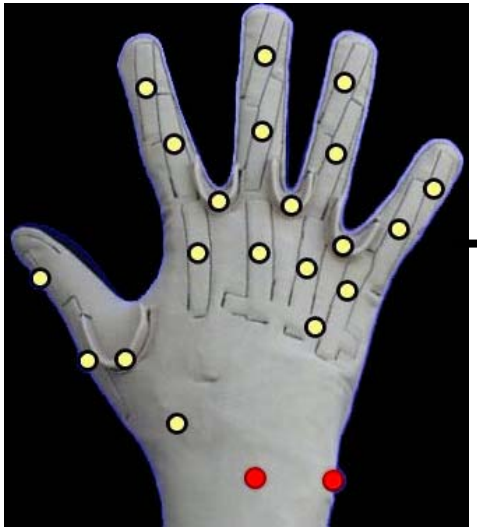
Selected Body Skeletal Joints

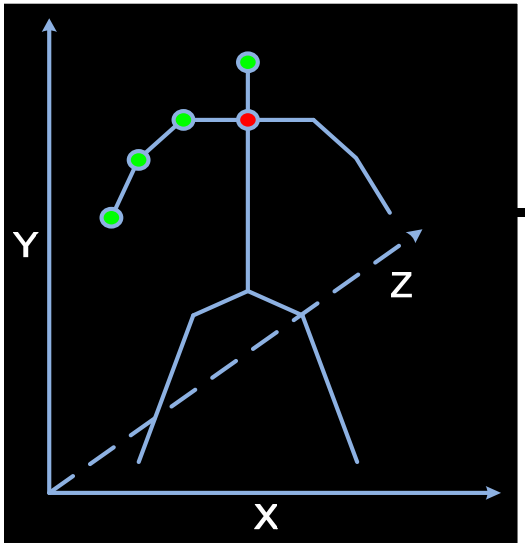
$$J_i = (x_i(t), y_i(t), z_i(t))$$

$$J_{ir} = J_i - J_r$$

$$F_{body} = (J_{1r}, J_{2r}, J_{3r}, J_{4r})$$

Upper Body Gesture Understanding



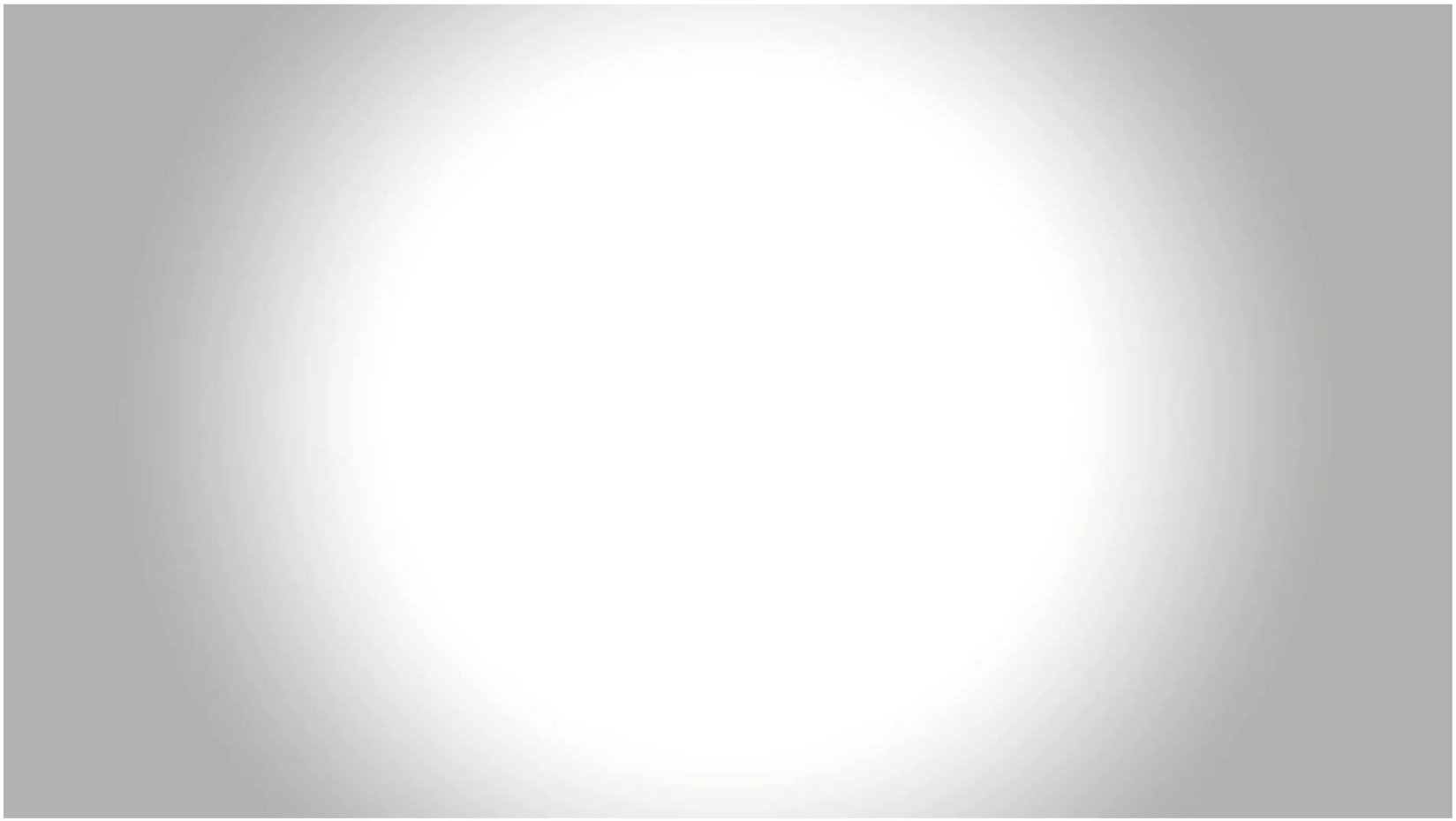


Feature Fusion

$$\widehat{F}_i = \frac{F_i - F_i^{min}}{F_i^{max} - F_i^{min}}$$

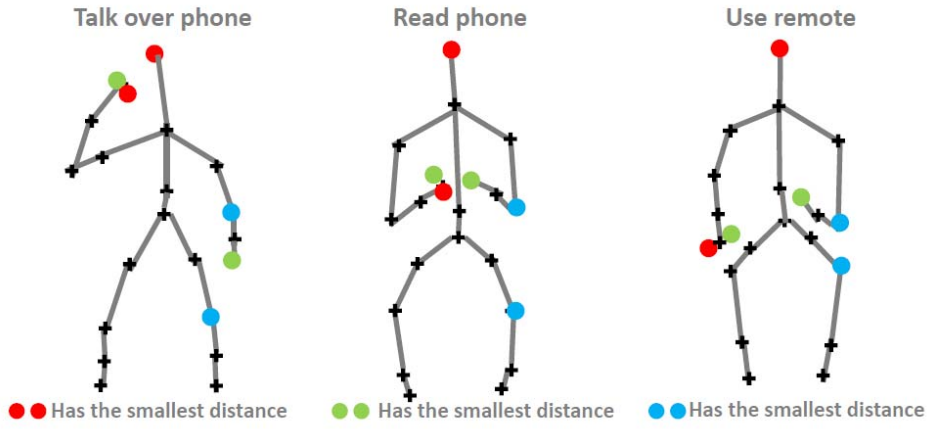
$$\widehat{F} = \left(\widehat{F}_{hand}, \widehat{F}_{body}\right)$$

Human Upper Body Gesture Dataset Samples



Action localization based RGBD cameras

- Problem
  - continuous human-object interaction recognition based on RGBD (Kinect camera)
  - Determine start and end frame of one action
- Motivation
  - Combine skeleton and object information



Orderlet: primitive feature

- Skeleton information

$s_i^{(t)}$, where t refers to the frame index, i is the joint index

$s_i^{(t)} = [x_i^{(t)}, y_i^{(t)}, z_i^{(t)}]$

  - Distance between skeleton point in one frame

$$\lambda^{(1)} = ||\mathbf{s}_i^t - \mathbf{s}_j^t||.$$

  - Spatial position for each skeleton point in one frame

$$\lambda^{(2)} = x_i^t \quad or \quad y_i^t \quad or \quad z_i^t.$$

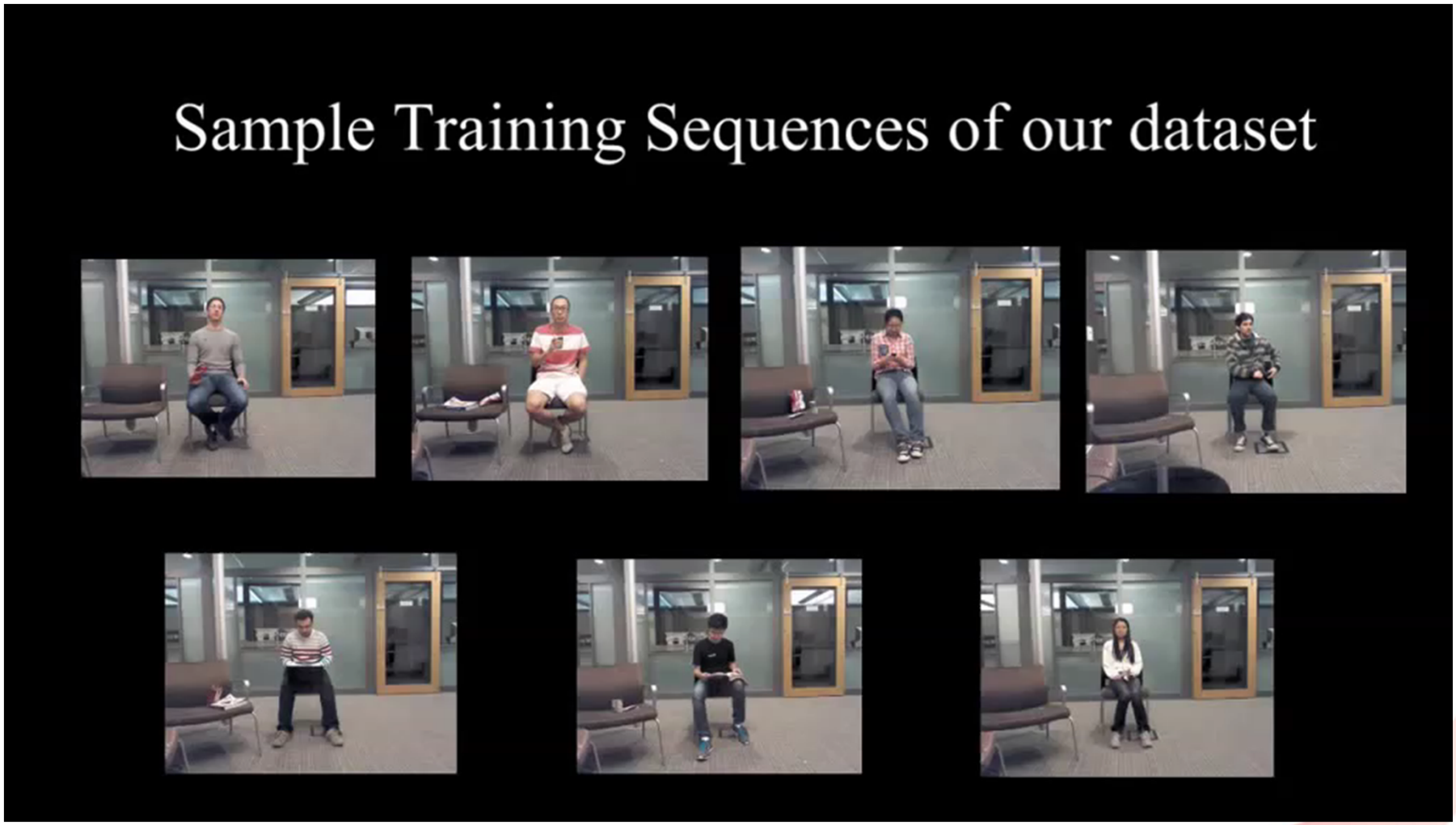
  - Distance between one specific skeleton point in different frames

$$\lambda^{(3)} = ||\mathbf{s}_i^t - \mathbf{s}_i^{t-\Delta}||,$$

- Object Information
  - Local Occupancy pattern

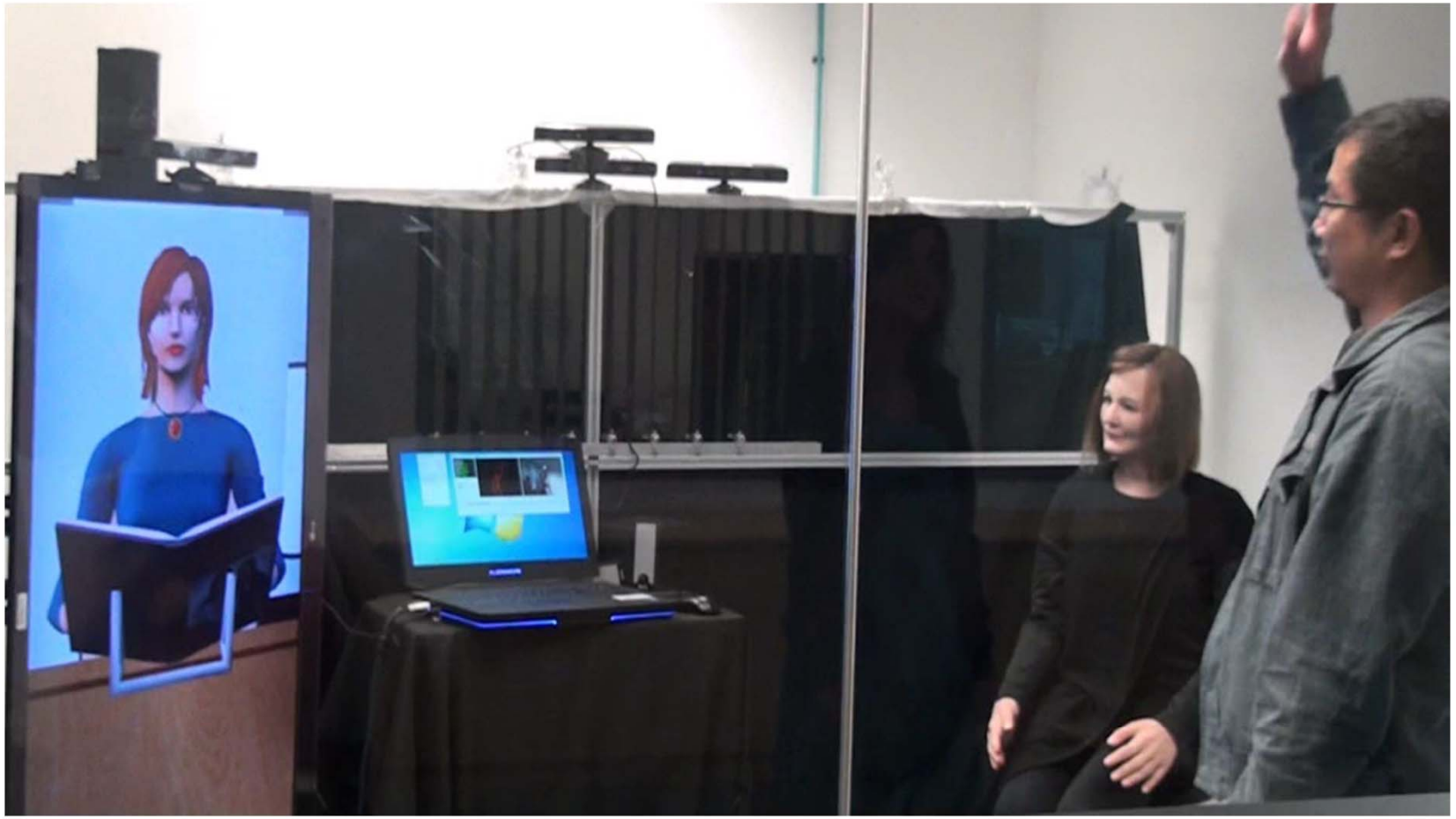
$$\lambda^{(4)} = ||\mathbf{d}(i) - \mathbf{d}(j)|| = ||l_i - l_j||, \quad 1 \leq i, j, \leq N_b, \quad i \neq j.$$

Video Results



Gang Yu, Zicheng Liu, Junsong YuanD, iscriminative Orderlet Mining For Real-time Recognition of Human-Object Interaction, Asian Conference on Computer Vision (ACCV) 2014

Demo: Body gesture recognition



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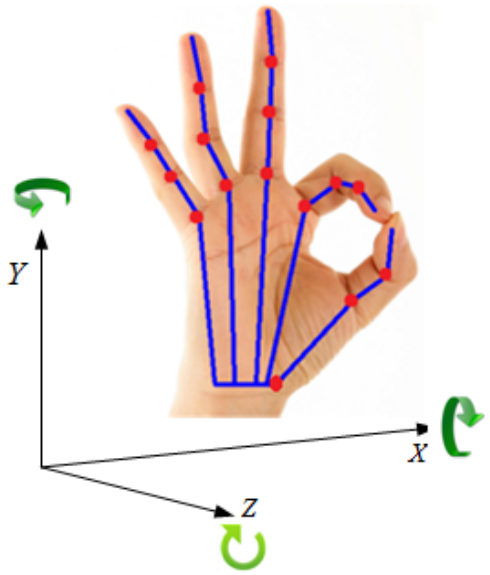
Hand Gesture Recognition

Motivation

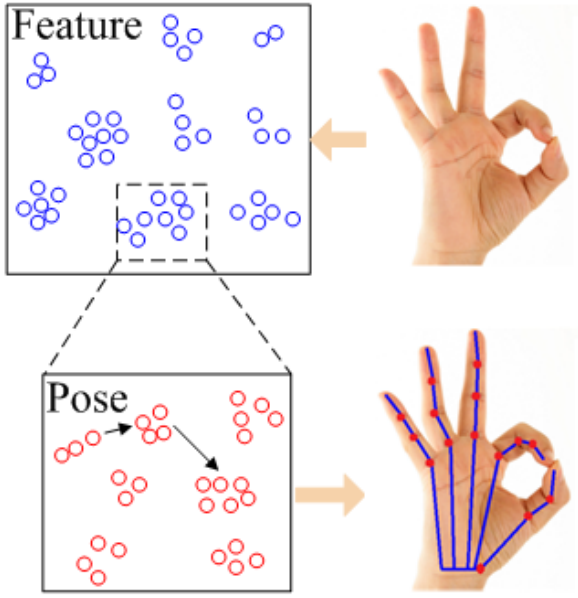
- Hand pose estimation has various applications
  - Sign language recognition
  - Virtual environment manipulation
  - Animation synthesis
- Why vision-based solution for bare-hand pose estimation?
  - Solutions with electro-mechanical devices, optical sensors and color gloves are expensive, or inconvenient to use
  - Vision-based method provides cheap and natural human-computer interaction experience
- Challenges in vision-based hand pose estimation
  - Lack of robust and efficient features
  - High degree-of-freedom hand motion

Problem Description

- We focus on vision-based full DOF pose estimation for bare-hand input
- The hand pose is parameterized as a 27D vector, including the global and local motion. The task is to restore the pose vector for each input frame



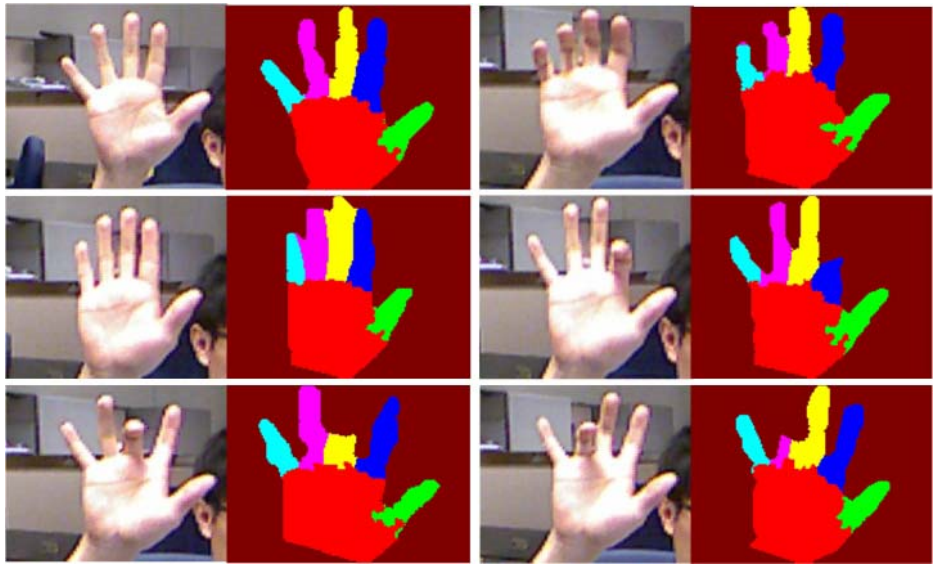
(a) Parameterized pose space



(b) Problem formulation

Hand Gesture Recognition

- Novelty: spatial-temporal feature, which enforces both spatial and temporal constraints in a unified framework for hand parsing and fingertip detection.
- Result: more accurate compared to existing methods.

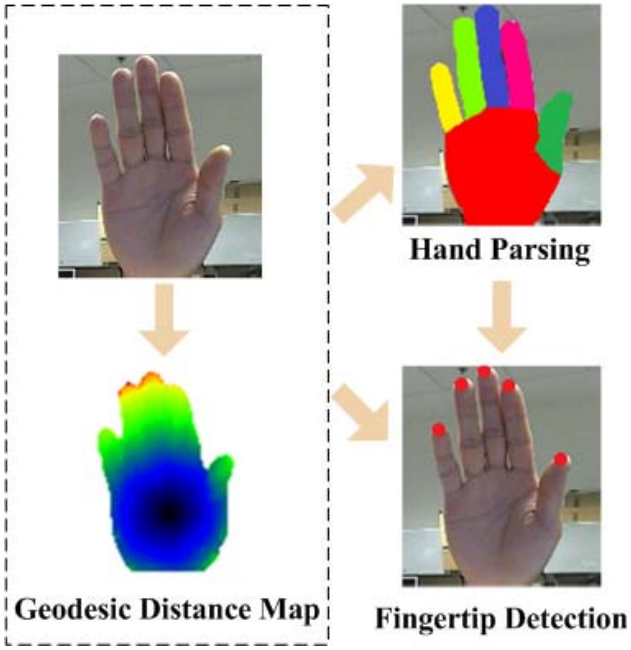


Hui Liang, et al. **3D Fingertip and Palm Tracking in Depth Image Sequences**, ACM International Conference on Multimedia 2012 (MM)

Hui Liang, Junsong Yuan and Daniel Thalmann, "**Model-based Hand Pose Estimation via Spatial-temporal Hand Parsing and 3D Fingertip Localization**", CGI 2013 (Visual Computer Journal)

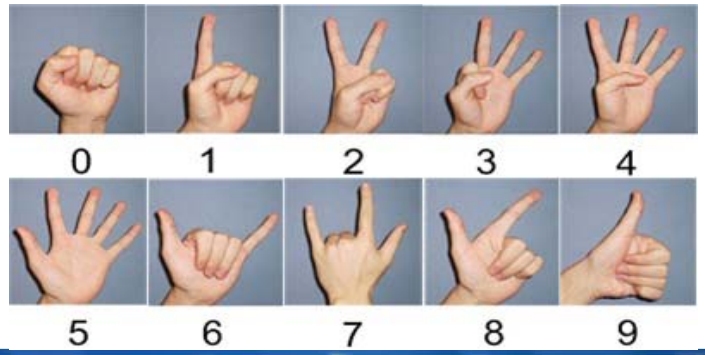
A New Method

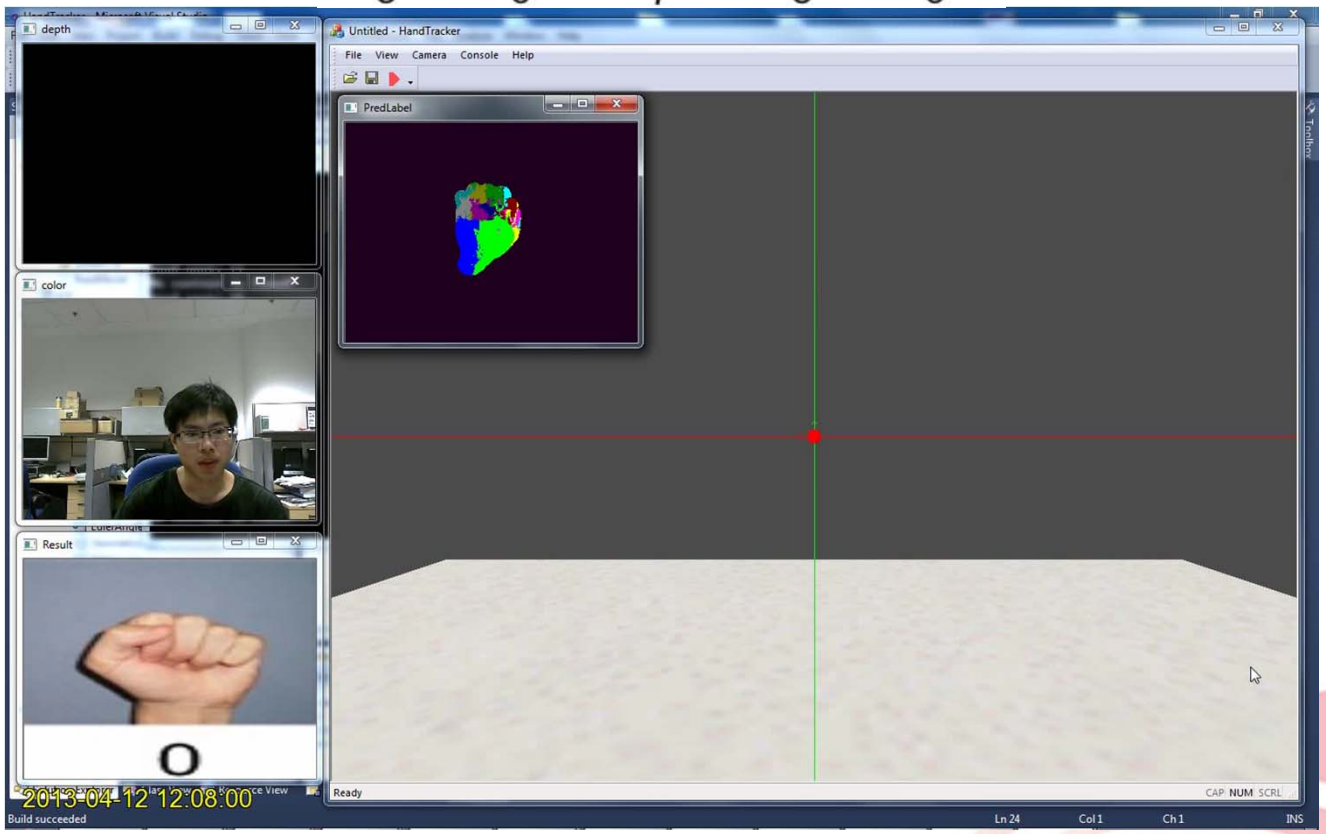
- Geodesic distance map
  - The geodesic distance from the palm center to all other points along the hand surface
- Hand parsing
  - Parse the hand region into individual hand parts
  - Combination of temporal and spatial information
- 3D fingertip detection
  - Use of parsing result to guide fingertip detection
- Hand pose estimation
  - Represent the transformed coordinate of the palm by the normal of the palm and the vector pointing from the palm center to the middle fingertip
  - Apply inverse kinematics (IK) to each finger with the fingertip positions to find the finger pose



Hui Liang, Junsong Yuan and Daniel Thalmann, "**Model-based Hand Pose Estimation via Spatial-temporal Hand Parsing and 3D Fingertip Localization**", The Visual Computer, 2013)

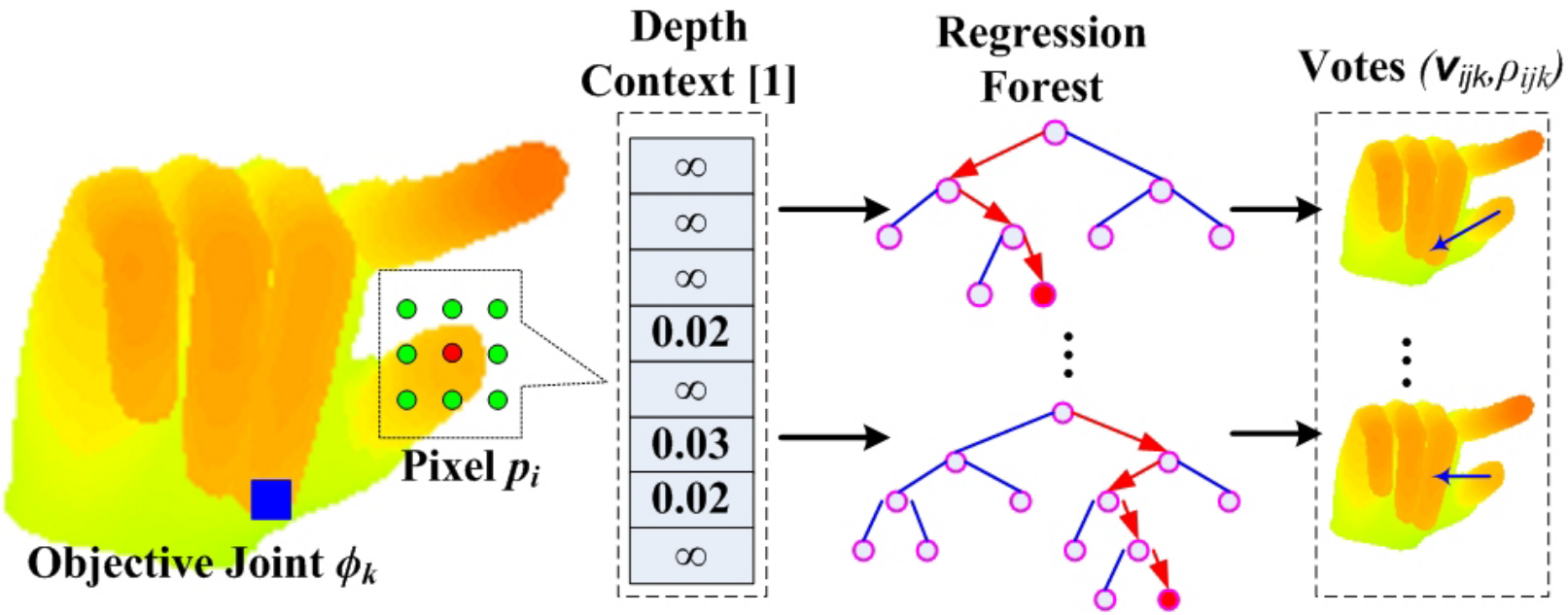
Demo: Hand Gesture Recognition





Regression forest = set of regression trees

Each tree can retrieve a vote (v_{ijk}, ρ_{ijk}) for each pixel p_i and each joint ϕ_k.

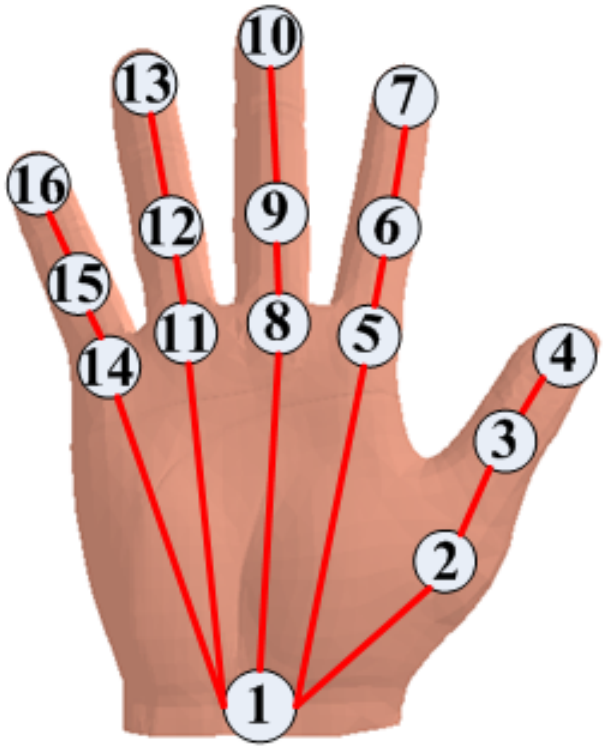


The Regression Forest (RF) proves very effective for articulated pose estimation

H. Liang, J. Yuan, D. Thalmann, **Parsing the Hand in Depth Images**, *IEEE Transactions on Multimedia*, Vol.16, No5, 2014, pp.1241-1253.

New Method

- Task: Predict the sixteen joint locations of the hand from single depth images
- The Regression Forest is utilized to get the per-pixel prediction votes for each hand joint
- Multimodal Prediction Fusion: Fuse the per-pixel predictions with the learned hand joint correlations
  - Learning the joint correlations: PCA analysis of the joint parameters $\boldsymbol{\Phi}$ in the training data
  - Seeking the optimal $\boldsymbol{\Phi}^*$ in this reduced dimensional space during testing



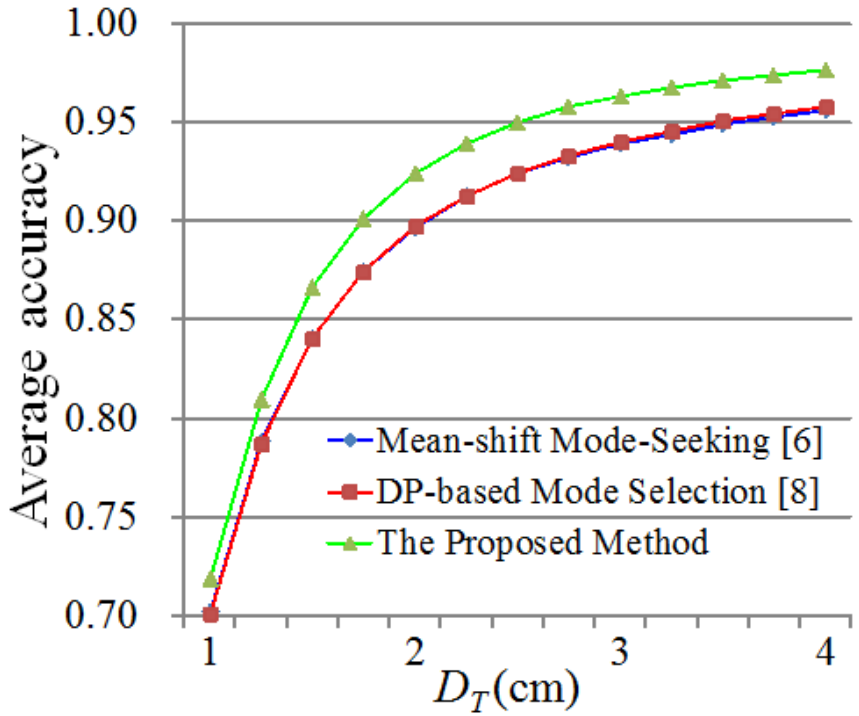
H. Liang, J. Yuan, D. Thalmann, **Resolving Ambiguous Hand Pose Predictions by Exploiting Part Correlations**, *IEEE Transactions on Circuits and Systems for Video Technology,* 2014 (to appear)

Quantitative Results

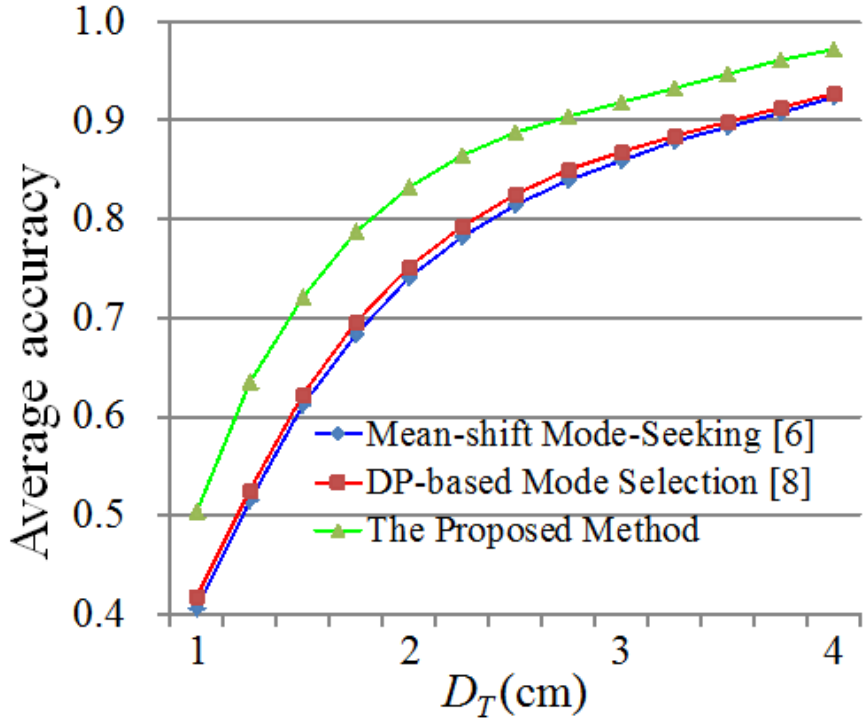
Training data: 90k synthesized depth images

Testing data: 23k synthesized and 600 real-world depth images

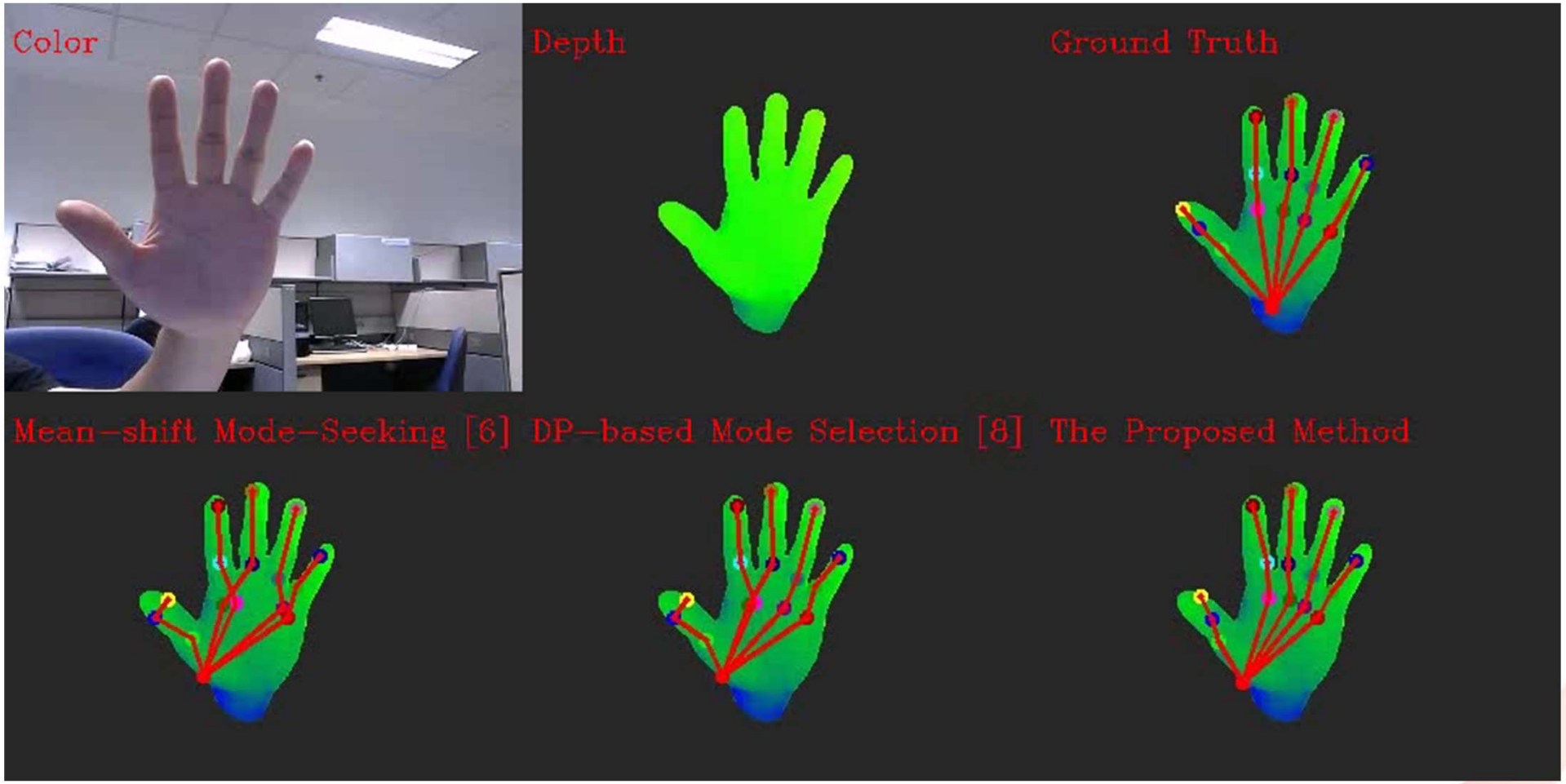
Evaluation Metric: average percentage of the predicted joints within a distance of D_T from the ground truth



Average prediction accuracies on synthesized data



Average prediction accuracies on real-world inputs


Color
Depth
Ground Truth
Mean-shift Mode-Seeking [6]
DP-based Mode Selection [8]
The Proposed Method

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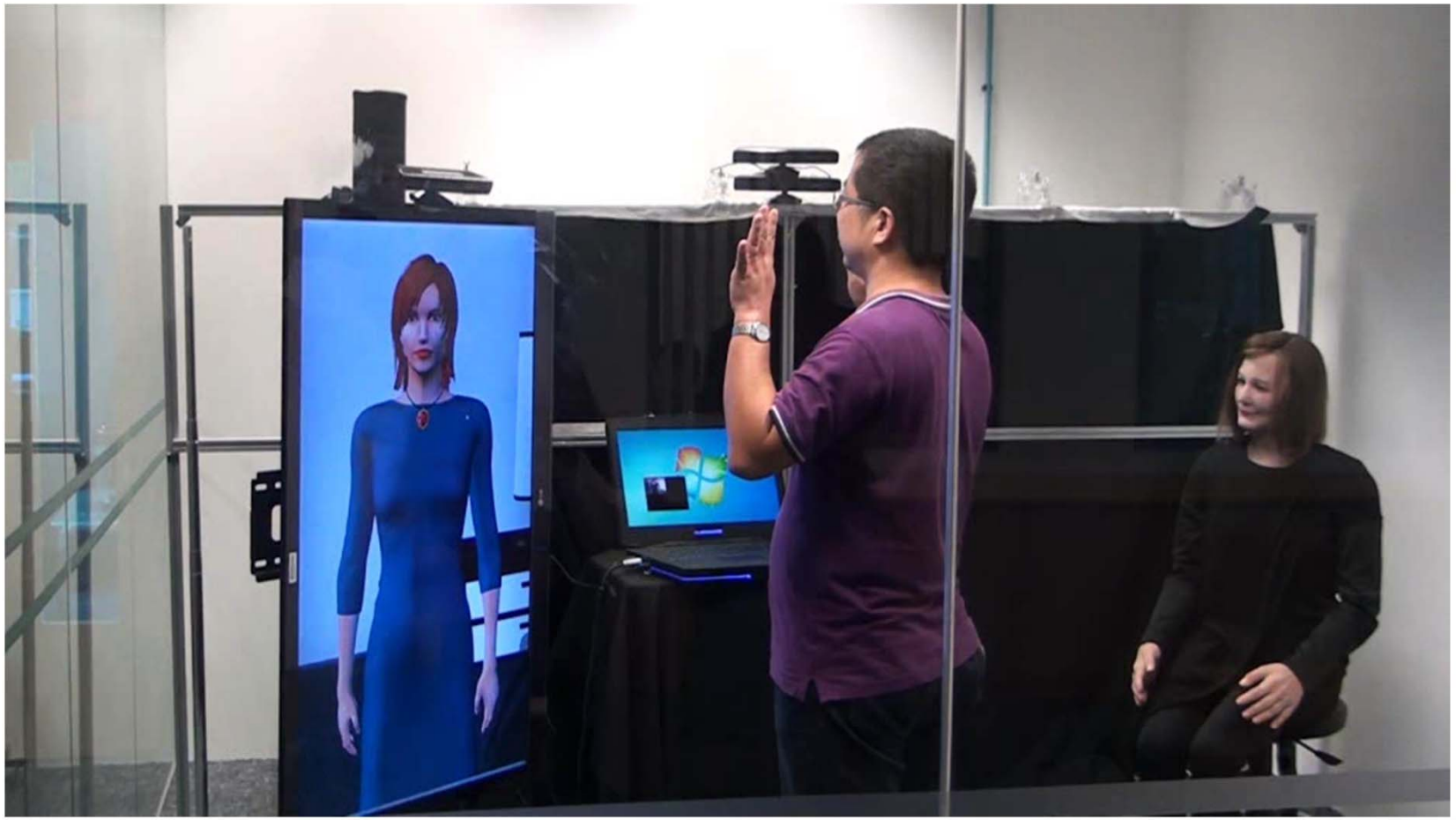
Applications



Dolphins for ASD Rehabilitation

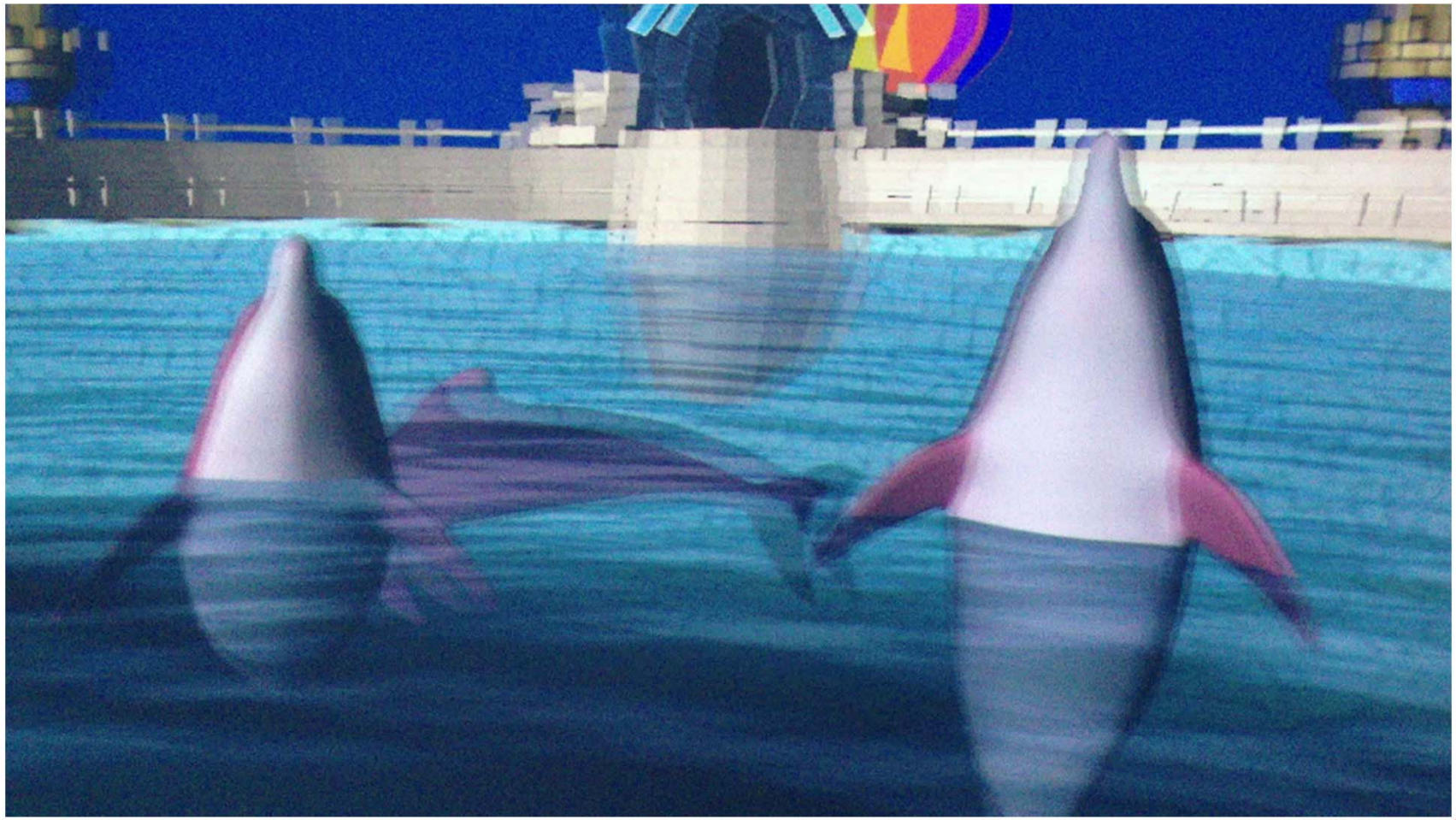
- Dolphin-assisted therapy (DAT), a structured program designed for ASD children (USA, Australia)
- L.N. Lukina (2001), On the question of rehabilitation of children with autistic syndrome using dolphin therapy procedures. Medichna reabilitsatsiya, kurortologiya, fizioterapiya. Vol. 2, pp. 24-27.

- Dolphin Encounter – A DAT program in Singapore
- Chia, Kee, Watanabe, & Poh (2009), *Journal of the American Academy of Special Education Professionals*.

Virtual Pink Dolphins for ASD Rehabilitation

- Immersive Virtual Environment in IMI/NTU
- 3D Virtual Pink Dolphins

- Replace the physical dolphins
- Immersive, Interactive, Serious Games
- Initial research with Special Schools on the use of Virtual Pink Dolphin for ASD Rehabilitation



Crowd Simulation

- Observation of interesting emergent behaviors, e.g., lane formations or panic effects, => crowd motion planning more realistic

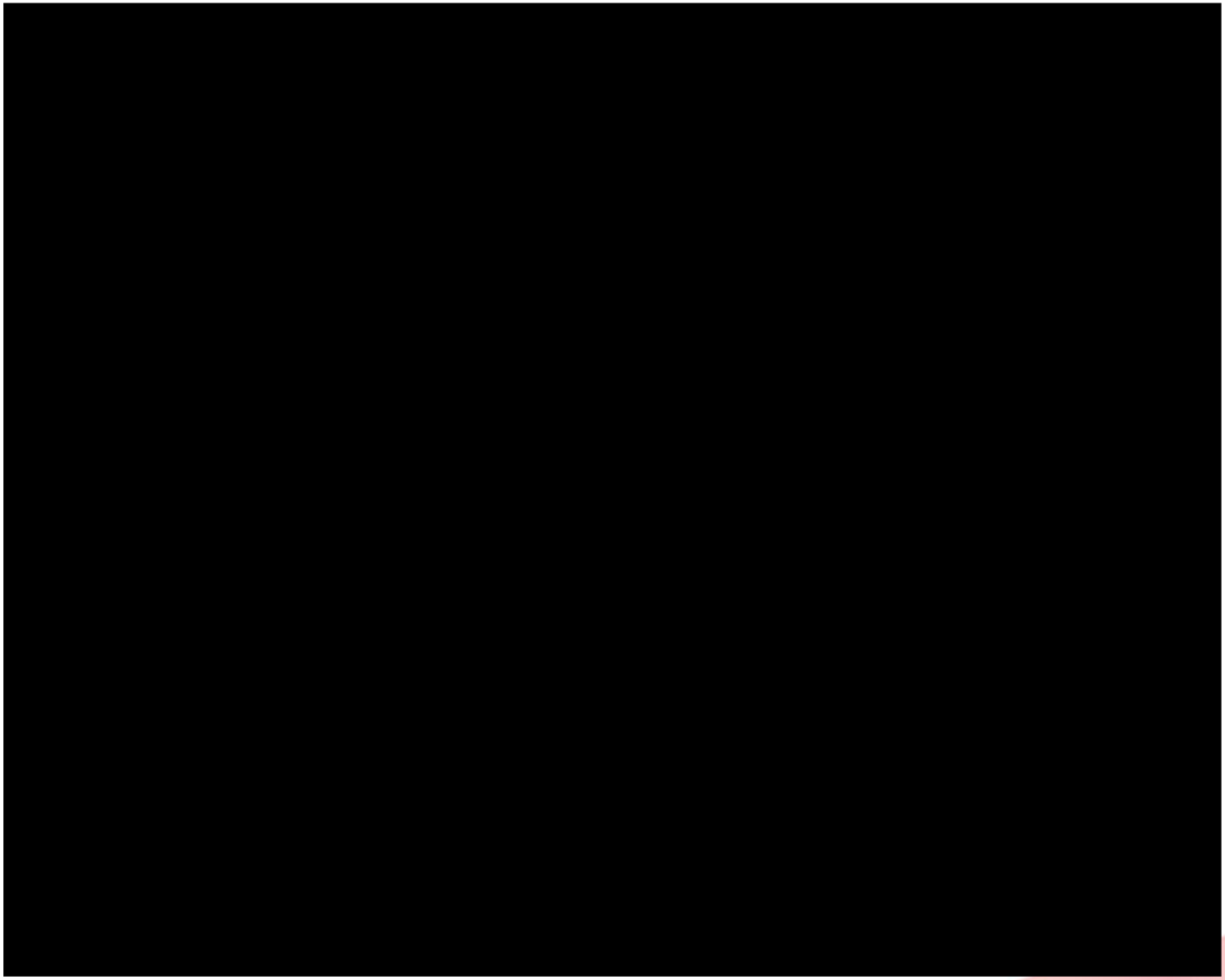
Interaction Design

- Natural interface for user
- Device
  - MS Kinect Sensor
- Method
  - Template-based gesture recognition
- Interactions
  - Walk
  - Pick
  - Direct
  - Gather
  - Disperse
  - Lead
  - Stop

Y.Wang, **R.Dubey**, N.Magnenat-Thalmann, D.Thalmann, **Interacting with the Virtual Characters of Multi-Agent Systems**, *The Visual Computer*, 2013

Two scenarios

- gathering the agents to a specific orientation.
- making agents disperse after gathering around the avatar




Thank you for your attention..
Questions ?…