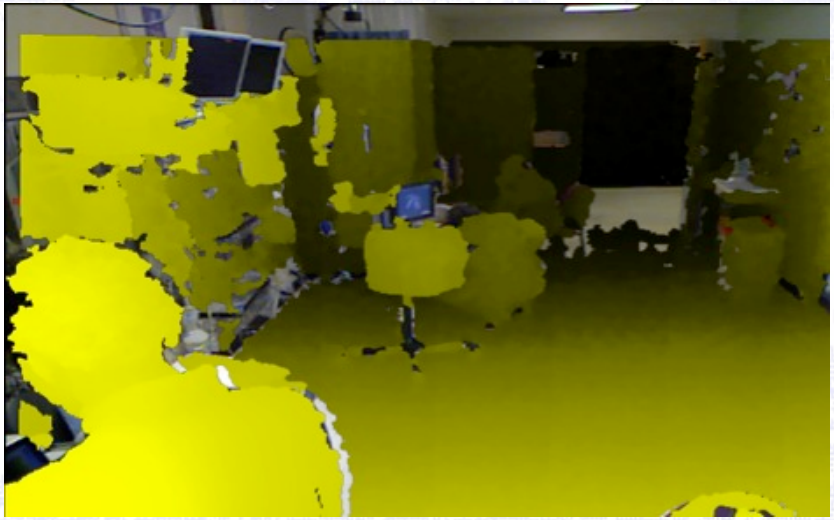
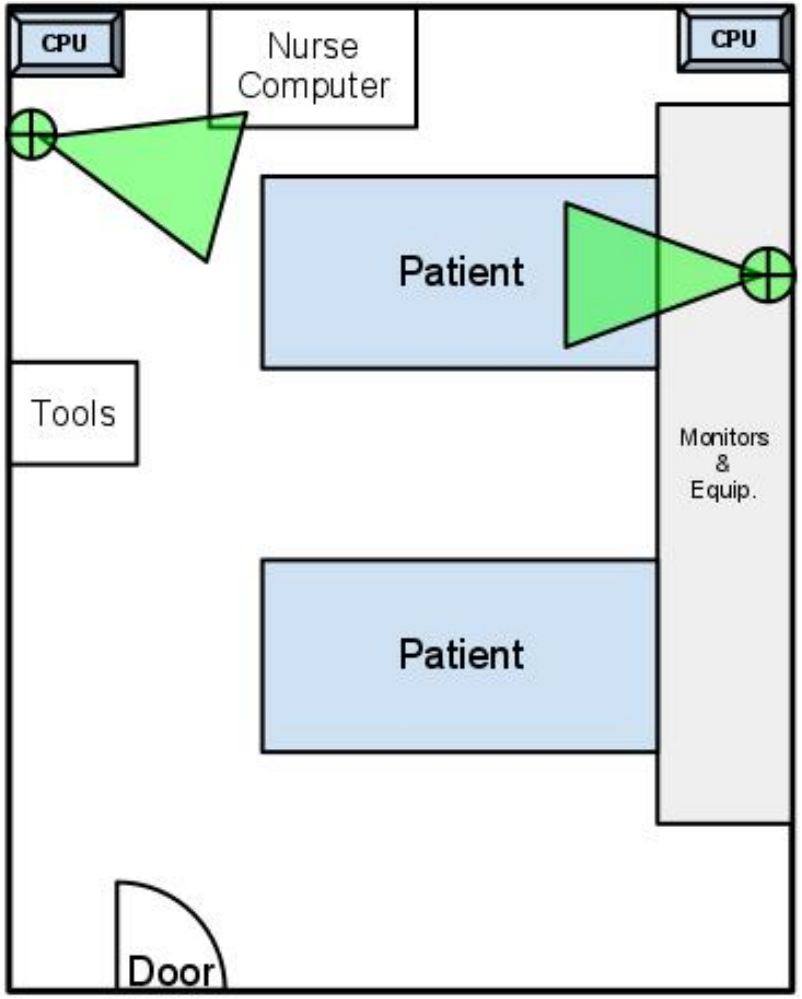
AWARE@ICU

Colin Lea

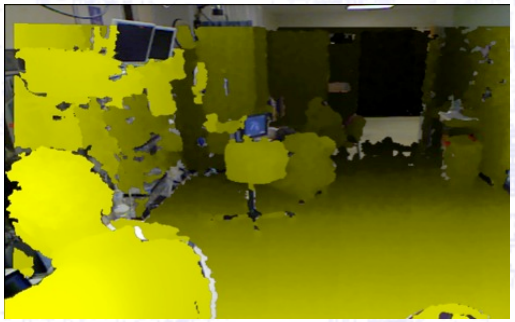
Automated **W**orkflow and **A**ctivity **Re**cognition
CIS2 Paper Presentation #10

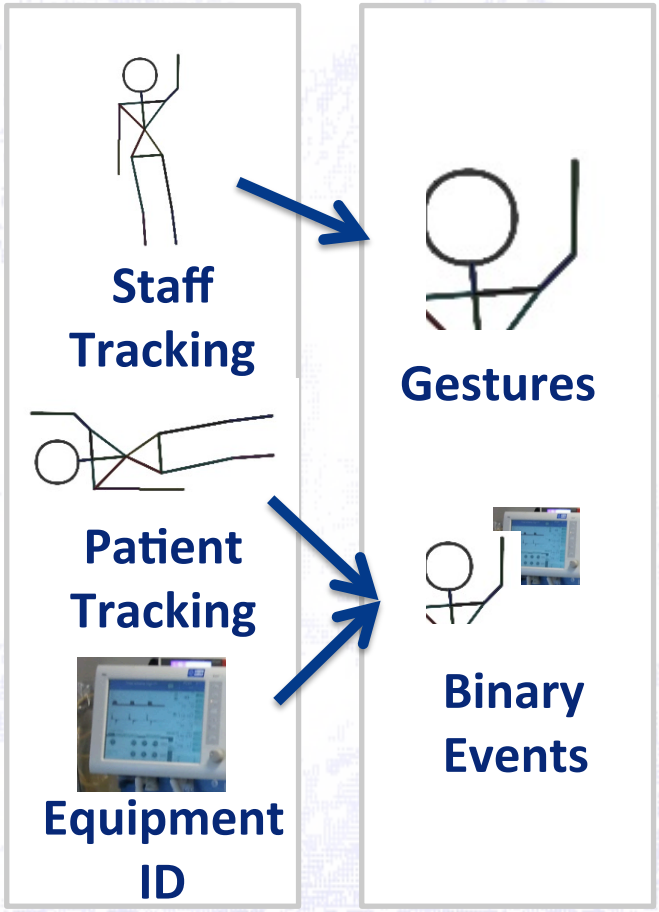
overview

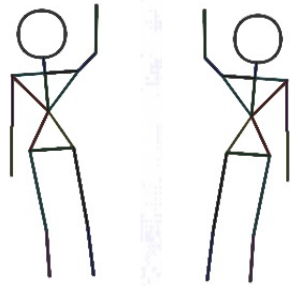



CPU
Nurse Computer
CPU
Patient
Tools
Monitors & Equip.
Patient
Door

activity pipeline



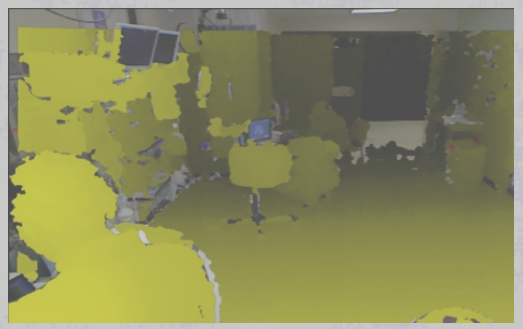




i.e. "Greeting"

Raw Signal **Derived Signals** **Action**

activity pipeline



Staff Tracking

Patient Tracking

Equipment ID

Gestures

Today's Focus

Binary Events

i.e. "Greeting"

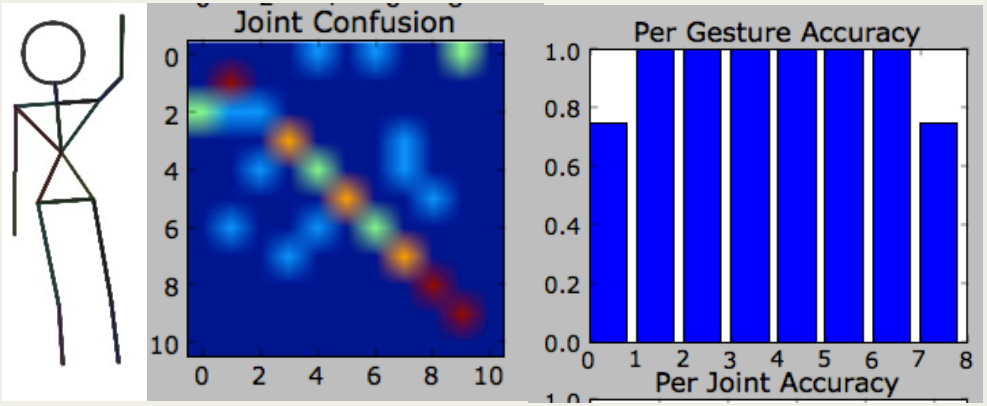
Raw Signal **Derived Signals** **Action**

models

Action Recognition

Staff gestures

- Determine sub-actions
  - i.e. Inserting tube
- Correlate input w/ each known gesture's PCA basis
- Temporal window?



Current results

Activity Logger

- Fuse all derived signals and output "action"
- Time-series graphical model (i.e. CRF, S-LDS, HMM)

Patient Body Tracker

- Establish metric for "unsafe" motion
- Track body over time
- Trigger alert (and log) when problematic

gesture literature @ TUM

Authors: **Ali Bigdelou,** Tobias Benz, Loren Schwarz, Nassir Navab

1) Simultaneous Categorical and Spatio-Temporal 3D Gestures Using Kinect, *(3DUI'12)*

2) An Adaptive Solution for Intra-Operative Gesture-based Human-Machine Interaction, *Intelligent User Interfaces (ICIUI'12)*

3) Learning Gestures for Customizable Human- Computer Interaction in the Operating Room, *MICCAI'11*

idea

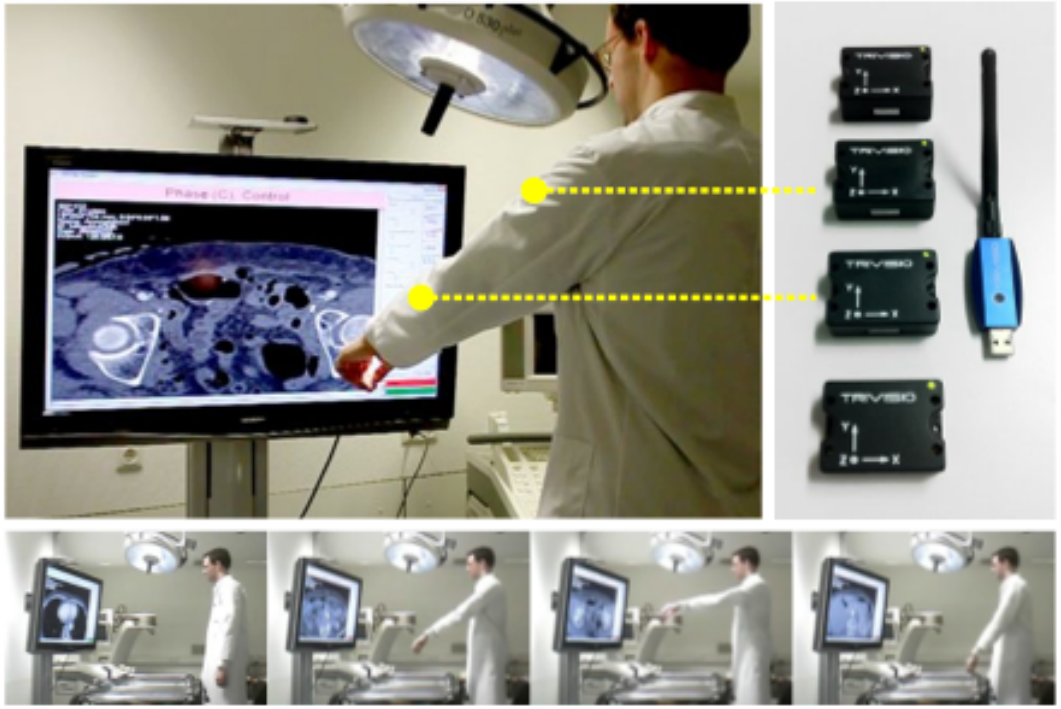
[Bigdelou, MICCAI'11]

Learn and identify a set of continuous gestures for manipulating medical imagery

idea

Video

sensing modalities



[Bigdelou, MICCAI'11]

Kinect

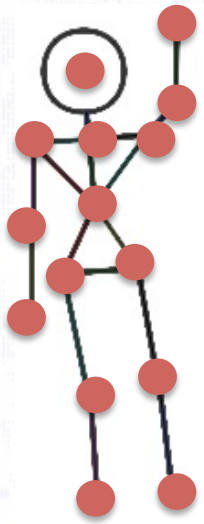
IMUs

problem

1) Lots of data!

Kinect: 15 joints * (X,Y,Z) = 45 dimensions

IMUs: 4 devices * Quaternion = 16 dimensions



Solutions:

Dimensionality reduction:

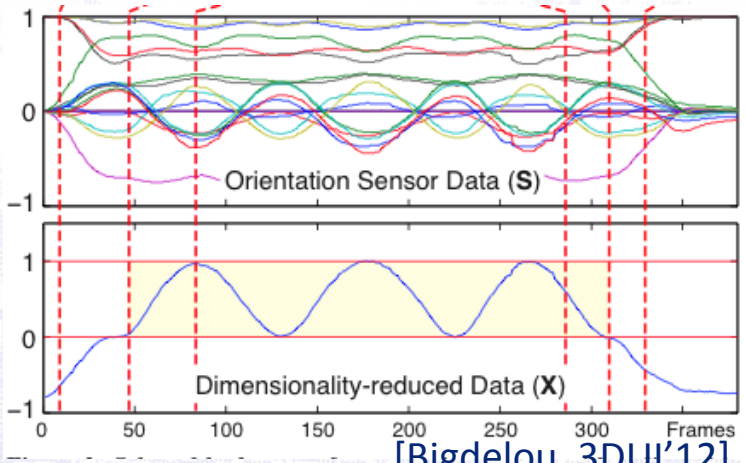
- PCA + Max Likelihood
- Manifolds + Particle Filter +Max Likelihood

2) Phase detection

Normalized spatial value

Solution:

- Kernel Regression Map

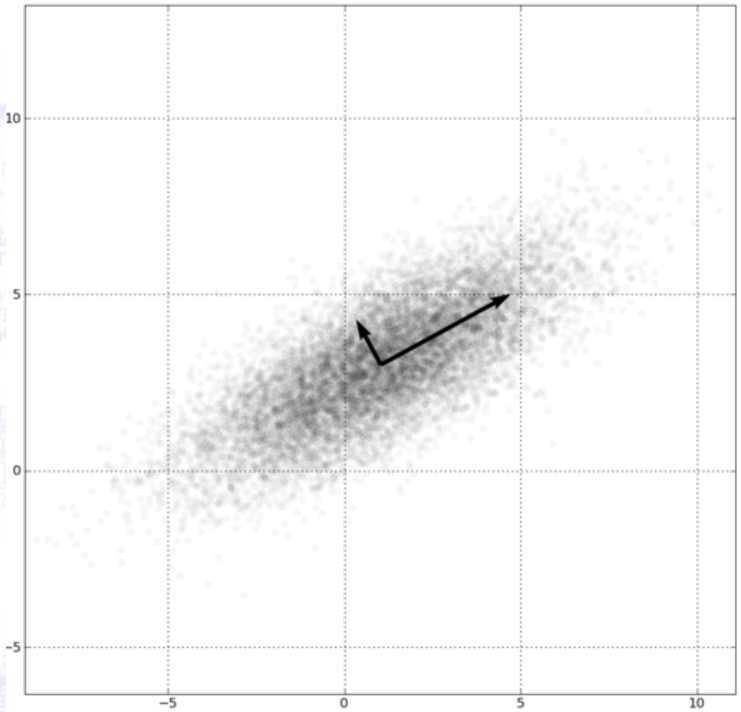


[Bigdelou, 3DUI'12]

dimensionality reduction

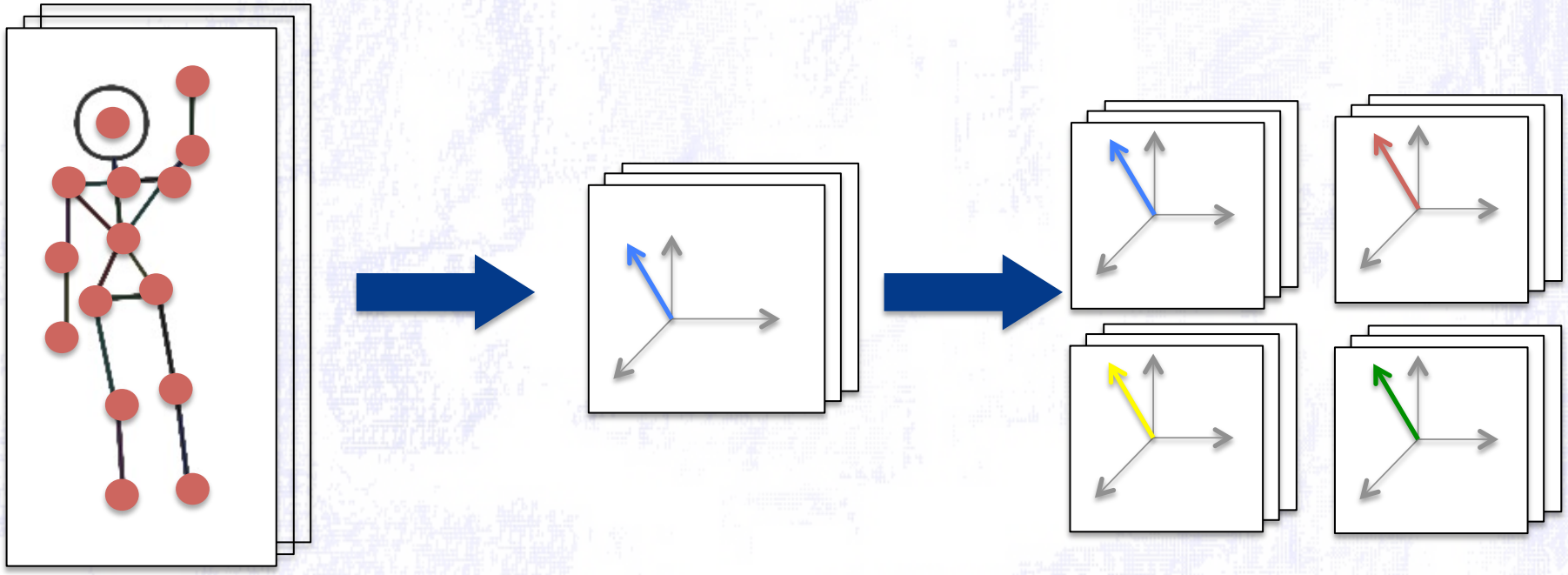
Principal Components Analysis

Intuition: Find the greatest variance in the data!



[Wikipedia]

dimensionality reduction

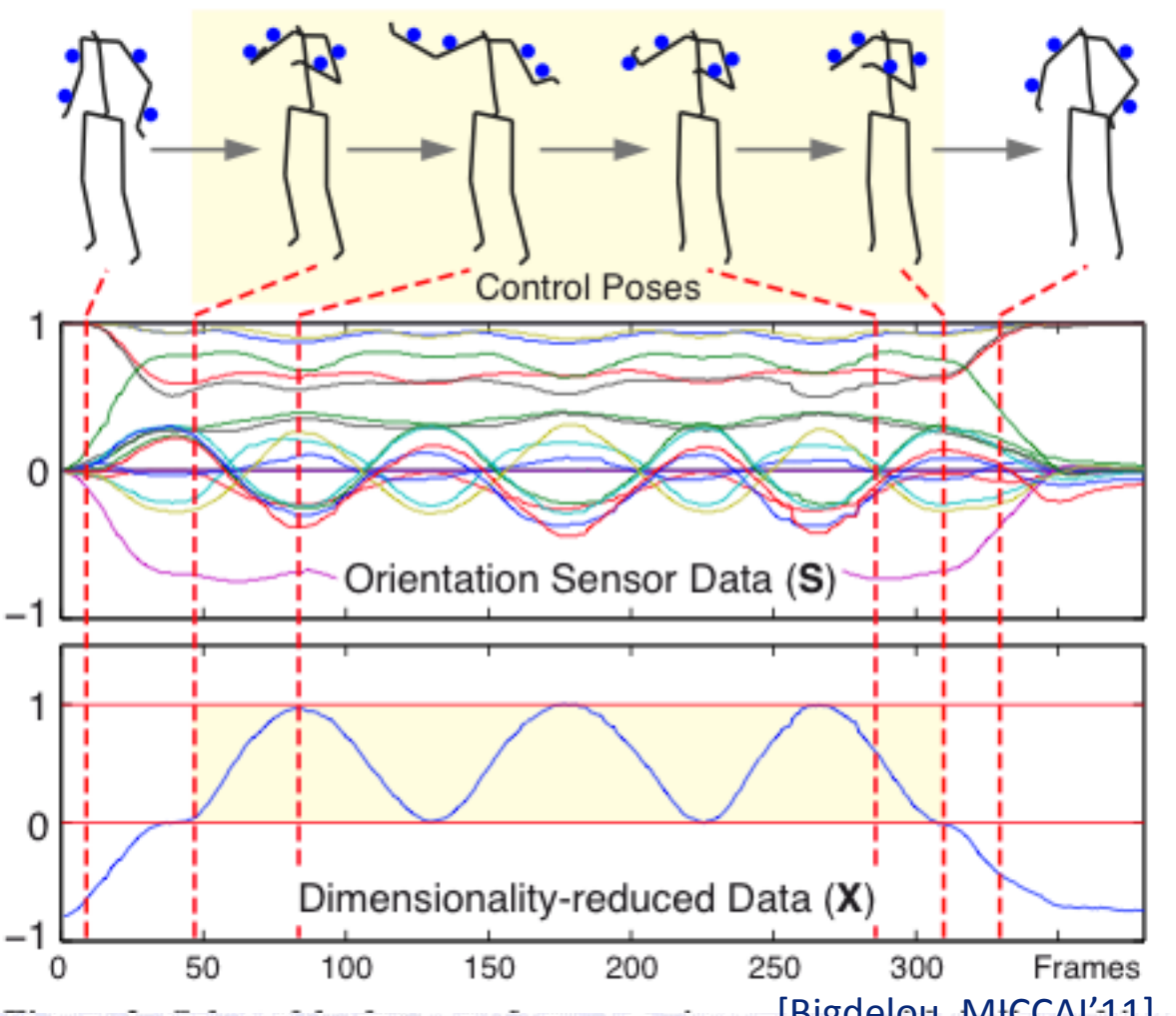


All gesture poses

Per class PCA component

Per class normalization

dimensionality reduction



[Bigdelou, MICCAI'11]

kernel regression

Intuition: weight test data with each of the training data

Calculate normalized value:

$$\hat{x}_t = f(\mathbf{s}_t) = \sum_{i=1}^{n} \frac{w_i(\mathbf{s}_t)}{\sum_{j=1}^{n} w_j(\mathbf{s}_t)} \cdot x_i.$$

Calculate weights:

$$w_i(\mathbf{s}_t) = \mathrm{k}(\mathbf{s}_t, \mathbf{s}_i) = \exp(-\tfrac{1}{2}\|(\mathbf{s}_t - \mathbf{s}_i)/\sigma\|^2)$$

Calculate class:

$$\hat{c}_t = c_{k_t}, \quad \text{where} \quad k_t = \arg\max_i w_i(\mathbf{s}_t).$$

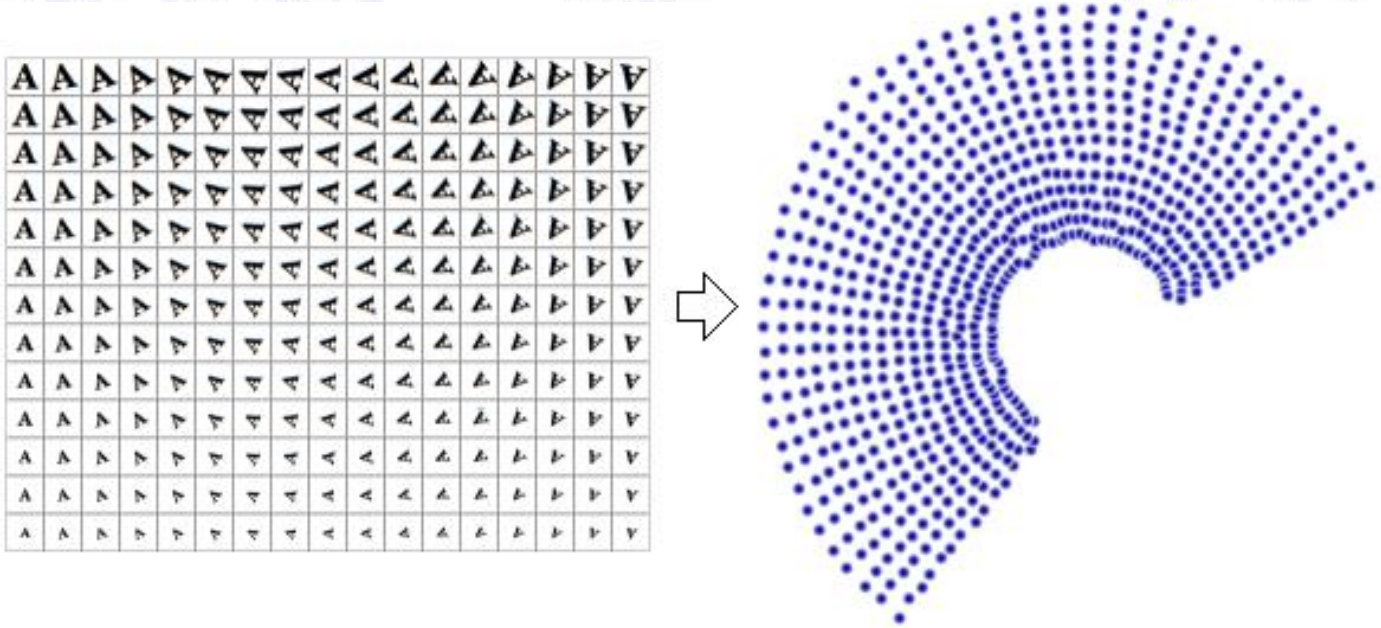
Smooth weights

$$\bar{w}_i(\mathbf{s}_t) = w_i(\mathbf{s}_t) \cdot \exp(-\frac{1}{2}((i - k_{t-1})/\sigma)^2).$$

dimension reduction

Manifold learning

Intuition: Find linear embedding from non-linear space

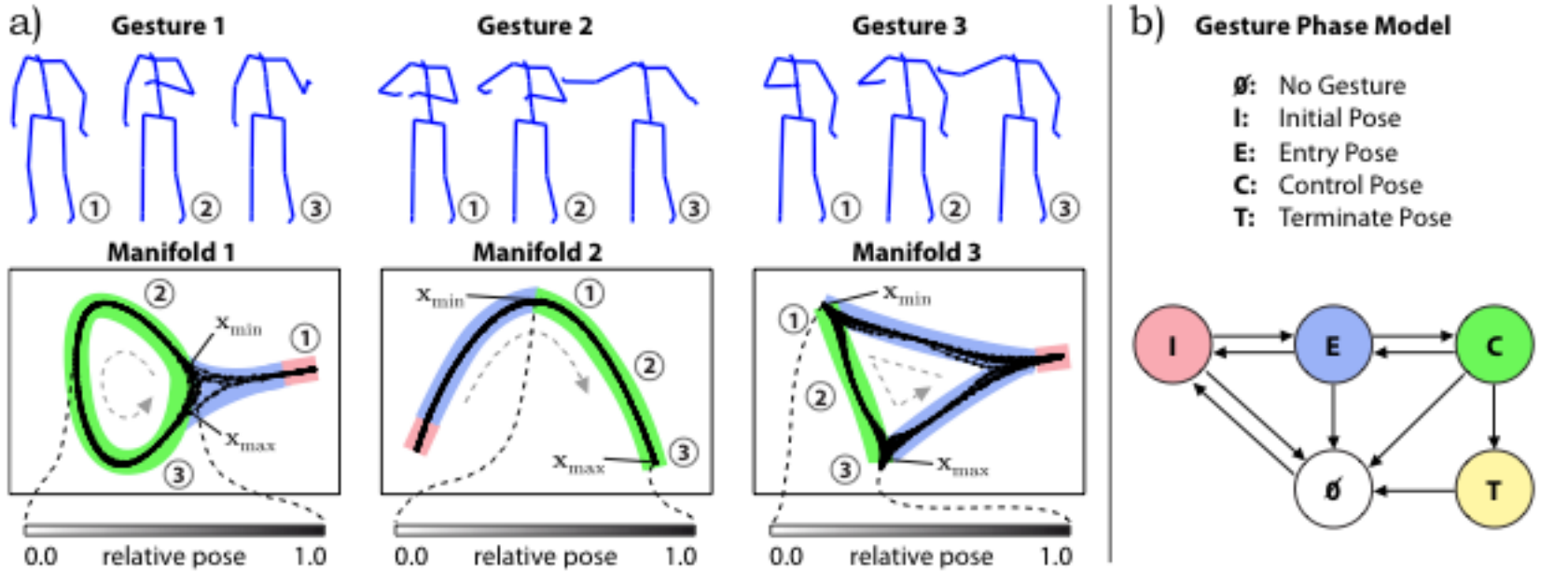


[Wikipedia]

dimension reduction

Laplacian Eigenmaps (16 dim to 2 dim)

1) Find nearest neighbors
2) Calculate "commute" time between each neighbor
3) Compute eigenvalues of commutes



[Bigdelou, MICCAI'11]

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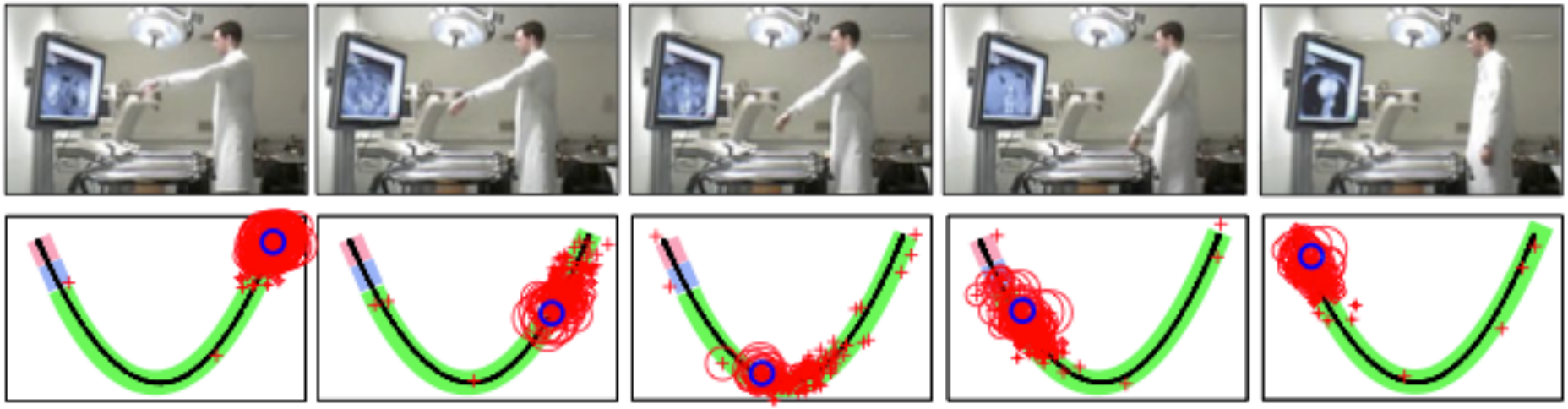
tracking

Particle filter

Intuition: Estimate class from sampling of prior distributions



[Bigdelou, MICCAI'11]

tracking

Particle filter

$$p(\mathbf{s}_t|c_t^i, \mathbf{x}_t^i) \propto \mathcal{N}(g_{c_t^i}(\mathbf{x}_t^i); \mathbf{s}_t, \mathrm{cov}(\mathbf{S}^{c_t^i})) \, \mathcal{N}(f_{c_t^i}(\mathbf{s}_t); \mathbf{x}_t^i, \mathrm{cov}(\mathbf{X}^{c_t^i}))$$

Prob of sensor reading for each class/embedding

Sample current embedded value centered at each training point (pose space)

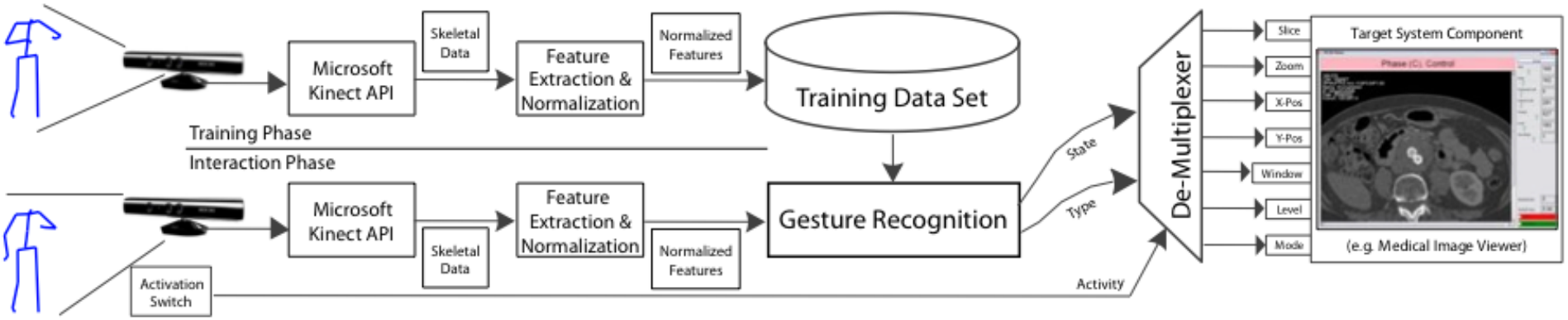
Sample current pose value centered at training point (embedded space)

x = embedding s = pose g(): x -> s f(): s -> x

Then:

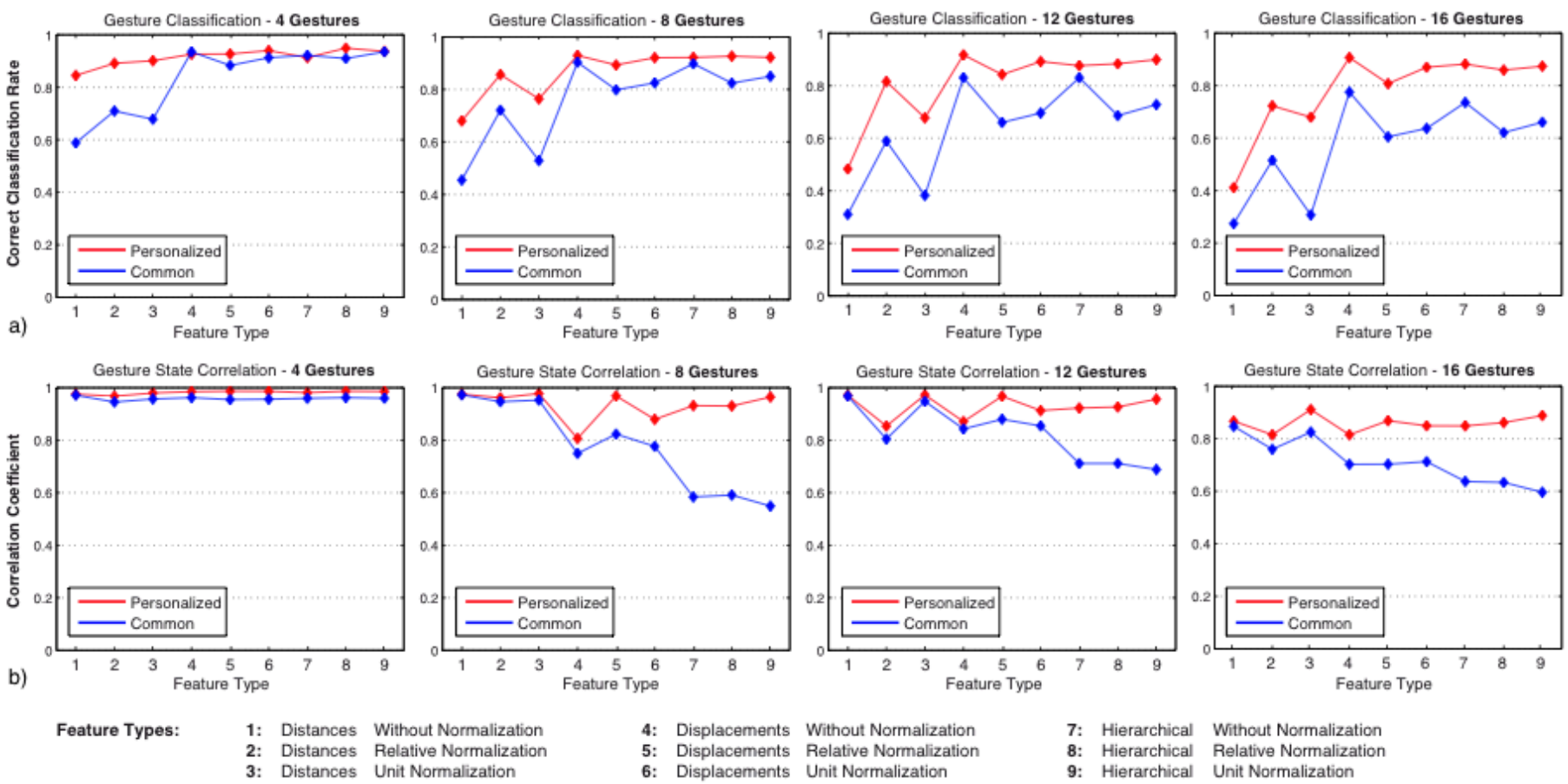
- Calculate max likelihood of classes
- Average x over estimated class

pipeline



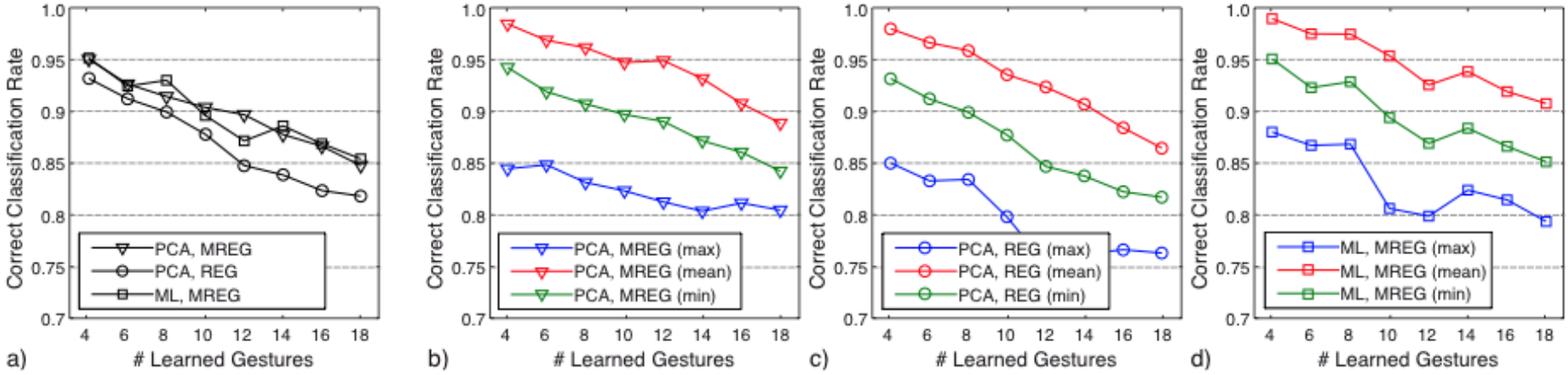
[Bigdelou, 3DUI'12]

kinect results



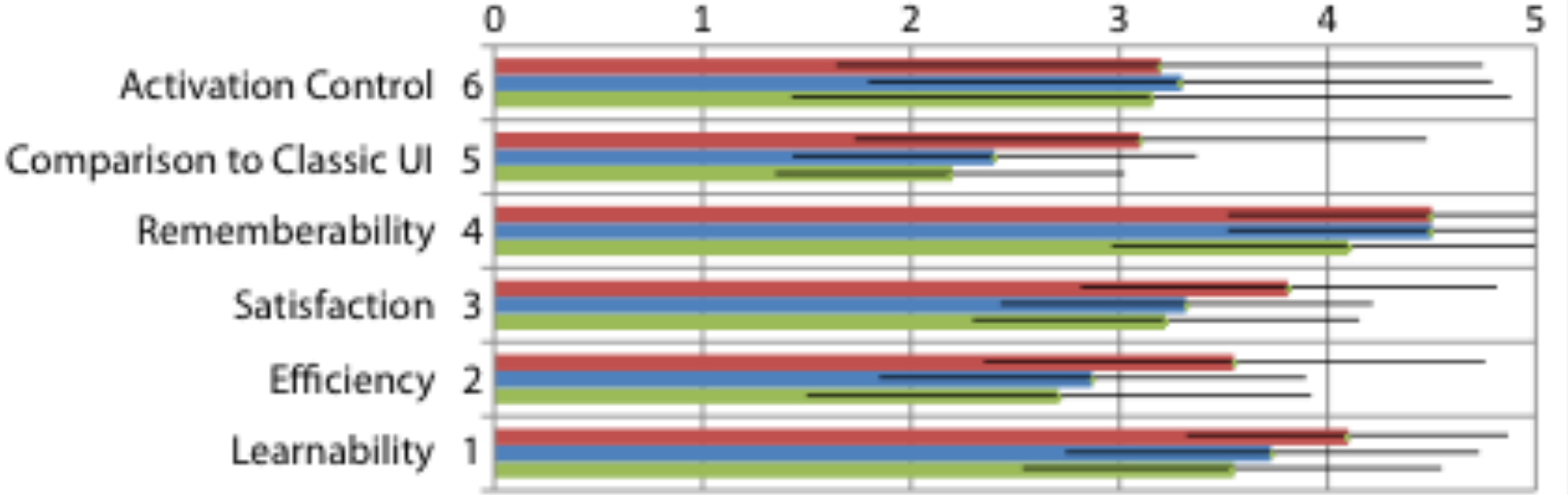
[Bigdelou, 3DUI'12]

imu results



[Bigdelou, MICCAI'12]

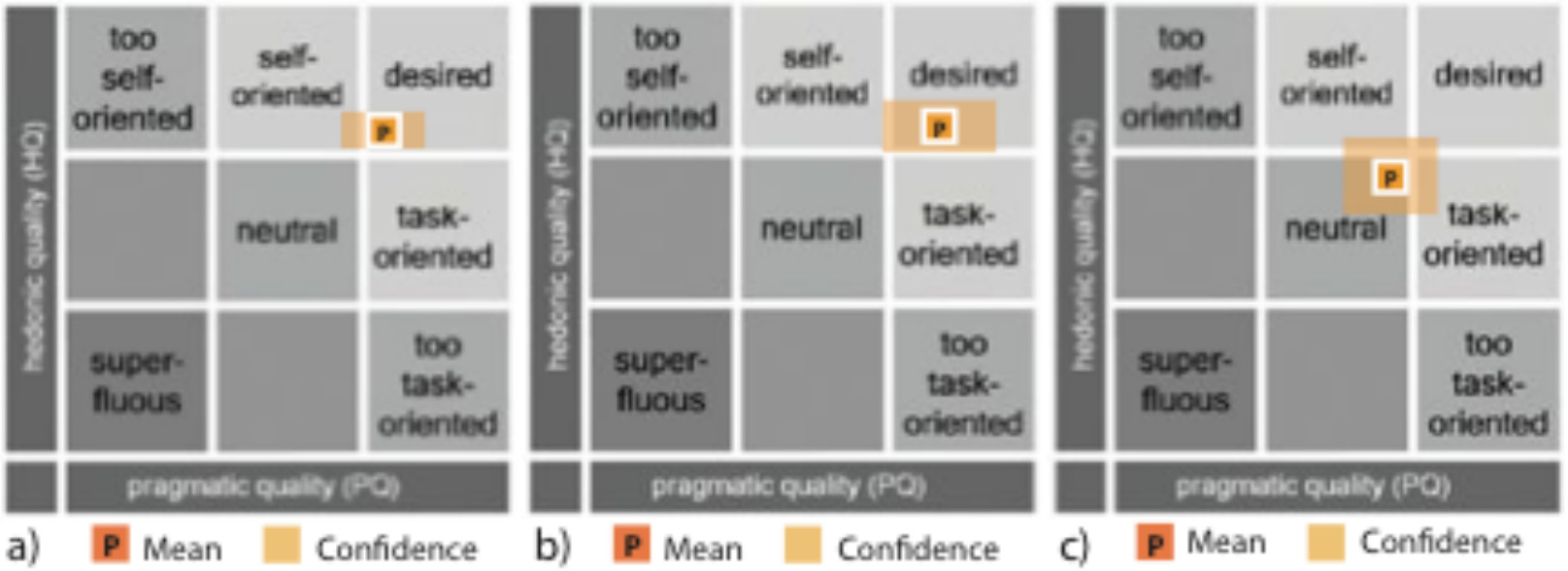
user study



	1	2	3	4	5	6
Personalized Learning	4.1	3.55	3.81	4.5	3.1	3.2
Common Learning	3.73	2.87	3.32	4.5	2.4	3.3
Inertial Sensors	3.55	2.708	3.22	4.1	2.2	3.16

[Bigdelou, 3DUI'12]

user study



[Bigdelou, 3DUI'12]

Kinect
Common Data Set

Kinect
Personalized Data Set

IMU

Questions?