Reinforcement Learning for Assisting Humans

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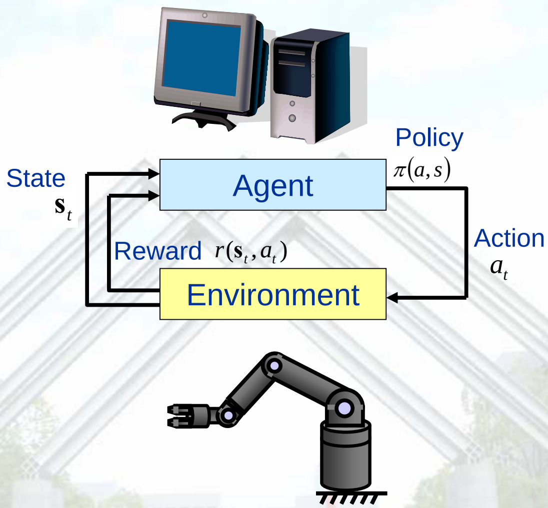
Outline

- Reinforcement leaning for assisting Humans
- Holding assist task
  - Virtual force sensing with the measurement of motion and EMG signals
- Learning for the holding assist task

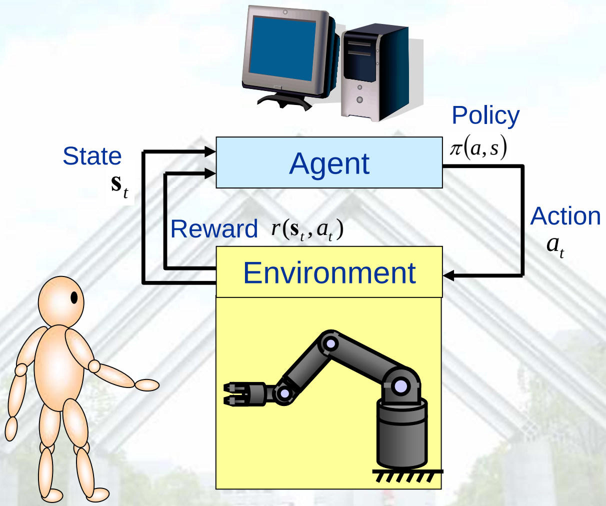
Reinforcement Learning

- Reinforcement learning
  - is probably the most general framework in which such learning problems of computational motor control can be phrased [Peters and Schaal. 2008]
- Challenges
  - Policy representation
  - Efficient algorithm
  - **Learning for assist** other agents such as humans

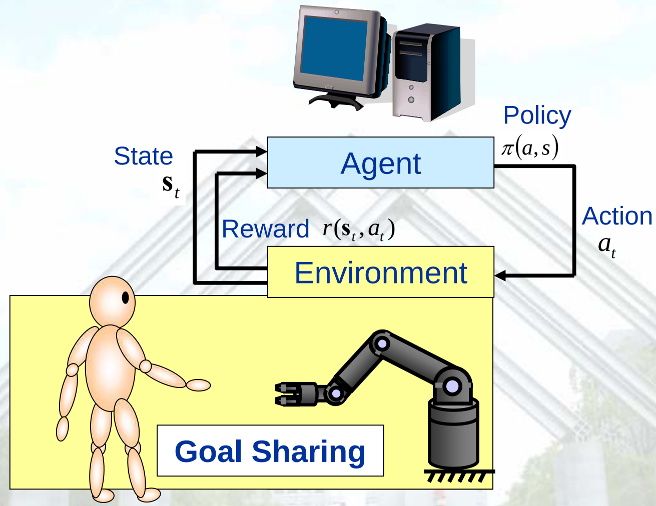
Reinforcement Learning



Reinforcement Learning for Assisting Humans



Reinforcement Learning for Assisting Humans



Related Studies

- Mitsunaga, et al. (2005)
  - Smooth robot-human interaction
  - Parameters
    - Interaction distance, the extent to which the robot meets a human gaze, waiting time between utterance and action, and motion speed
  - Reward
    - Amount of movements and the period for gazing at the robot
- Tapus, et al. (2007)
  - Hands-off therapist robot
  - Parameters
    - interaction distance/proxemics, speed and vocal content
  - Reward
    - number of exercises performed by the patient

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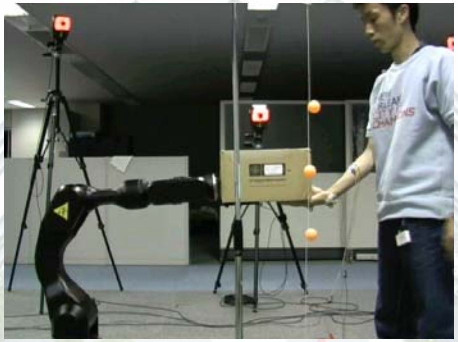
Working Task: Holding Assist Task

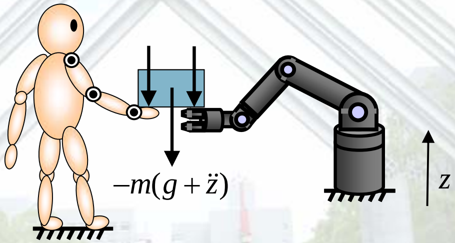
- The user and the robot move a load cooperatively without actual force sensors
- Hands-on kinetic Interaction



[Tamei, et al. 2007; 2008]

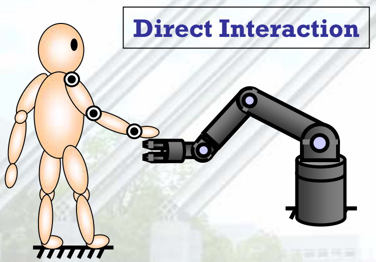
Overview of the Holding Assist Task

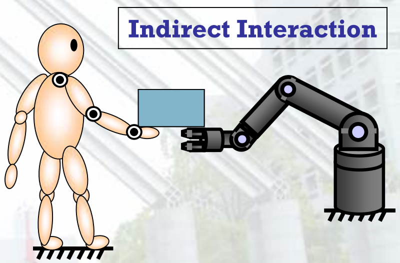
- Reading the user's motor intention by means of virtual force sensing
- Force feedback control in which the target force is $-\frac{1}{2}m(g+\ddot{z})$



Virtual Force/Tactile Sensing

- Tamei, et al. 2007; 2008
- Virtual realization of force/tactile sensors in robots without real sensors using user's biological signals





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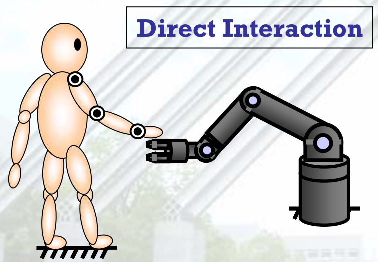
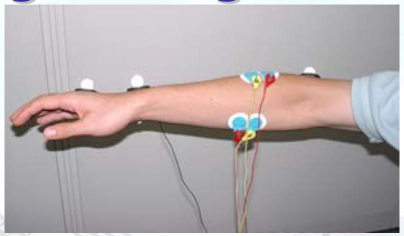


Measured Biological Signals

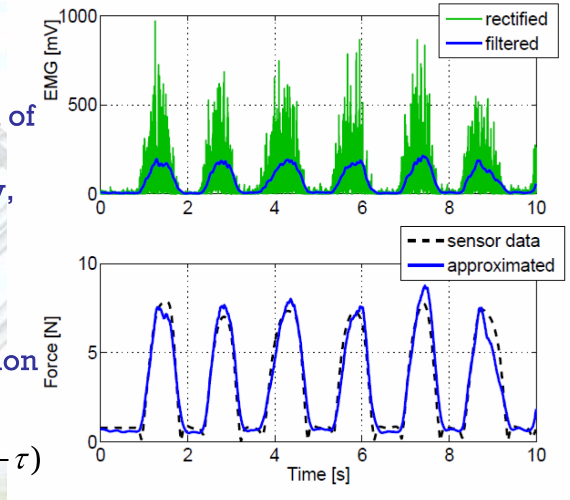
- Motion
  - Upper extremity
- EMG
  - Flexor carpi radialis (FCR): flexor of the wrist
  - Extensor carpi radialis longus (ECRL) : extensor of the wrist



Function Approximation of the Applied Force

- In general
  - Muscle tension is a non-linear function of the muscle length, shortening velocity, and the motor command
- In this study
  - Linear approximation has been sufficient

$$\mathbf{f}(t) = \sum_{\tau=1}^{T} \mathbf{A}(\tau)\mathbf{EMG}(t-\tau)$$



Control Law

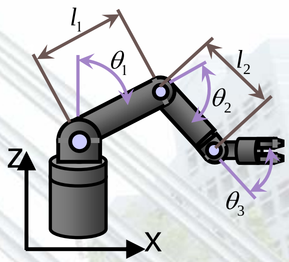
- First step

$$m\ddot{z} + c\dot{z} + kz = C(f_1 - f_d)$$
$$\dot{x} = 0$$

f_1 : force applied to the user's hand
f_d : desired force for the user
C : constant

- Second step

$$\begin{bmatrix} \dot{\theta}_1 \\ \dot{\theta}_2 \end{bmatrix} = J(\boldsymbol{\theta})^{-1} \begin{bmatrix} \dot{x} \\ \dot{z} \end{bmatrix}$$
$$\theta_3 = -\theta_1 - \theta_2$$

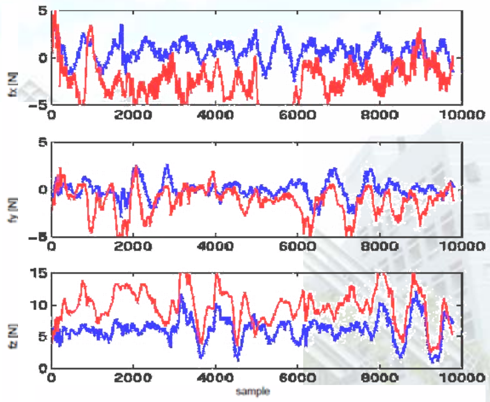


Simple Extension to the 3-Dimensional Task

[Tamei, et al. Submitted]

General Difficulties in EMG Signals

- Muscle-force relationship is nonlinear
- Muscle coordination can vary
- Force sensor output during calibration phase does not necessarily reflect the user's motor intention
- Recalibration on the fly is not possible



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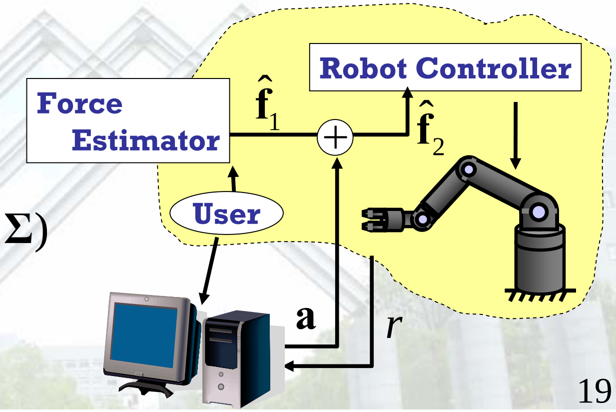
Application of Reinforcement Learning

- Learning Control of the user-coupled system [Tamei, et al. In prep]

$$\hat{\mathbf{f}}_2 = \hat{\mathbf{f}}_1 + \mathbf{a}$$

$$\mathbf{a} \sim \mathcal{N}(\mathbf{a}; \boldsymbol{\mu}, \boldsymbol{\Sigma})$$

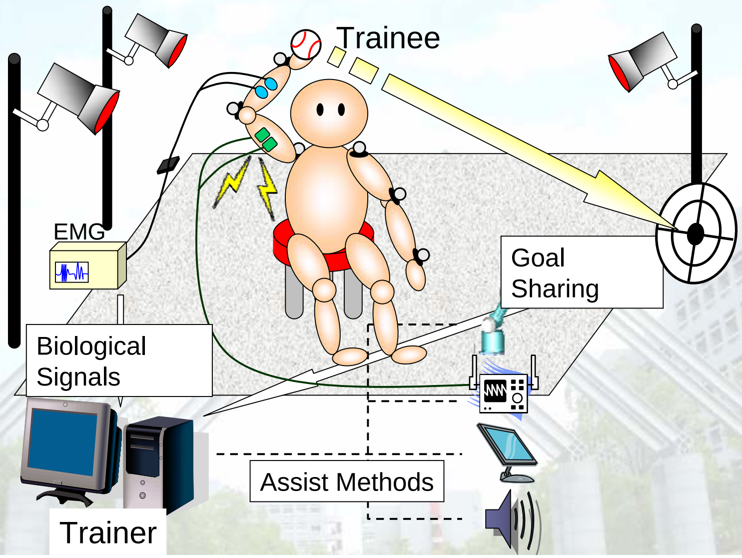


Summary and Future Work

- Summary
  - Reinforcement learning for assisting humans
    - User-coupled system
  - Learning holding assist using the user's biological signals
    - Hands-on kinetic interaction
- Future work
  - Feature selection
  - Different tasks
  - Use in computational neuroscience

My Dream

– Learning Trainer –



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