Robotics and Animatronics in Disney

Lecture 8: Physical Human-Robot Interaction

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Goals

- Introduce two case studies of physical human-robot interaction
  - Object handoff
  - Ball catch and throw
- Discuss the hardware, motions, and time span issues in realistic human-robot interactions

Object Handoff

Consider comfort for human
[Sisbot and Alami 2012]

Specialized protocol
[Edsinger and Kemp 2007]
Perception and planning issues
[Micelli et al. 2011]

Object Handoff

Robot initiates the motion

Human initiates the motion

Object Handoff

Robot initiates the motion
Robot decides where handoff takes place

Human initiates the motion
No pre-determined handoff location

Object Handoff

Robot initiates the motion
Robot decides where handoff takes place
Robot can start planning early

Human initiates the motion
No pre-determined handoff location
Quick planning required

Goal

Realize natural human-to-robot object handoff

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Human-to-Human Handoff

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Human-to-Human Handoff

- Passer starts moving the object
- Receiver recognizes the intention and starts reaching out
- Passer and receiver implicitly agree on handoff position
- Receiver grasps the object
- Passer releases the object

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Human-to-Robot Handoff

- Passer starts moving the object
- Robot recognizes the intention and starts reaching out
- Passer and robot implicitly agree on handoff position
- Robot grasps the object
- Passer releases the object

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Observation

- Similar motions in similar situations
  - Relative orientation and distance
  - Grasp type

- Can we predict the receiver's pose from the passer's?

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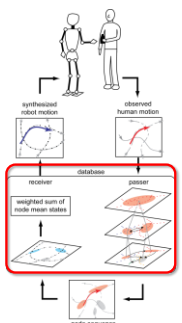
Method Overview



Database of human-to-human handoff motions

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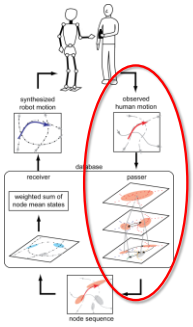
Method Overview



Search observed human motion with passer motion in the database

Database of human-to-human handoff motions

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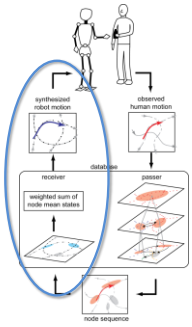
Method Overview



Synthesize robot motion based on the corresponding receiver motion

Search observed human motion with passer motion in the database

Database of human-to-human handoff motions

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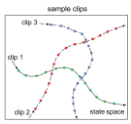
Single-Person Database

[Yamane, Yamaguchi, Nakamura 2011]



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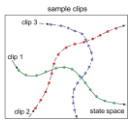
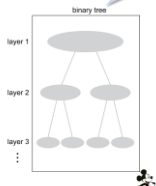
Single-Person Database

[Yamane, Yamaguchi, Nakamura 2011]



Binary tree
Quick search



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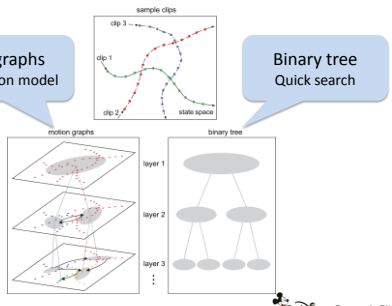
Single-Person Database

[Yamane, Yamaguchi, Nakamura 2011]

Motion graphs
Pose transition model

Binary tree
Quick search



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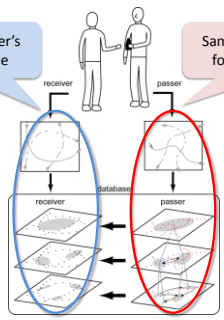
Two-Person Database

Link to the receiver's motion database

Same database structure for the passer motion



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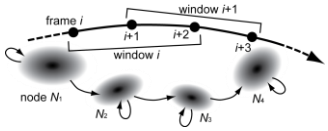
Online Database Search

Find the node sequence with the maximum probability of generating the observed motion

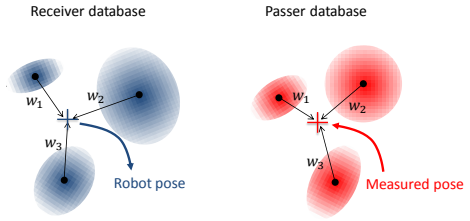
- Sliding window: online search



- Consistency: match the original node sequence across windows

Robot Motion Synthesis

Interpolate nearby nodes



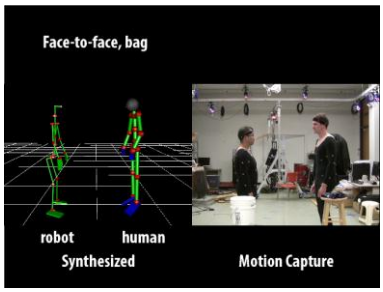
Simulation

Sample data

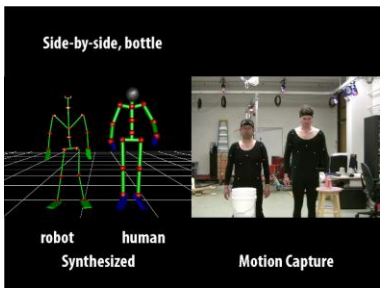
- "Face-to-face" dataset (1686 frames, 10 layers)

- "Side-by-side" dataset (863 frames, 9 layers)

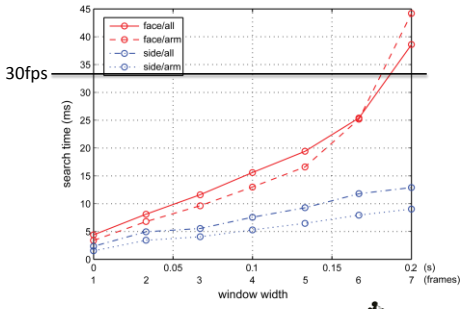
Simulation



Simulation

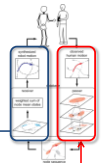


Search time



Hardware Implementation

- Hardware platform
  - Disney Audio-Animatronic Figure
  - 4 left arm joints used for experiments
  - Data-based inverse kinematics for 9 markers
- Optical motion capture for detecting human motion
  - OptiTrack (NaturalPoint, Inc.)
  - 13 markers on right arm and trunk



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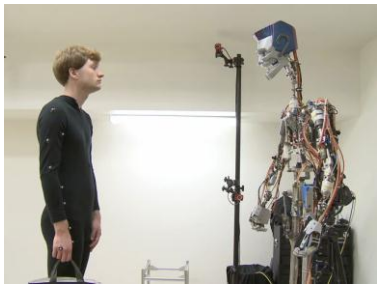
Hardware Implementation



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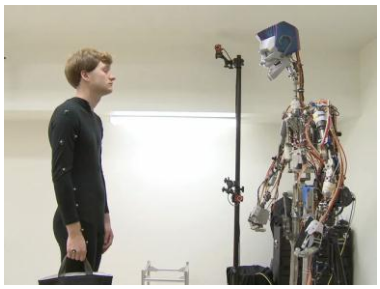
Hardware Implementation



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Summary

- Natural human-to-robot object handoff by
  - Human motion database
  - Efficient sliding window search with frame-to-frame coherency
- Validation
  - Simulation: able to distinguish three grasp types
  - Hardware: quick and reasonable response with an upper-body humanoid robot

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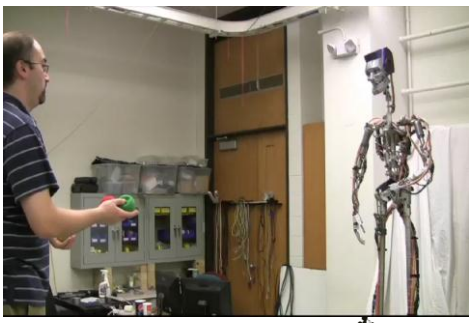
Ball Catch and Throw



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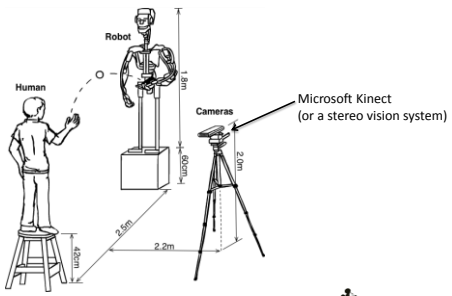
Ball Catch and Throw



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Discussion

- Safe physical human-robot interaction
  - With existing Disney figures
  - New hardware
- Realistic interaction vs. realistic motion
- Short-term interaction vs. long-term interaction

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Report

- Each lecture had a list of discussion points
- Select one of the lectures and write an essay on its discussion points
- Length: up to 2 pages (~1000 words)
- Deadline: Friday August 9, 2013
- Email PDF to kyamane@disneyresearch.com with subject "UTOKYO REPORT <your_name>"

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1a: Humanoid Robot Dynamics

- Real robots are different from simulation models
- A controller that works in simulation does not always work on real robot
- Is simulation useful at all?
  - Simulation gives baseline (ideal) results
  - Compare experiments with simulation
  - Compare different controllers/parameters

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2: Geometric Algorithms for Robotics

- Advantages of geometry-based algorithms
  - Global optimum
  - Fast
  - Consists of a few basic geometric computation
  - Accuracy comparable to standard numerical optimization
- Applications
  - Planning
  - Contact simulation
  - Grasp analysis

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3: Physics-Based Character Animation

- Physics is rarely used in production for character animation
- However, simulation is used for different purposes:
  - Dynamics simulation for very complex systems such as cloth, hair, and fluid
  - Light simulation for rendering
- Recent trend
  - Art-directable: artists can intuitively control the results

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4: Controlling Humanoid Robots with Motion Capture Data

- Is human motion source necessary for synthesizing human-like motions?
- Is human-like motion enough for making robots look alive?

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5: Adapting Human Motion Data to Different Kinematics

- Significantly different character / environment
  - Large change required
- How much change is acceptable to
  - Maintain the style
  - Look natural

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6: Humanoid Modeling and Control

- Accurately estimating model parameters is difficult
- Articulated rigid body models don't capture many aspects of humanoid robot dynamics
  - Joint friction, backlash
  - Link deformation
- What are the right levels of detail for
  - Control
  - Simulation

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7: Human Modeling and Control

- Level of details
  - We started from a very detailed human model
  - Then used simpler model for further validation
  - Many researchers work with simple models
- Which model makes sense?
  - Simple models can miss details?
  - Parameter identification?
  - Signal/noise ratio?

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8: Physical Human-Robot Interaction

- Safe physical human-robot interaction
  - With existing Disney figures
  - New hardware
- Realistic interaction vs. realistic motion
- Short-term interaction vs. long-term interaction

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The End

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