Online Recognition of Daily-Life Movements

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University of Karlsruhe (TH)
Background

Collaborative Research Center 588
Humanoid Robots - Learning and Cooperating Multimodal Robots
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Collaborative Research Center 588
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- Understanding
- Cooperating
- Learning
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Humanoid Robots - Learning and Cooperating Multimodal Robots

• Understanding
• Cooperating
• Learning

→ 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"

Online Recognition of Daily-Life Movements
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- Online motion recognition with Hidden Markov Models
- Recognition of user motion \( \rightarrow \) e.g. “stirring”

Online Recognition of Daily-Life Movements
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Recognition of user motion \(\rightarrow\) e.g. "stirring"

Online Recognition of Daily-Life Movements
Data acquisition

Live tracking by VICON

3D-Marker-positions

Mapping on human model

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

- BioMotion Center: Vicon system
- 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

Online Recognition of Daily-Life Movements
Motion Capture with Vicon

Example: Motion capture setting

Result: Vicon record
Joint angle generation

Livetrackin with VICON

Mapping on human model

Recognition of user motion \( \rightarrow \) e.g. "stirring"

HMMs

Online motion recognition with Hidden Markov Models

3D-Marker-positions

Motion Database

Joint angles

Left shoulder

\( \lambda' \)
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

Online Recognition of Daily-Life Movements
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

⇒ 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:

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

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

- \(X\) : the set of the result of the forward kinematics
- \(\text{weight}(x_0)\) : the weight of the markers

\rightarrow \text{Reconstructed body pose / motion}
Motion recognition

Live tracking with VICON

Mapping on human model

Motion Database

HMMs $\mathcal{\lambda'}$

Online motion recognition with Hidden Markov Models

Motion probabilities

Joint angles

Recognition of user motion $\rightarrow$ e.g. “stirring”

Online Recognition of Daily-Life Movements
Problem: human motion

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

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

*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“

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

  ![Diagram of HMM for picking_bottle](image)

<table>
<thead>
<tr>
<th>State</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$s_1$</td>
<td>move hand towards the bottle</td>
</tr>
<tr>
<td>$s_2$</td>
<td>grasp the bottle</td>
</tr>
<tr>
<td>$s_3$</td>
<td>take bottle to target position</td>
</tr>
</tbody>
</table>

Online Recognition of Daily-Life Movements
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

Mapping on human model

Online motion recognition with Hidden Markov Models

Recognition of user motion → e.g. “stirring”
Online Motion Recognition

**Visualisation, Analysis- and Modelling System**
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

Online Recognition of Daily-Life Movements
Connection Vicon - *Vamos*

[Diagram showing connection between marker, tracking system, and Vicon server]


*Online Recognition of Daily-Life Movements*
Connection Vicon - Vamos

Marker → Tracking → Vicon Server

Online Recognition of Daily-Life Movements
Example: Online Recognition of movements


Online Recognition of Daily-Life Movements
Results

- Error rate for motion phases: 5.5%
  → With CFG over 10 different motion sequences and 50 data sets
- Correct recognition of all motion sequences
- Runtime ~ 20 fps
Future work

- Motion recognition independent of the individual person
  → Training with more than one person
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
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'

Online Recognition of Daily-Life Movements
Project group

**M3 – Motion and Action models**

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Thank you!