Slide 1

CPG-Based Manipulation : Generation of Rhythmic Finger Gaits from Human Observation

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Slide 2

Background

* Traditional robot manipulation
  * Model-based, stability analysis
* A rhythmic pattern is observed in human's rotating manipulation
* Rhythmic motor patterns are coordinated by neural circuits referred as Central Pattern Generator (CPG)
  * Locomotion in animals and insects

Apply the CPG-based control to the dexterous manipulation

Slide 3

Measurement of the contact pattern

* Human contact condition is measured using FSRs (Force Sensing Resistors)
  * Thumb, index, middle, and ring fingers
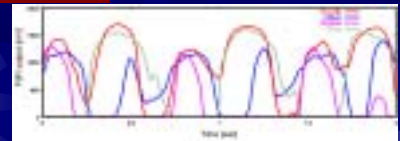 * diameter:65[mm], weight:20[g]
  * 5 Subjects

Slide 4

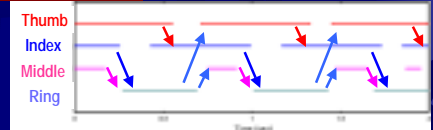# Contact condition

FSR Data

Subject A

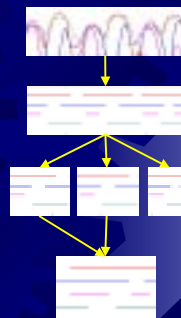**Contact Condition**
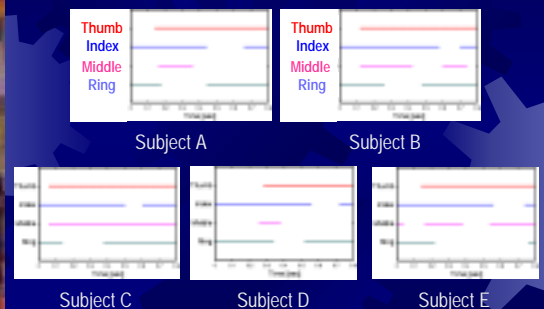
Binarized

Thumb
Index
Middle
Ring

Slide 5

Detecting the typical contact pattern

* Binarizing of the FSR data to the contact/release condition.
* Segmenting the binarized data
  * The thumb becomes the contact condition from the release condition.
* Extracting periodic data in a certain range (700-800[msec])
* Interpolating each extracted data in order that the data length becomes 800[msec].
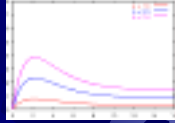* Averaging and binarizing again.

Slide 6
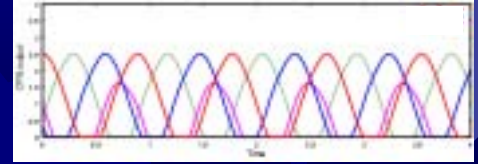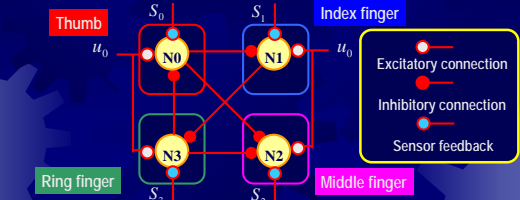
Typical pattern of each subject

Thumb
Index
Middle
Ring

Subject A

Thumb
Index
Middle
Ring

Subject B

Subject C

Subject D

Subject E

Neuron model

Matsuoka(1987) and Taga(1991) model

$$\gamma \, \dot{u}_i = -u_i - \beta \, v_i + \sum_{j=1}^{n} w_{ij} \, y_j + u_0 + S_i$$

$$\gamma' \, \dot{v}_i = -v_i + y_i$$

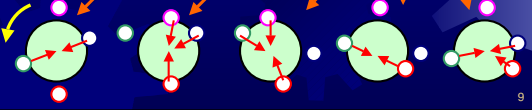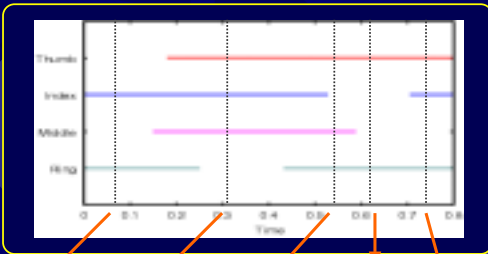$$y_i = f(u_i) \qquad f(u_i) = \max(0, u_i)$$

u_i : internal state of the i-th neuron
v_i : degree of the adaptation
y_i : output of the i-th neuron
u_0 : external input
w_{ij} : connecting weight γ, γ' : time constants
S_i : feedback signal β : adaptation constant

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Constructed model

Thumb
u_0
S_0 S_1
Index finger
u_0

N0 N1

N3 N2

Ring finger
S_3 S_2
Middle finger

Excitatory connection
Inhibitory connection
Sensor feedback

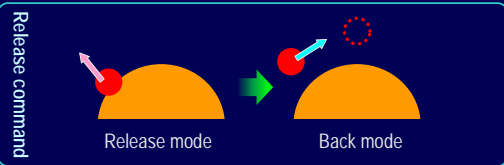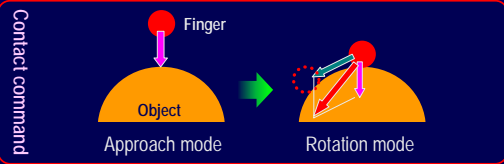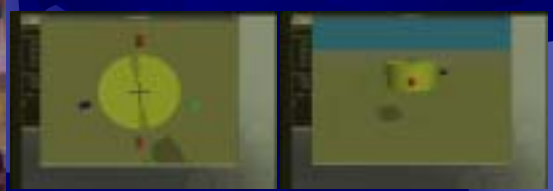8

Generated pattern

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Simulation

☀ CPG-based rotating manipulation is simulated.
  ● Linux, Open Dynamics Engine(ODE)
☀ Condition
  ● The generated outputs are used as contact/release commands
  ● Sensor feedback to CPG
    ● Measured force along z-axis
  ● The world gravity is set as -0.1[m/s^2]
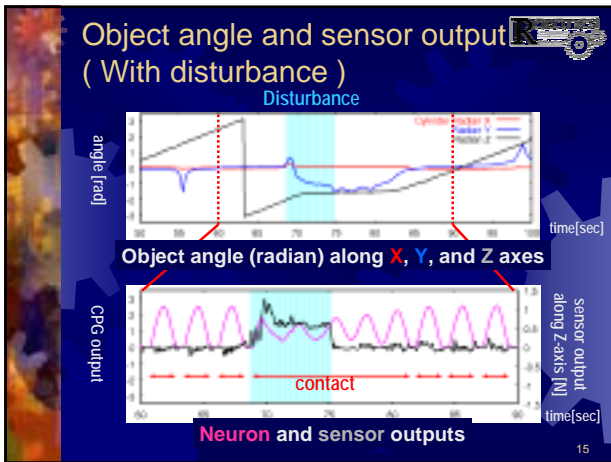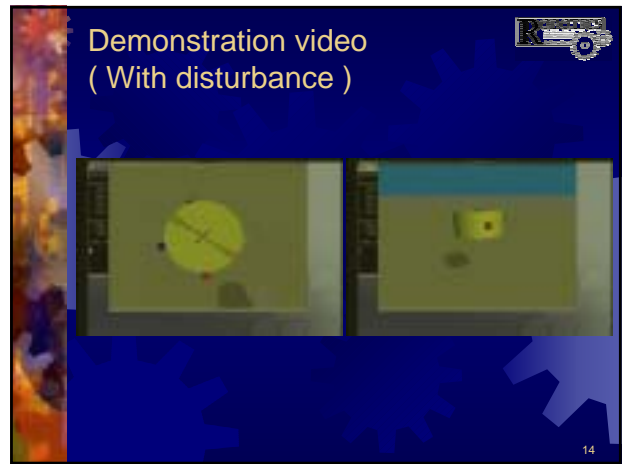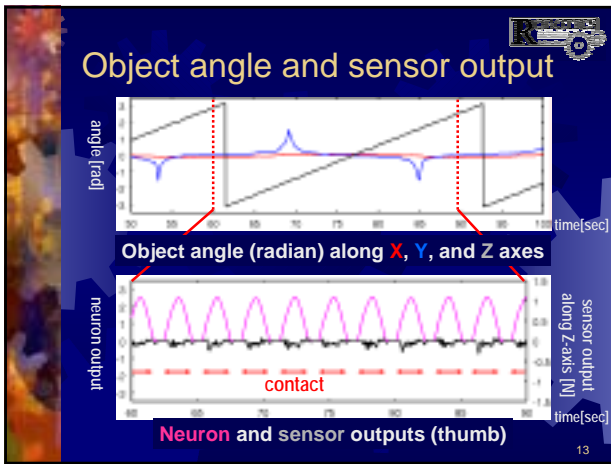
Release Command
Contact Command

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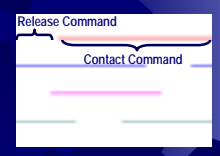
Control modes of each finger

Contact command

Finger

Object

Approach mode Rotation mode

Release command

Release mode Back mode

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Demonstration video

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Object angle and sensor output

Object angle (radian) along X, Y, and Z axes

contact

Neuron and sensor outputs (thumb)

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Demonstration video
(With disturbance)

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Object angle and sensor output
(With disturbance)

Disturbance

Object angle (radian) along X, Y, and Z axes

contact

Neuron and sensor outputs

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Conclusion

✸ Measurement of the typical contact pattern
  ● Contact/Release condition
✸ Construction of CPG model
  ● Generating the similar contact pattern
✸ Simulation
  ● Rotating manipulation with/without a disturbance

✸ Future works
  ● Additional feedback
  ● Experiment using a robot hand

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