Online Recognition of Daily-Life Movements

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Background

Collaborative Research Center 588

Humanoid Robots - Learning and Cooperating Multimodal Robots

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- Understanding
- Cooperating
- Learning

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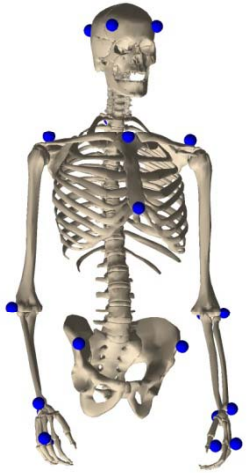
→ What is the user doing?

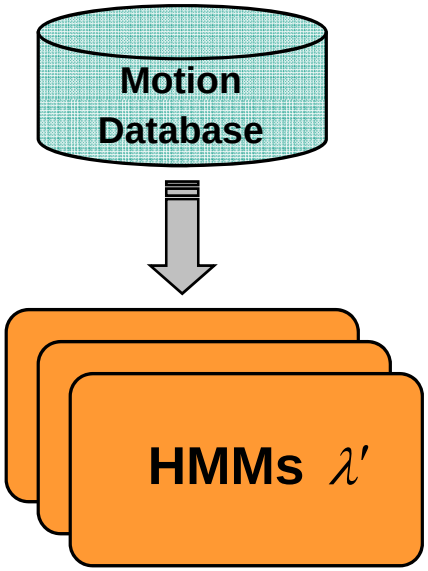
- Needed: motion recognition system

Motion Recognition System

Live tracking by VICON



Mapping on human model



Online motion recognition with Hidden Markov Models

Recognition of user motion → e.g. *„stirring“*

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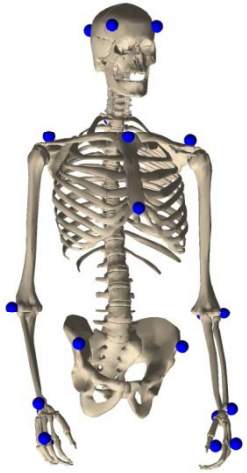

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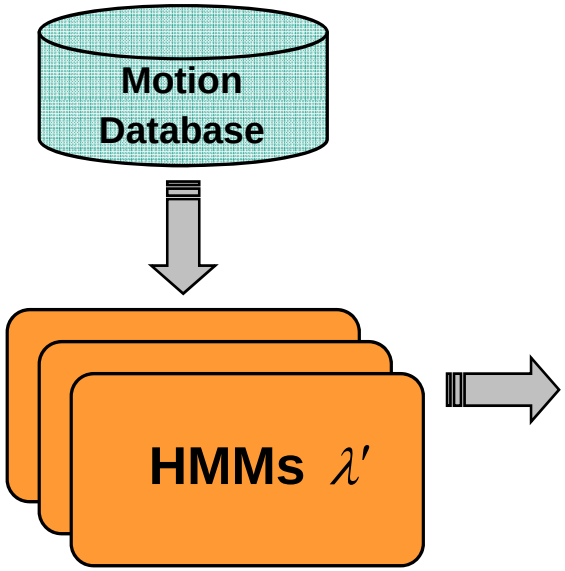

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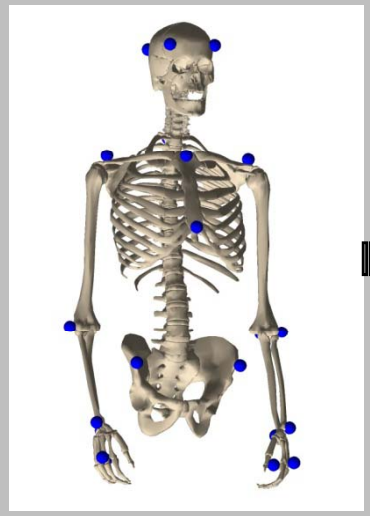

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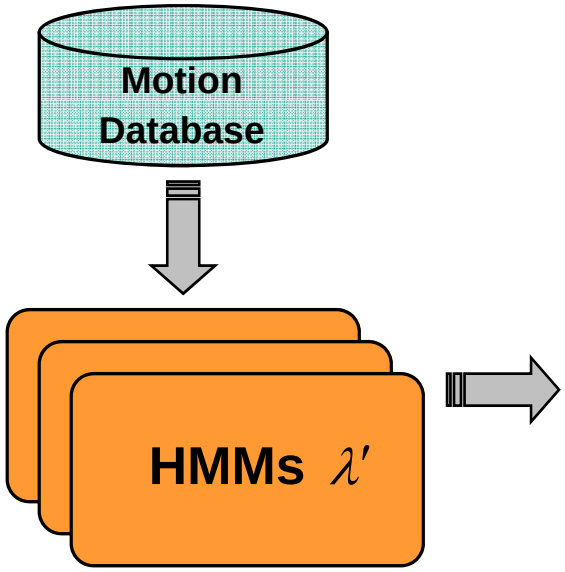

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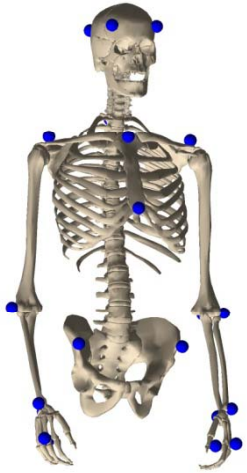

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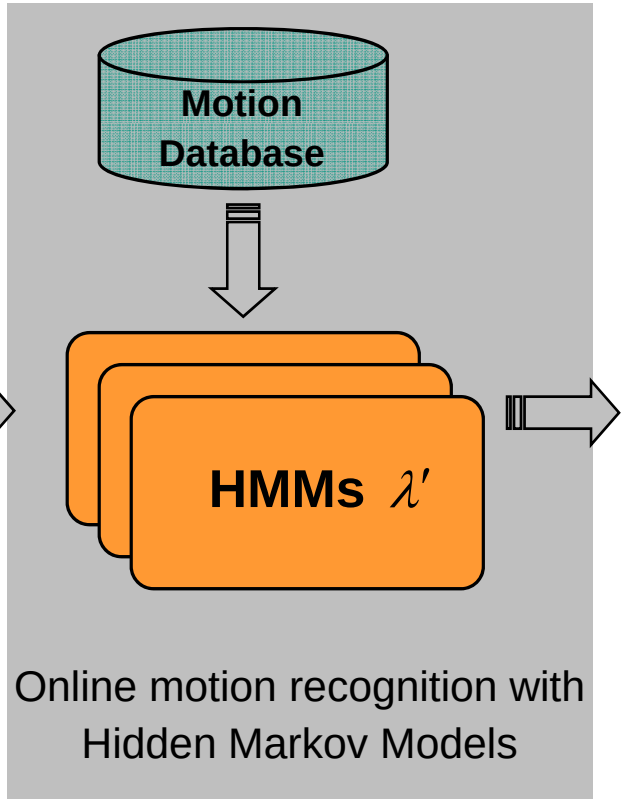


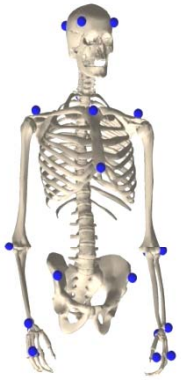
Online motion recognition with Hidden Markov Models

Recognition of user motion → e.g. *„stirring“*

Data acquisition

Live tracking by VICON

3D-Marker-positions



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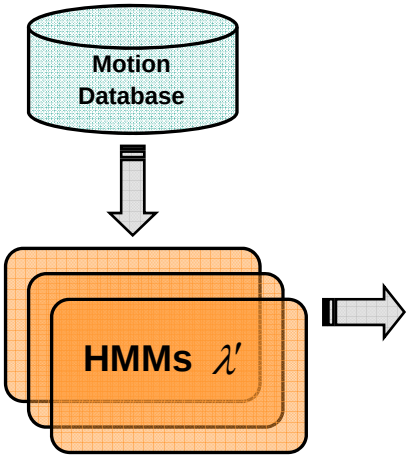

Online motion recognition with Hidden Markov Models

Recognition of user motion → e.g. *„stirring“*

Motion Capture with Vicon

- BioMotion Center: Vicon system

Motion Capture with Vicon

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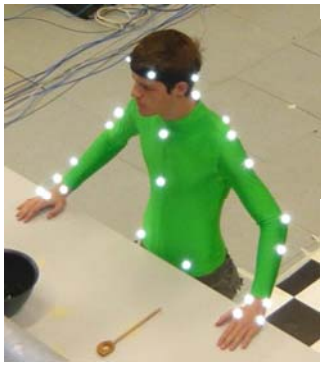
- 8 – 12 infra-red cameras
- Design of different marker sets

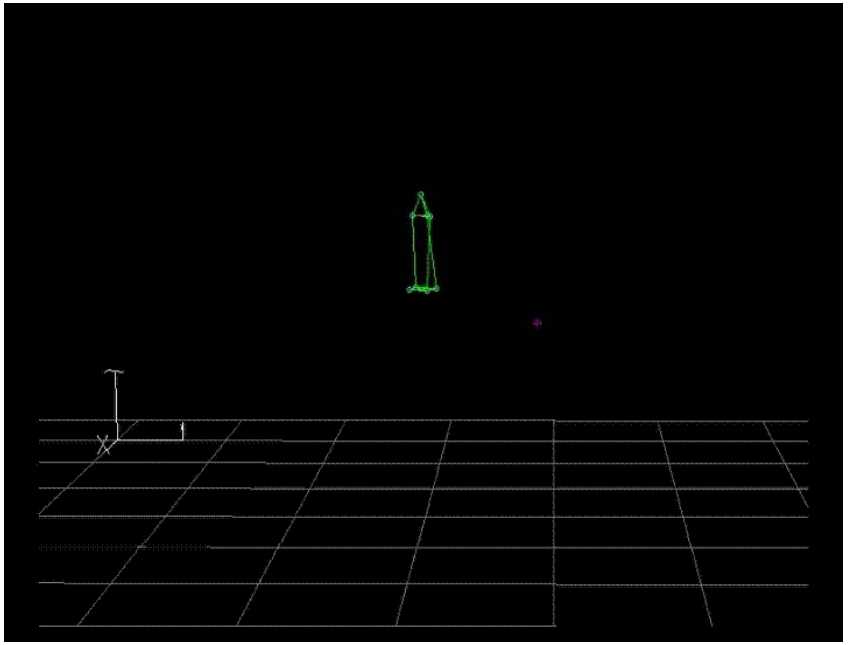
Motion Capture with Vicon

- BioMotion Center: Vicon system
- 8 – 12 infra-red cameras
- Design of different marker sets
- Marker motion Capture with Vicon
  - 2D marker positions from every camera
  - reconstruction of 3D position
  - marker labeling



Motion Capture with Vicon

Example: Motion capture setting

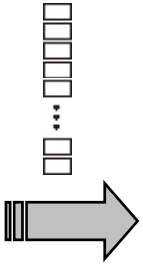


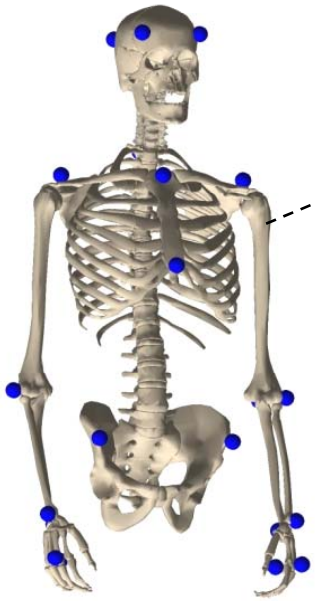
Result: Vicon record

Joint angle generation

Livetracking with VICON

3D-Marker-positions

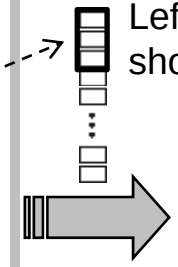


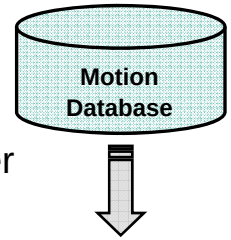


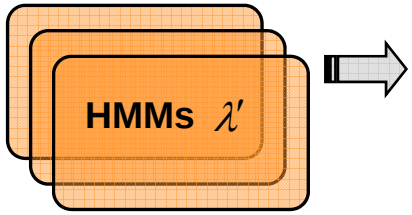
Mapping on human model

Joint angles

Left shoulder







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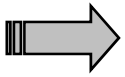
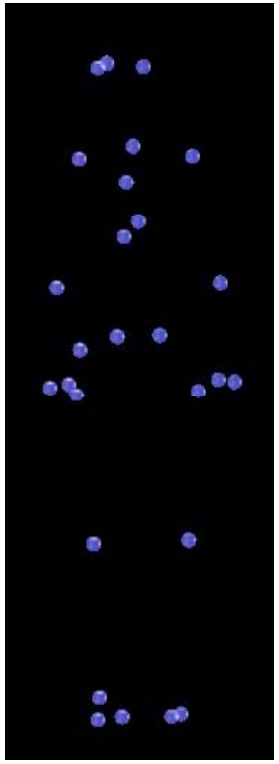


Recognition of user motion → e.g. „*stirring*“

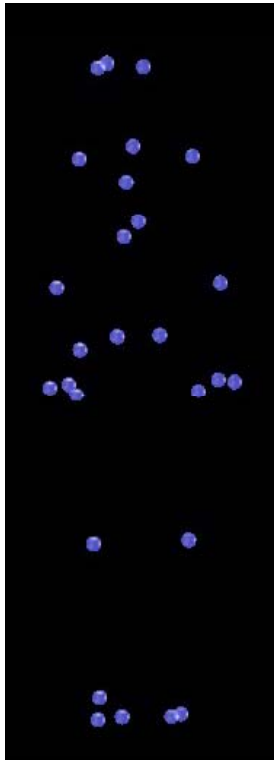
Estimation of joint angles



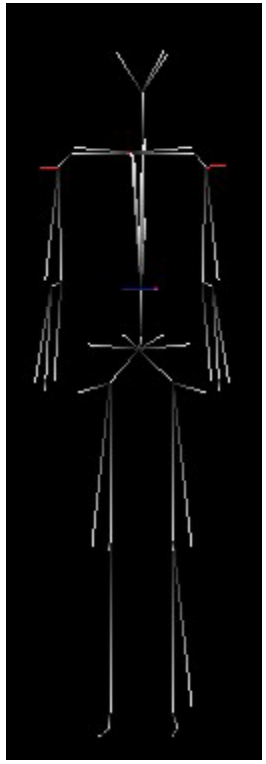
Input:

3D marker positions

Estimation of joint angles



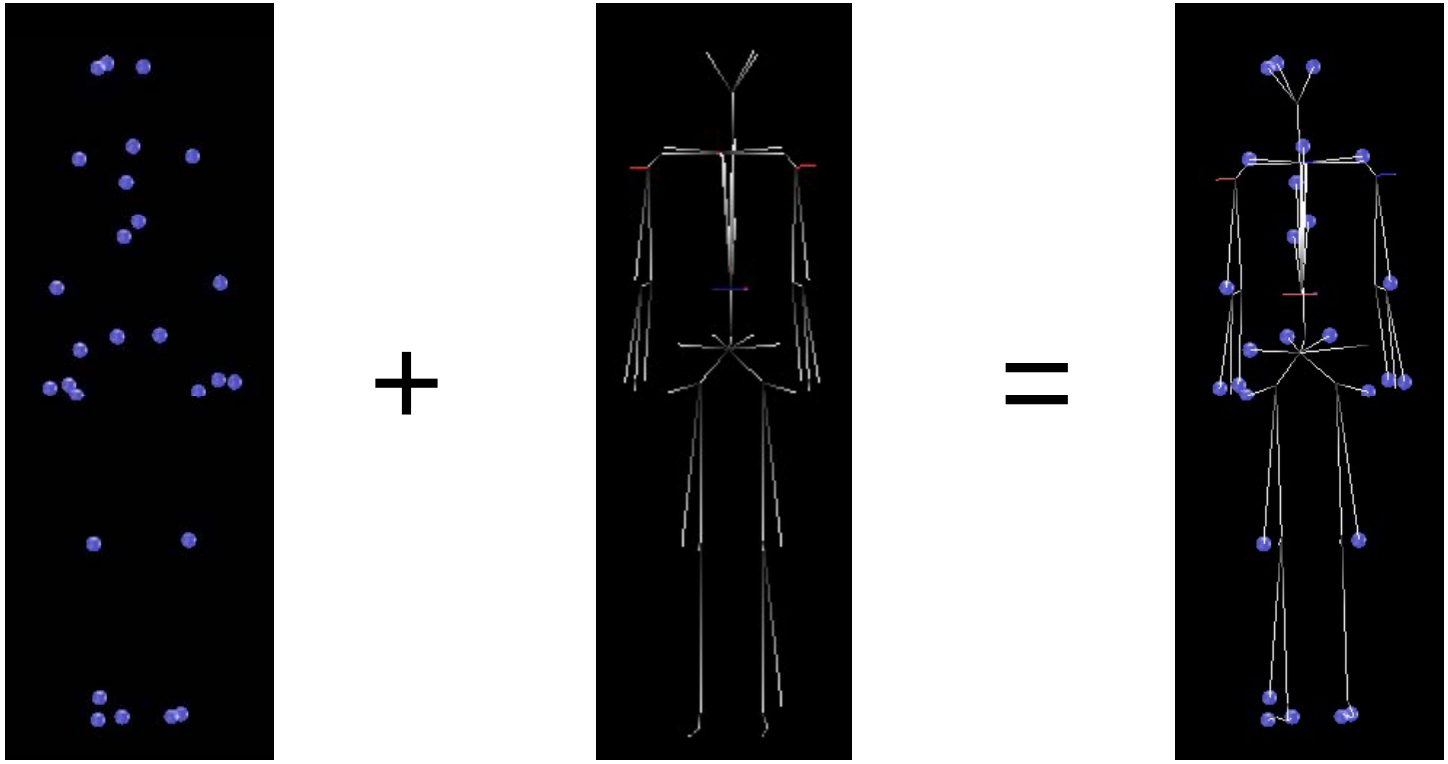
+



Input:
3D marker positions

Human model with
markers and joints

Estimation of joint angles



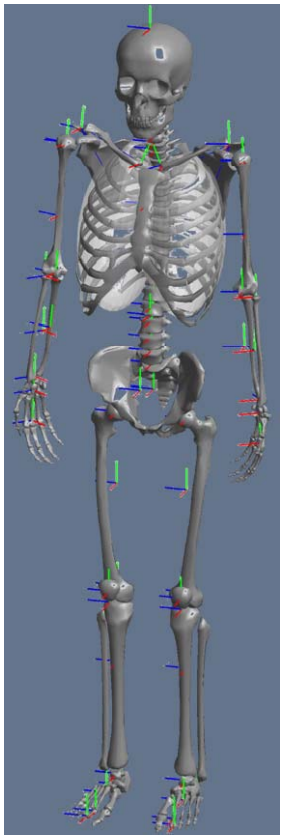
Input:
3D marker positions

Human model with
markers and joints

Pose
reconstruction

CRC 588 Human Model

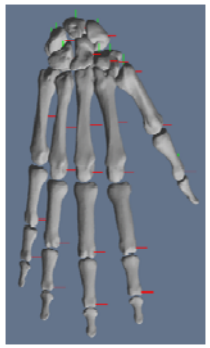
Kinematic human model



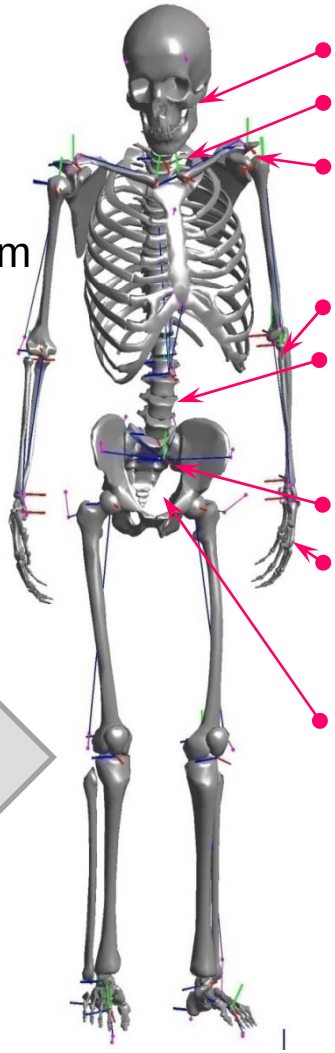
- full definition of the human body:

→maximum of 108 degrees of freedom

- following real human joint kinematic
- basis for reduced models, marker sets and joint angle reconstruction



Example with reduced degrees of freedom (DOFs)



⇒ 30 DOFs used

Estimation of joint angles

Main Idea

- Optimize the joint angles of the model so, that the distance of the actual marker set and the result of the forward kinematics of the reconstructed pose becomes minimal:

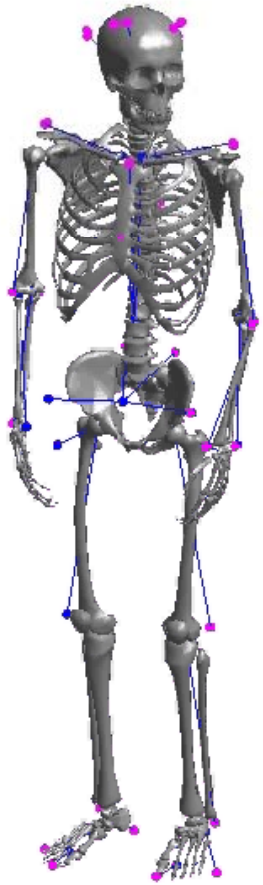
$$d(x, x_0) = \sqrt{(x_a - x_{0a})^2 + (x_b - x_{0b})^2 + (x_c - x_{0c})^2}$$

$$\min \sum_{x \in X} (d(x, x_0) \times weight(x_0))^2$$

X : the set of the result of the forward kinematics

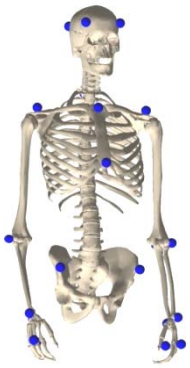
$weight(x_0)$: the weight of the markers

→ Reconstructed body pose / motion



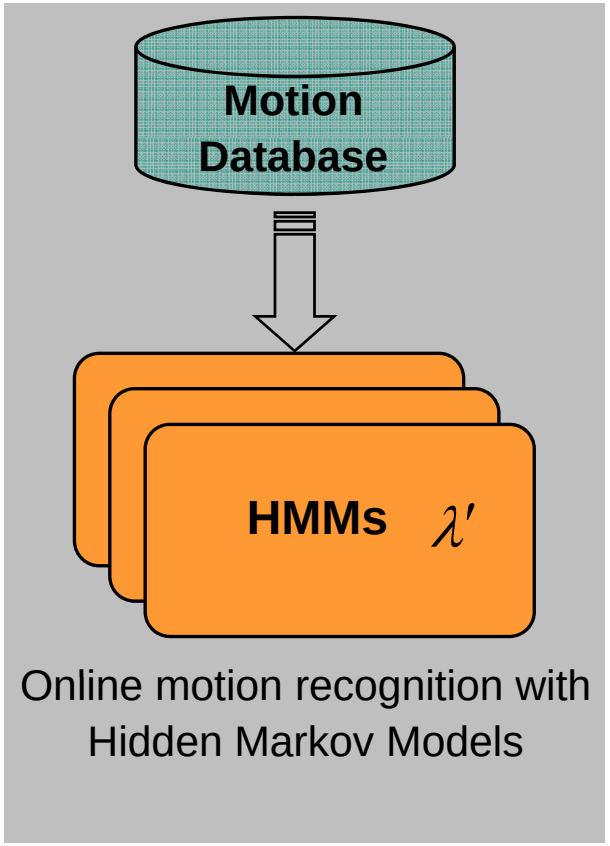
Motion recognition

Live tracking with VICON



Mapping on human model

Joint angles



Motion probabilities

Recognition of user motion → e.g. *„stirring“*

Problem: human motion

- Every motion sequence is unique
  - Individual characteristics
    → Anatomie, mental condition, concentration…
  - Environmental conditions
    → Utensils (bags, etc…), interaction with other subjects …

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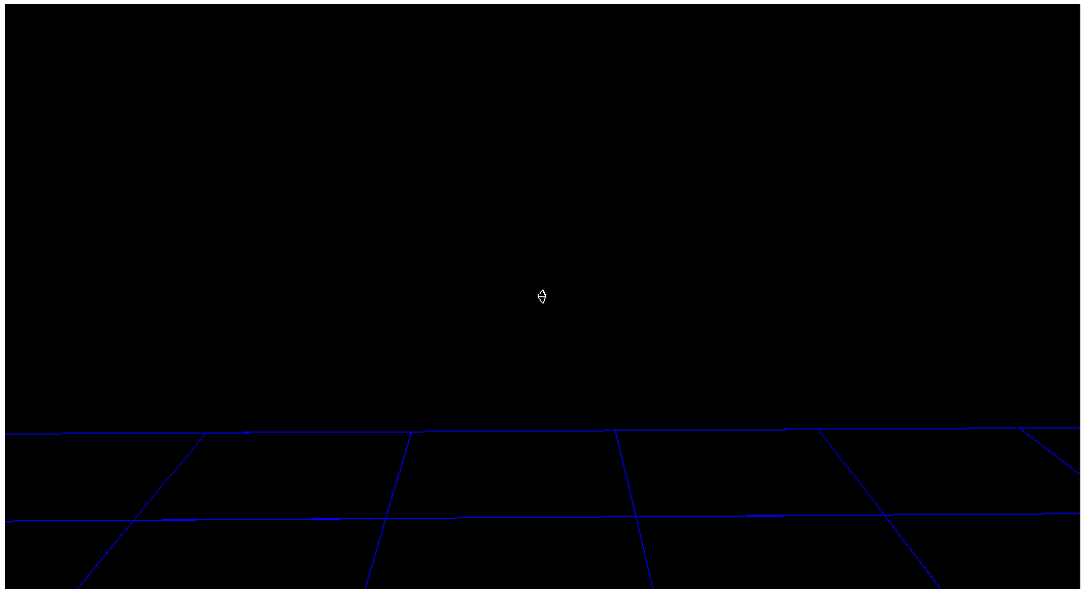
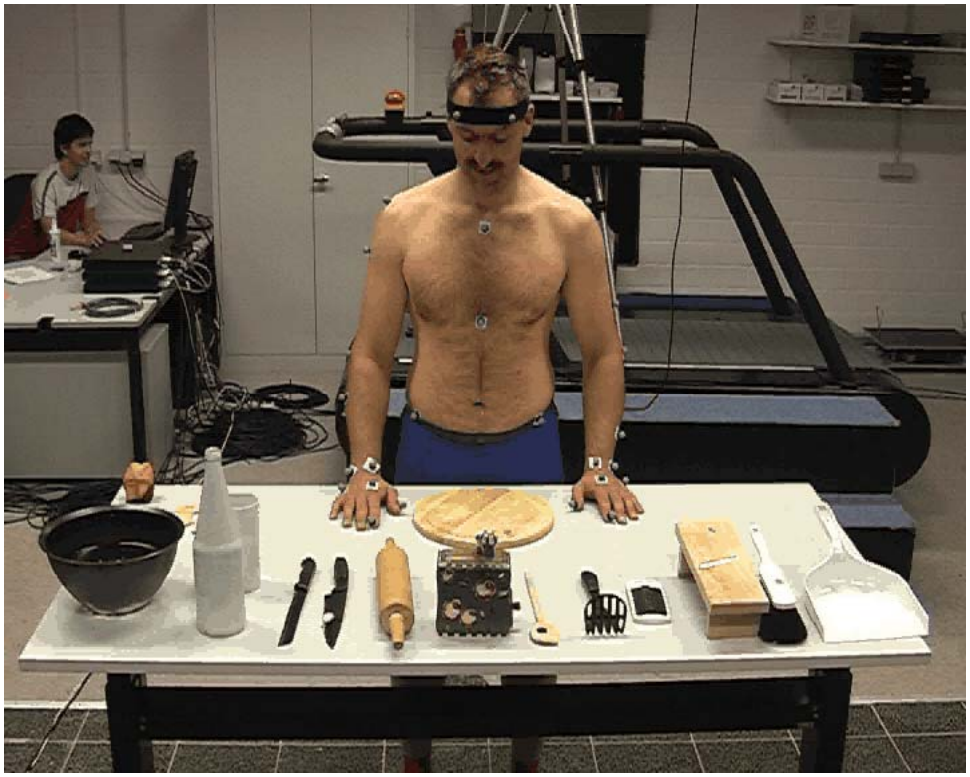


For stochastic modelling → Lots of training data needed

Solution - Motion segmentation

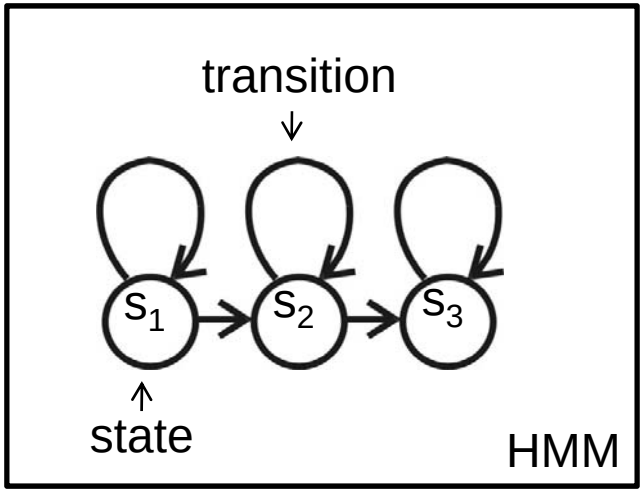
- Solution
  - Segmentation of motion sequences into smaller motion units
  - Modelling of motion units (motion phases)
  - Recognition of motion sequences by concatenation of motion phases



- idle_position
- picking_glass
- idle_position
- picking_bottle
- idle_position_bottle
- pouring
- putting_away_bottle
- idle_position
- putting_away_glass
- idle_position

Example: HMM for picking_bottle

- HMM for motion phase „picking a bottle“

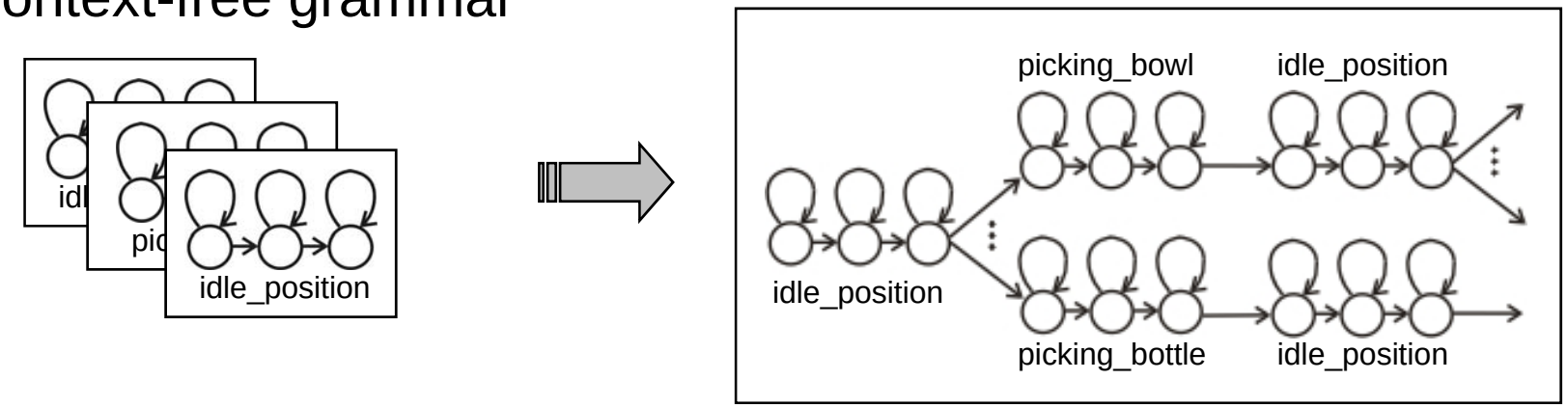


states
- s_1: move hand towards the bottle
- s_2: grasp the bottle
- s_3: take bottle to target position

- Linear 3-state model
- Every state models on phase of the picking process

Recognition of continuous motion

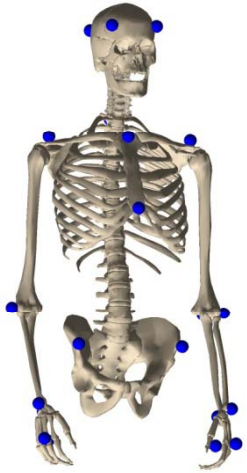
- Context-free grammar



- Context-free grammar
  1. Generated by experts (knowledge)
  2. Recognition of limited set of sequences

Motion Recognition System

Live tracking by VICON



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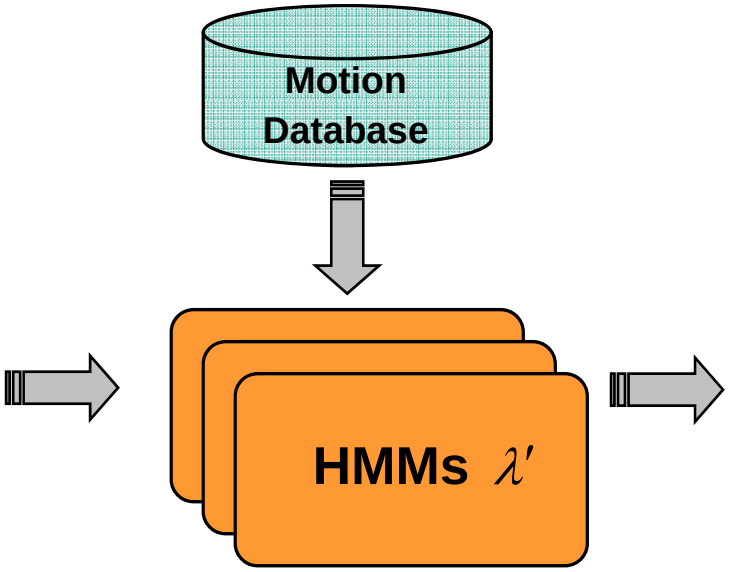
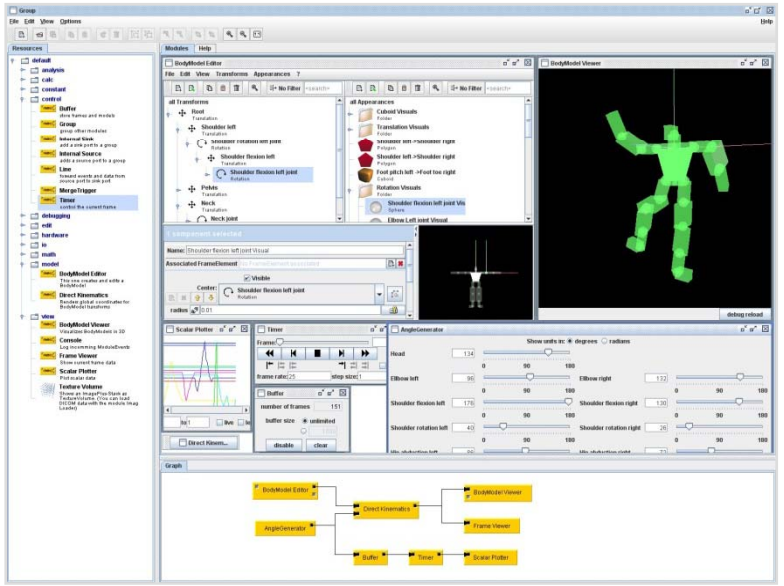


Online motion recognition with Hidden Markov Models

Recognition of user motion → e.g. *„stirring“*

Online Motion Recognition

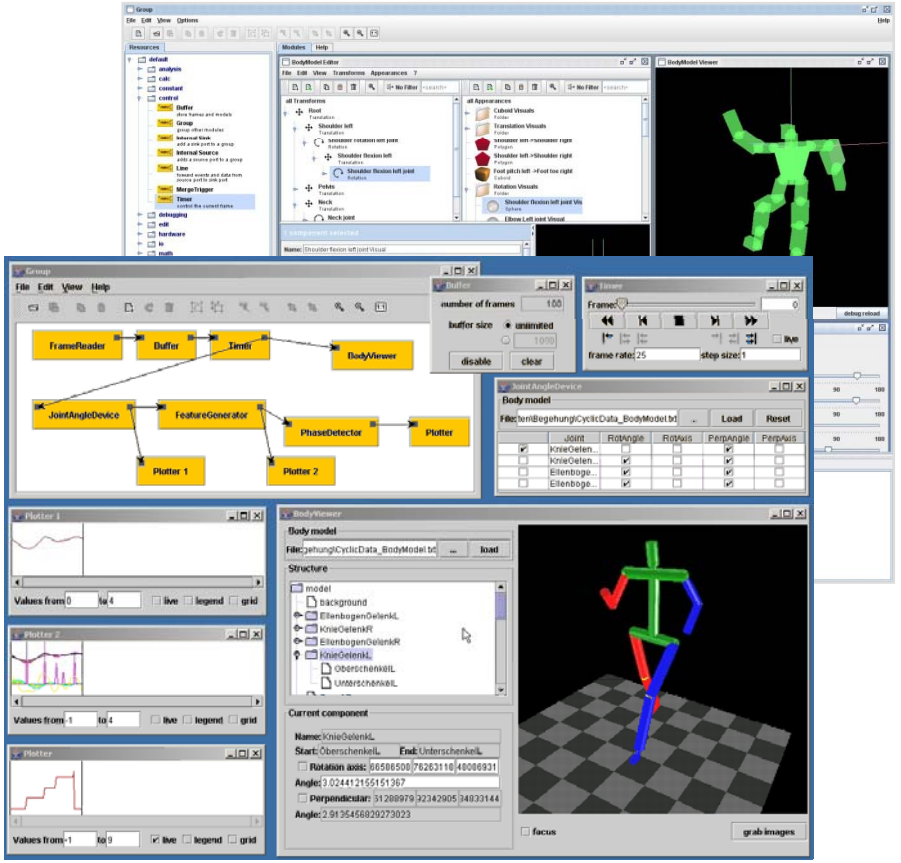
*V*isualisation, *A*nalysis- and *Mo*dellation *S*ystem



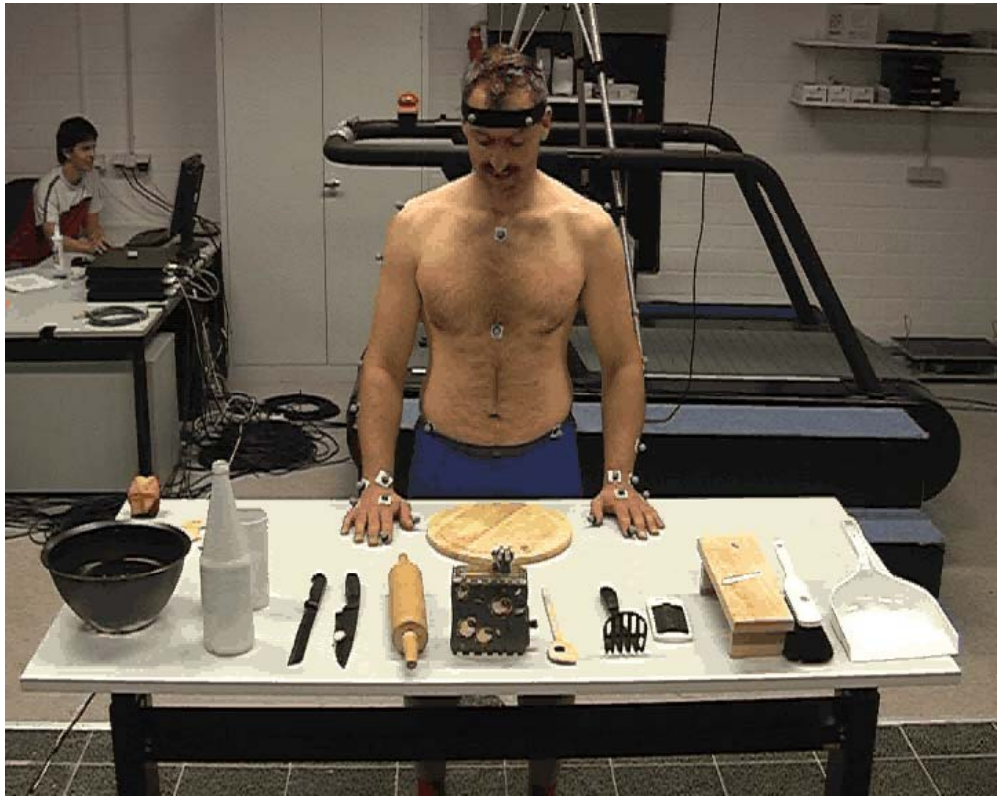
Online Motion Recognition

*V*isualisation, *A*nalysis- and *Mo*dellation *S*ystem

- Application
  - Signal processing
  - Data pre-/post-processing (Filtering, smoothing, signal transformationen)
  - Visualisation
  - Acquisition and Analysis of human motion



Motion data for CRC 588

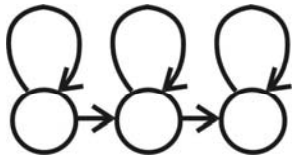


Training data

- 3 subjects
- 10 typical kitchen moves
  - rolling pastry
  - pouring water
  - planing apple
  - grinding coffee
  - sweeping
  - grating apple
  - stirring
  - cutting cake
  - cutting apple
  - pitching

Motion recognition for CRC588

- Online motion recognizer
  - Development framework: Janus Recognition Toolkit
  - HMMs for 49 motion phases
    (idle_position, picking_bottle, etc. …)
  - Each HMM has 3 states
  - HMM-Topology: left-to-right
  - Motion representation by a context free grammar



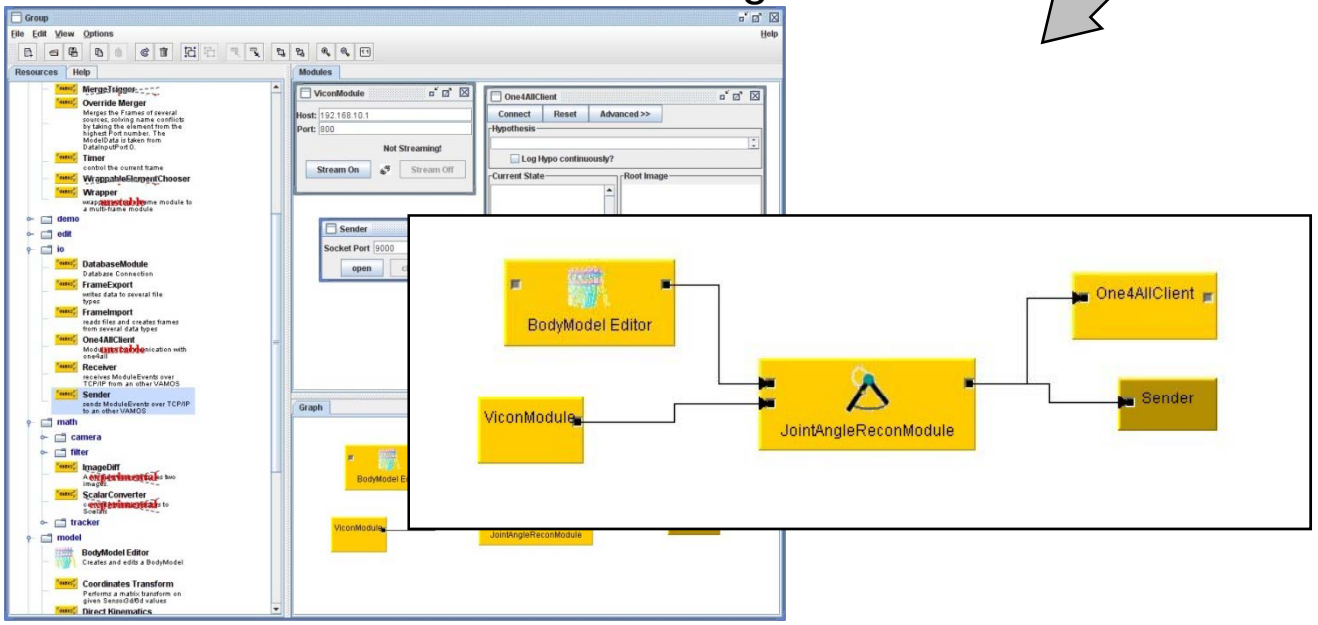
- Motion data
  - 1 subject
  - 600 motion sequences (10 different types)
    (500 training, 50 development, 50 test data)
  - 24 normalized joint angles

Connection Vicon - *Vamos*

Marker

Tracking

Vicon Server



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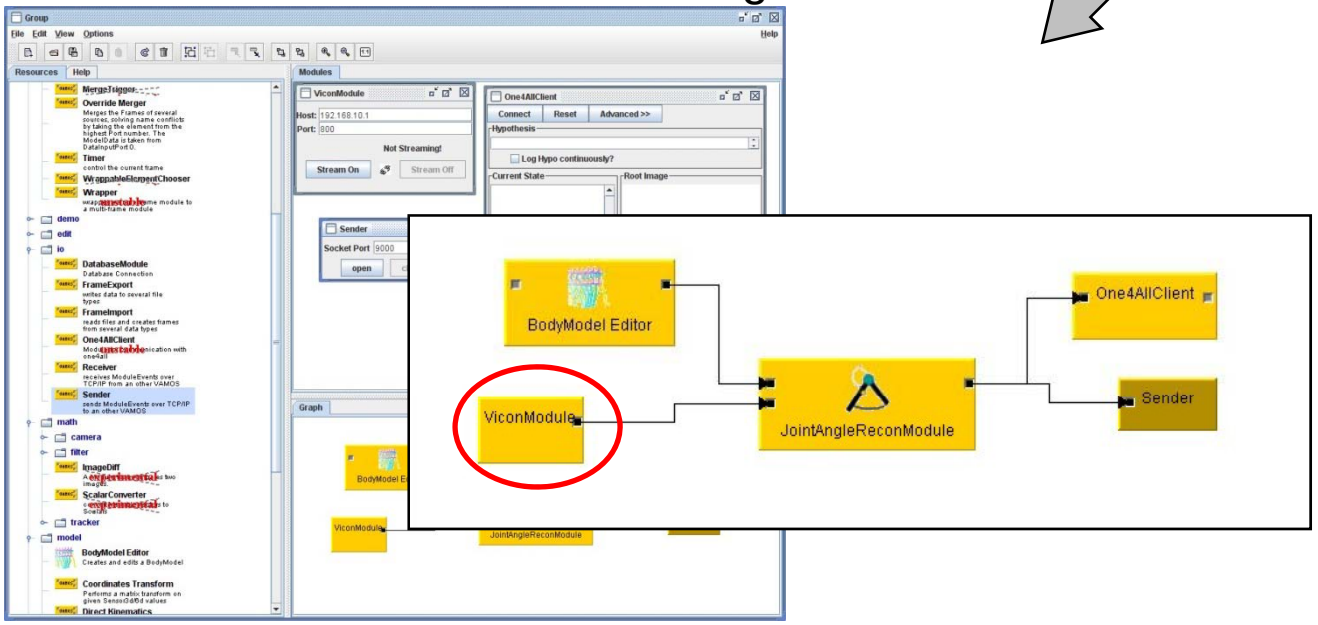

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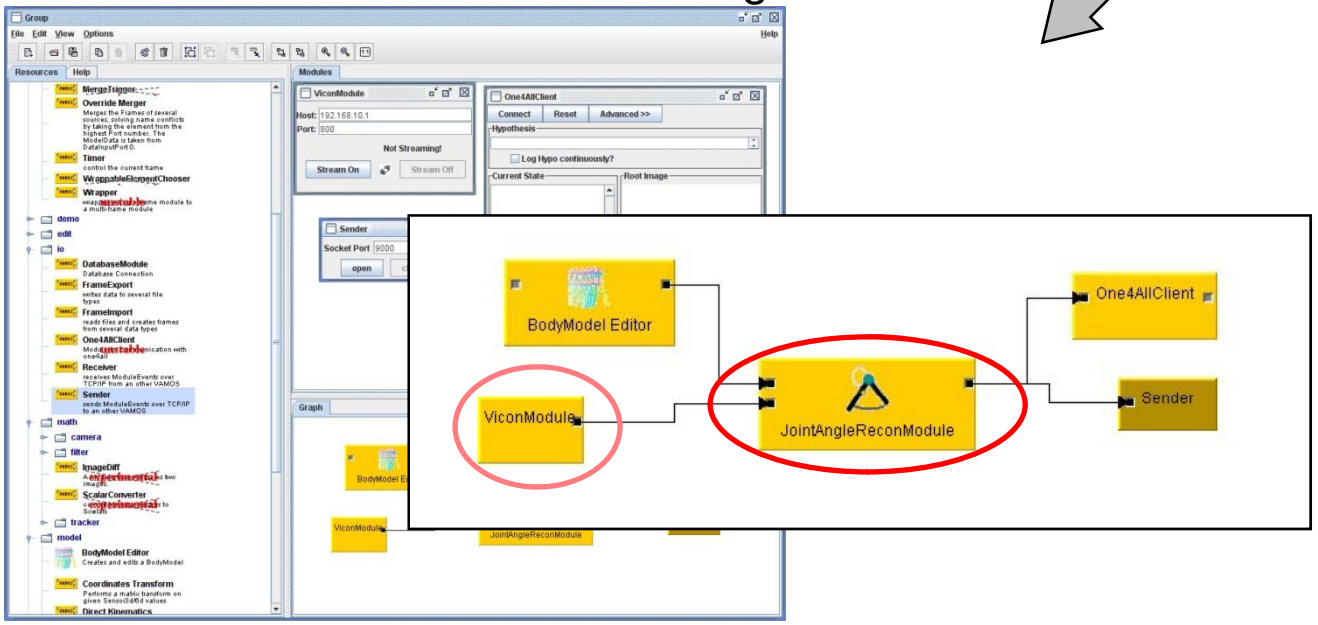
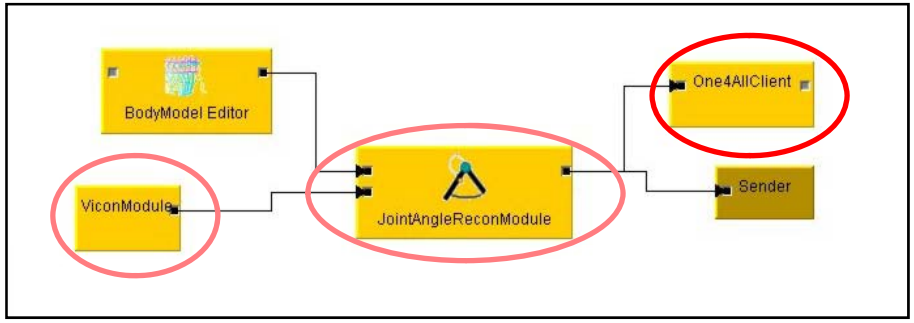
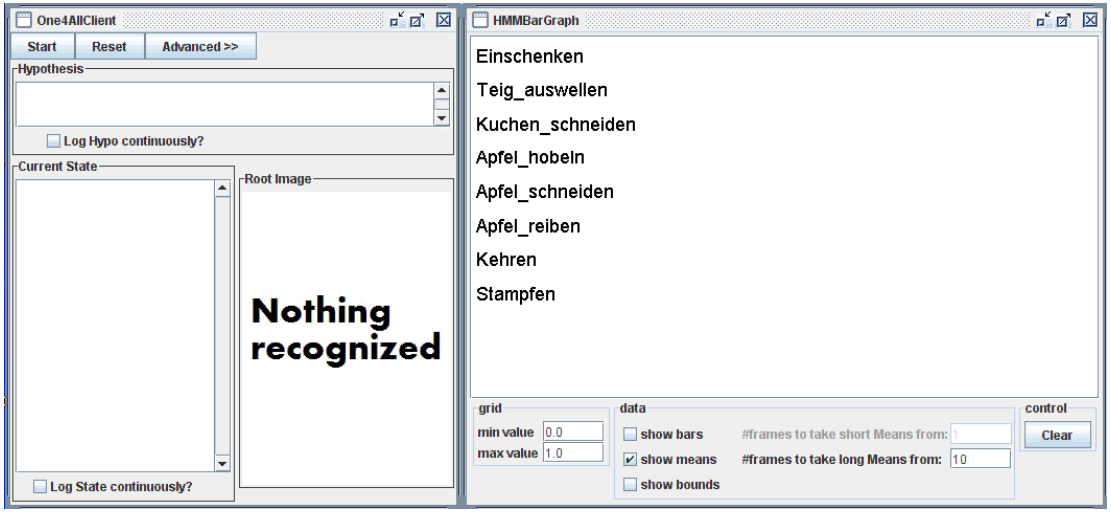


Example: Online Recognition of movements





Results

- Error rate for motion phases: 5,5%
  → With CFG over 10 different motion sequences and 50 data sets
- Correct recogniton of all motion sequences
- Runtime ~ 20 fps

Future work

- Motion recognition independent of the individual person

  → Training with more than one person

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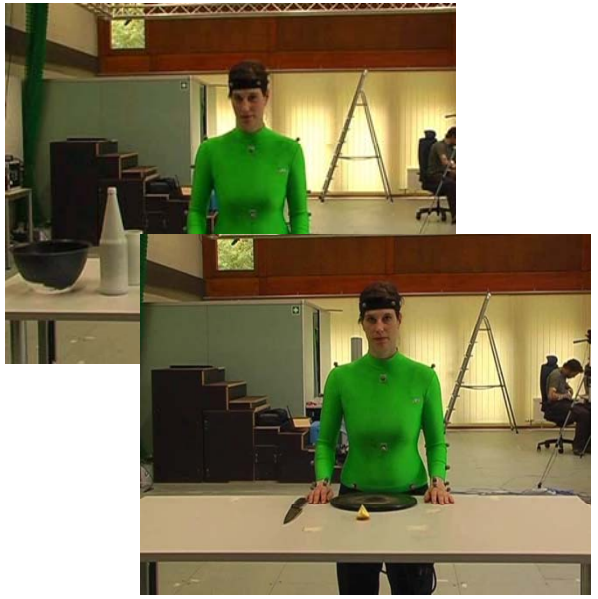
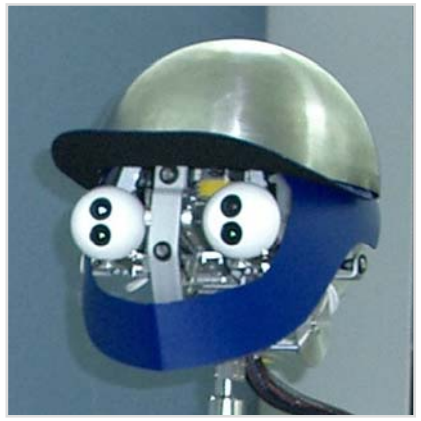
  → Training with more than one person
- Natural movements:
  - Flexible object positionen
  - Fluent motion and motion variations
- Coordinated and concurrent movements

Future work

- Motion recognition independent of the individual person

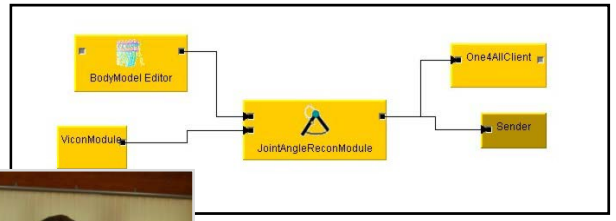
  → Training with more than one person
- Natural movements:
  - Flexible object positionen
  - Fluent motion and motion variations
- Coordinated and concurrent movements
- Adaption of motion recognition to the robots visual system





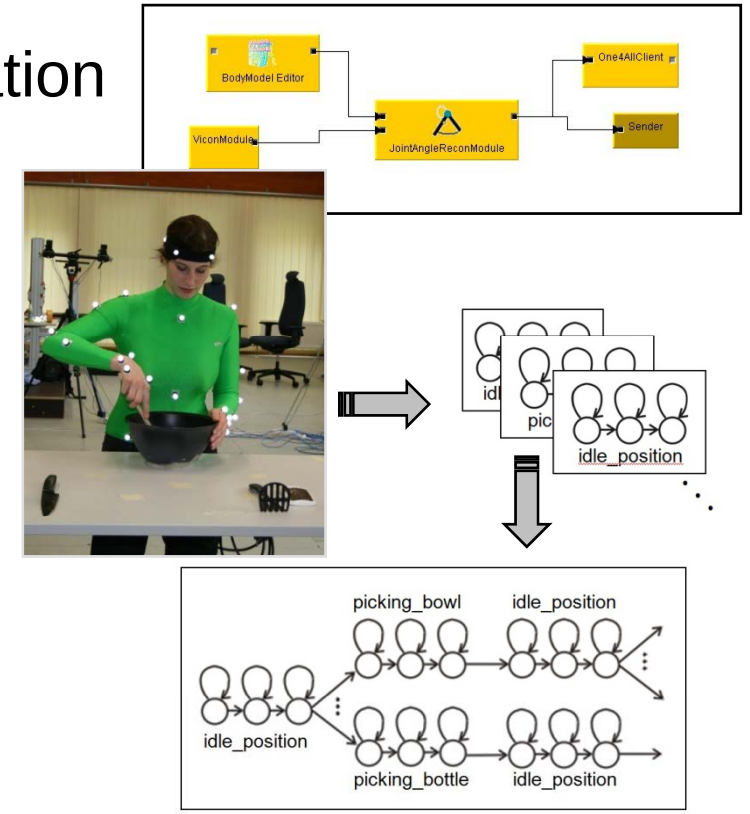
Conclusion

- Online motion recognition application
- Usage of marker-based tracking



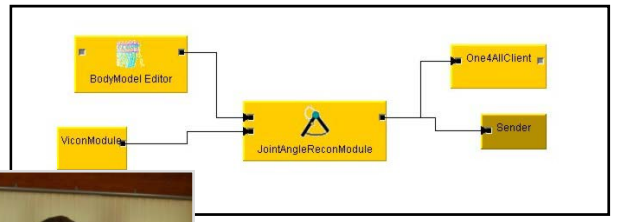
Conclusion

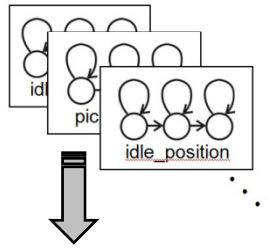
- Online motion recognition application
- Usage of marker-based tracking
- Motion recognition with HMMs
- Temporal motion segmentation
- CFG for motion sequences

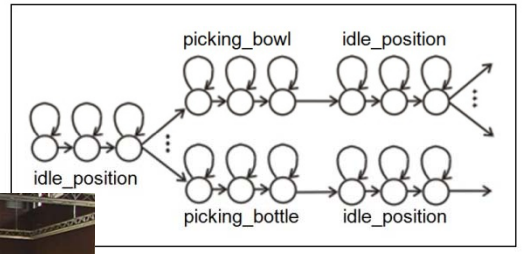


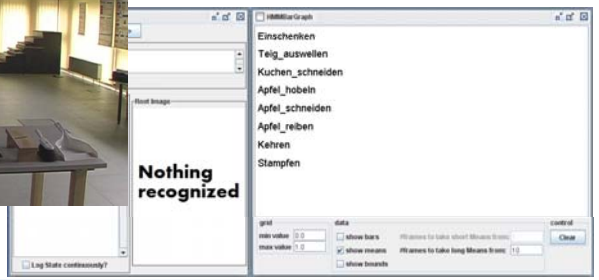
Conclusion

- Online motion recognition application
- Usage of marker-based tracking
- Motion recognition with HMMs
- Temporal motion segmentation
- CFG for motion sequences
- Over 90% recognition
- Recognition in almost ‚real-time‘









Project group

M3 – Motion and Action models

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Thank you!