FEELEX: Adding Haptic Surface to Graphics

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Limitations in current haptic interface

- Point contact

  haptic surface is not

  spatially continuous

- Separated visual/haptic display

Desktop Force Display
(Iwata, SIGGRAPH 90)

Goals of project FEELEX

(1) to provide a spatially continuous su rface that enables users to feel virtua l objects using any part of the fingers or even the whole palm.

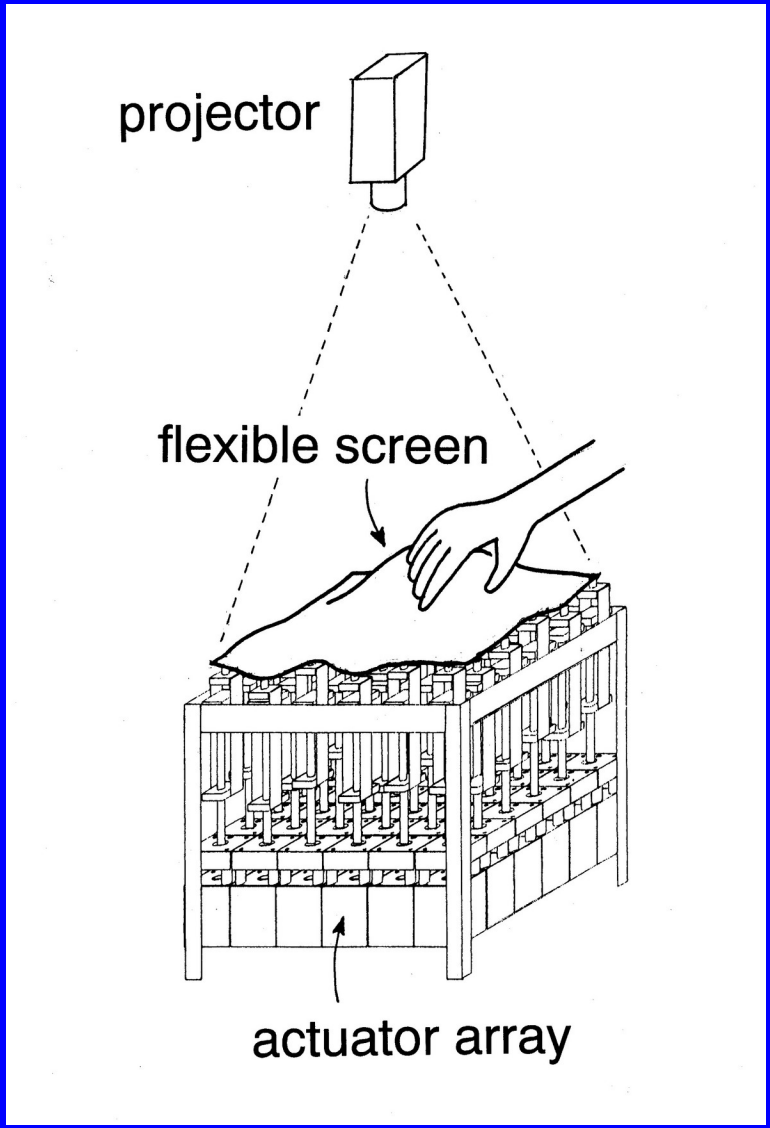
(2) to provide visual and haptic sensati ons simultaneously using a single de vice that doesn't oblige the user to w ear any extra apparatus.

Basic Idea of FEELEX

- Image is projected on a flexible screen.

- Flexible screen is deformed by an actuator array.

- Deformation occurs according with force sensing.



Related Work

(1) Haptic Interface

exoskeleton; Iwata(1990), Burdea(1992)

tool-handling-type; Iwata(1993), Massie(1994)

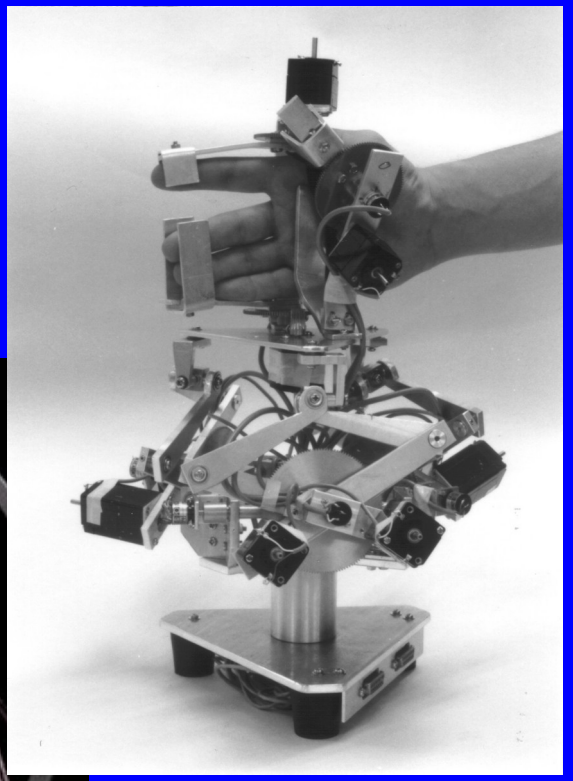
object-oriented-type; Tachi(1994), Hirota(1996)

(2) Real World Graphics

Wellner(1991), Ishii(1999)

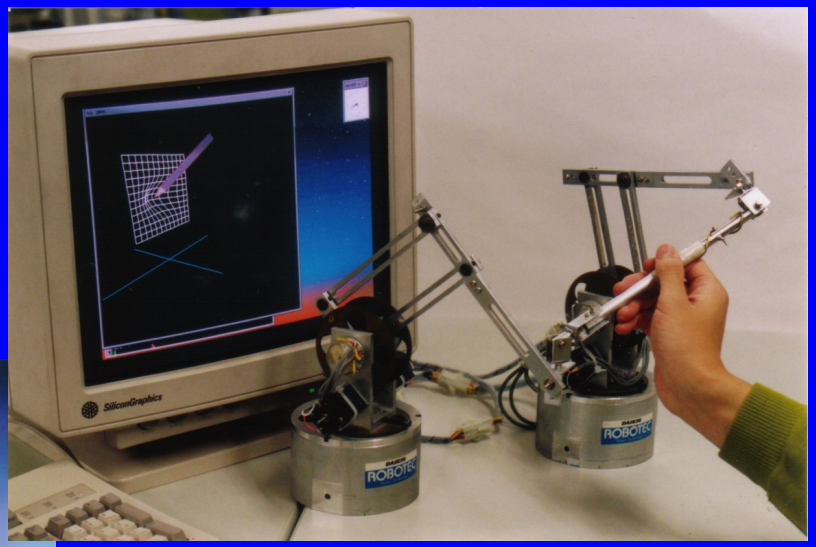
Method for Haptic Interface (1) exoskeleton

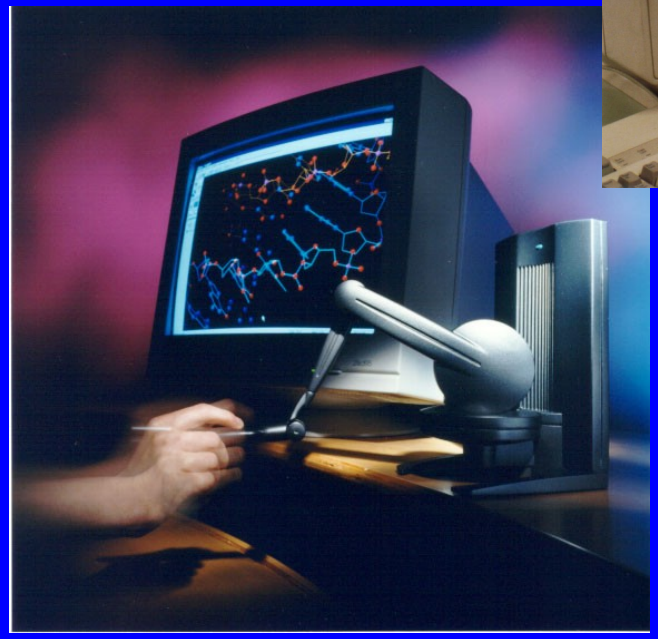
- ○ many degrees of freedom
- × difficulty in pu g on/off



Method for Haptic Interface (2) tool-handling-type

- ○ free from fitting
- × single point contact

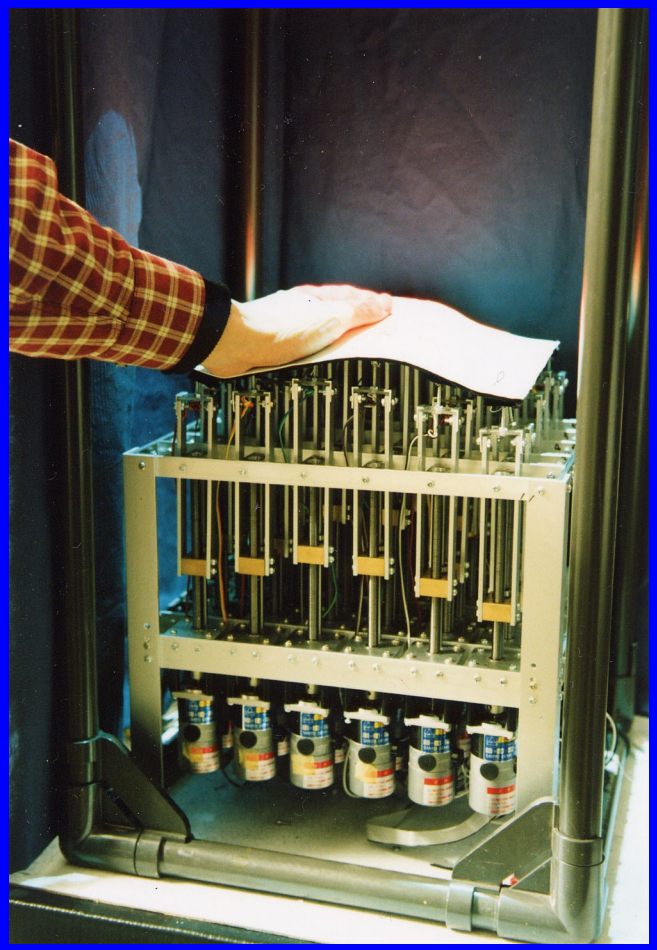




Method for Haptic Interface (3) object-oriented-type

Device deforms to simul ate virtual object.

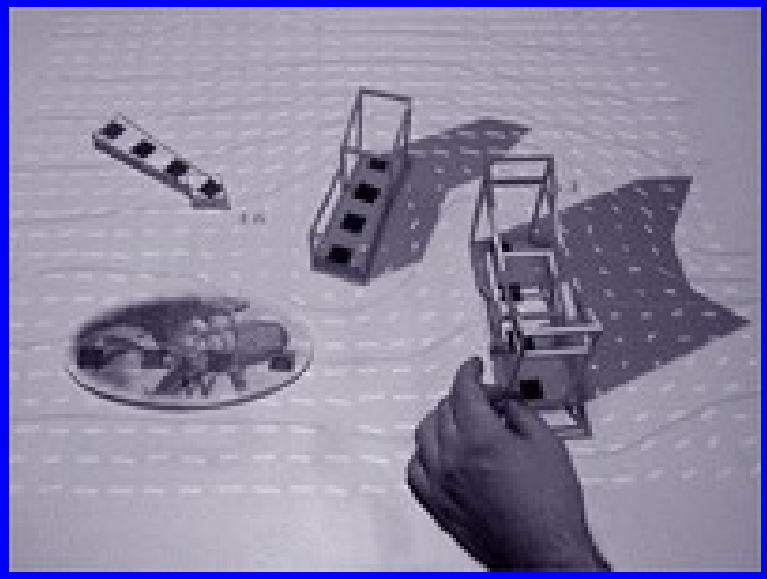
- ○ continuous surface contact
- × difficult to fabricate



Real World Graphics

Image projection on physical objects

- ○ intuitive interaction
- × deformation is not presented



I/O Bulb (Hiroshi Ishii)

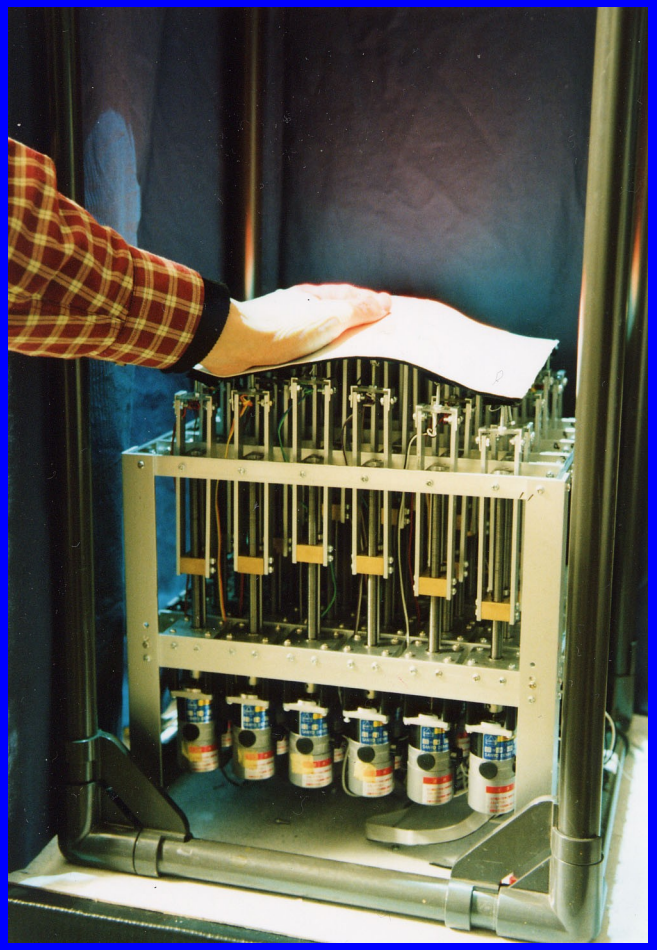
FEELEX = object-oriented-type haptic interface

\+ real world graphics

Prototype Implementation FEELEX 1

Design specification

Two-hand, whole palms
Motor with tangible power
→ 6 X 6 actuator array
24cm X 24cm screen



Actuator for FEELEX 1

1) Screw mechanism

self-lock

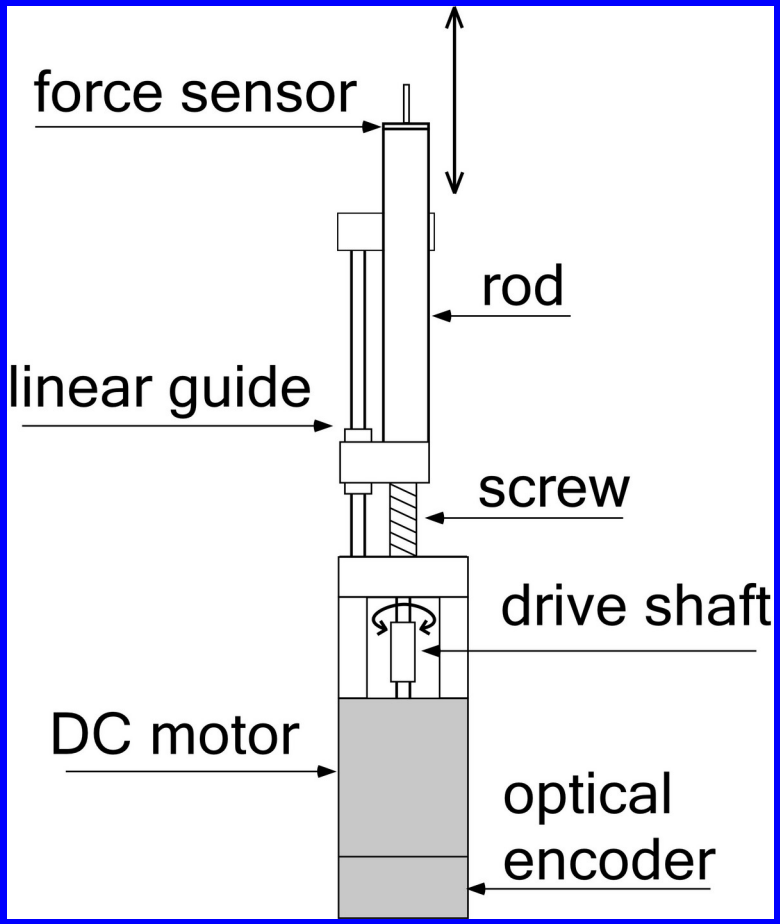
→ free from vibration

stroke = 80mm

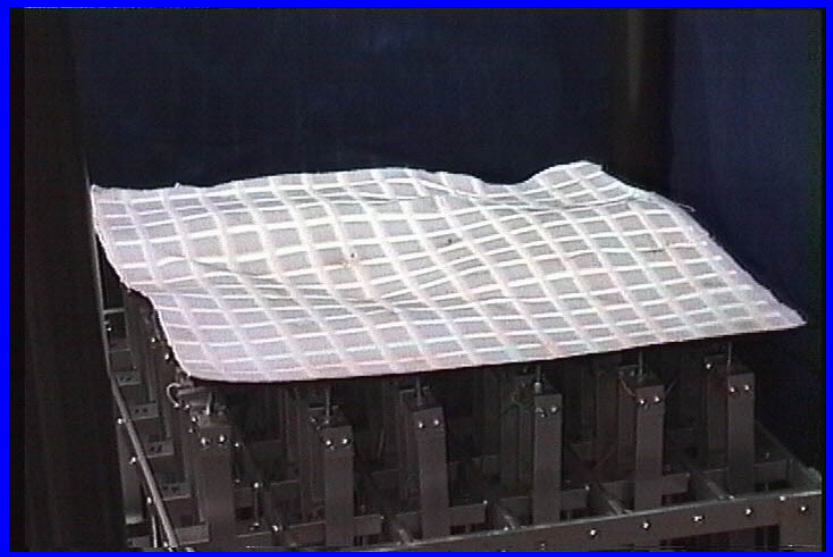
max speed = 100mm/s

2) Force sensor

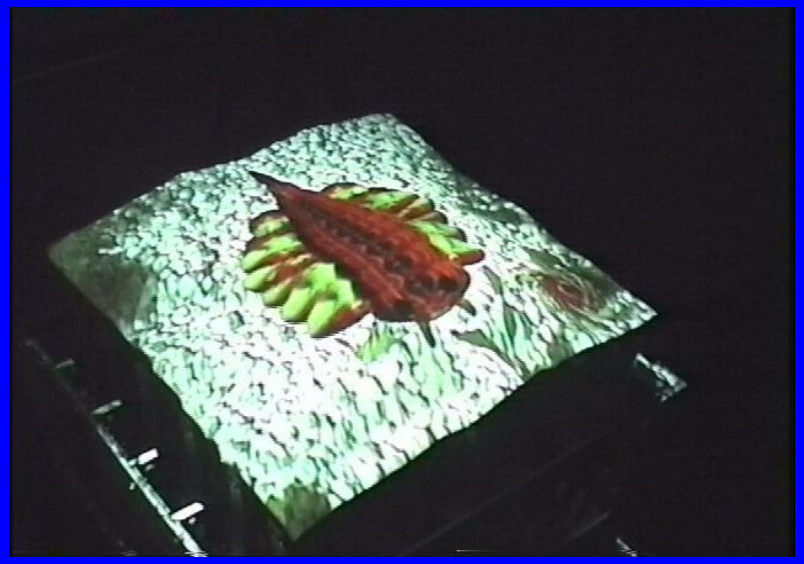
strain gauge



Graphics for FEELEX 1



Projected grid on the deformed screen



Anomarocaris

Prototype Implementation FEELEX 2

Design specification

- Palpation by 3 fingers
- Hard object smaller than 8 mm is difficult to palpate

(Lederman & Klatzky, 1999)

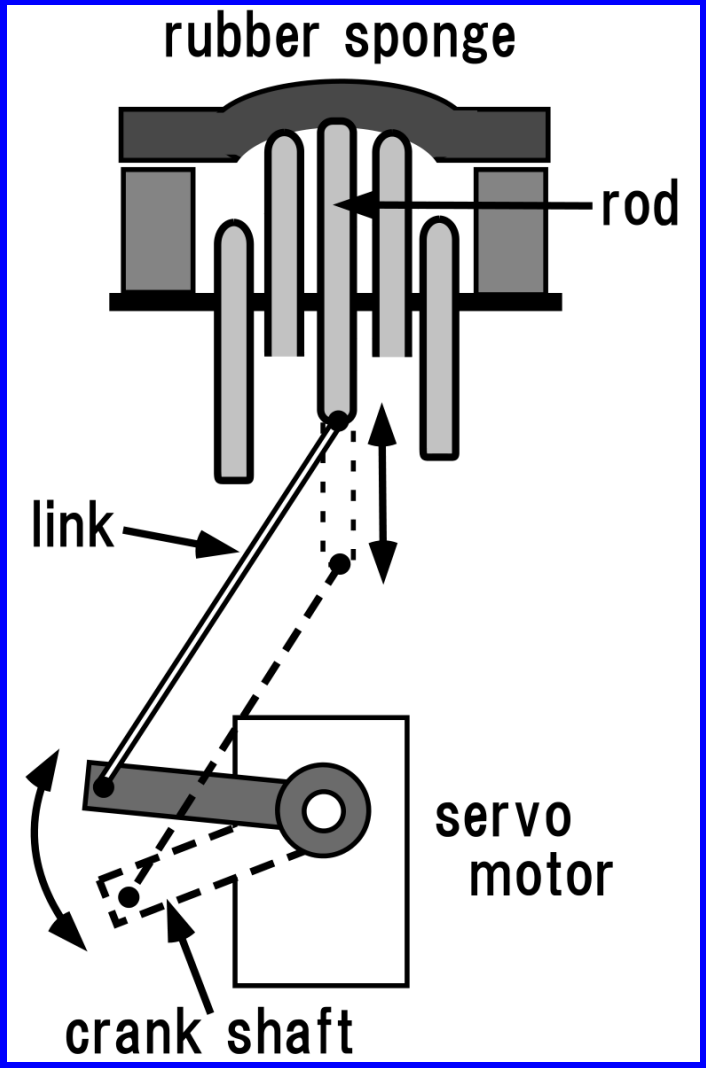
→ lod size = 6mm
distance between lods
= 8mm
display area = 5cm X 5cm

Actuator for FEELEX 2

1) Piston-crank mechanism
   offset position
   → motor can move small rod

   stroke = 18 mm
   max speed = 250 mm/s
   max force = 1.1 Kgf

2) Force sensor
   measuring electric current



Evaluation of FEELEX 1 Observation of User's Behavior

Test environment:

SIGGRAPH'98

Content:

Anomarocaris

Procedure:

only a signage saying "You can touch it"

Number of subjects:

1,992

Results of Observation of User's Behavior

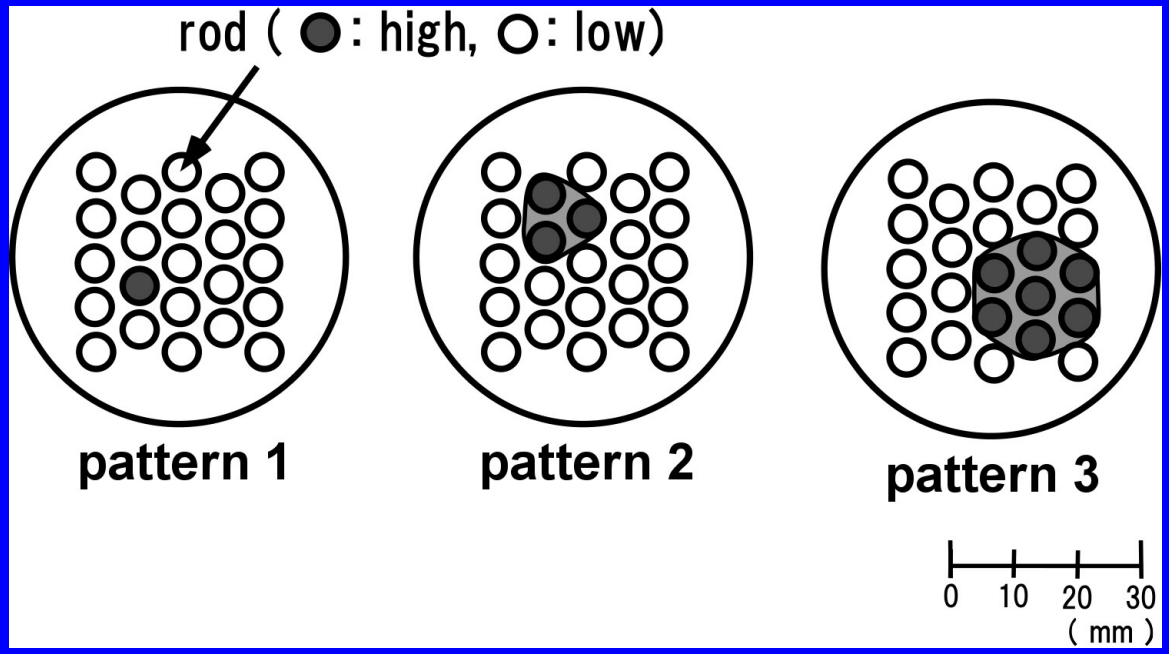
Category	number of subjects
(1) Touched the creature using a single finger	299 (15%)
(2) Touched the creature using multiple fingers	319 (16%)
(3) Touched the creature using the whole hand including the palm	1374 (69%)

85% of the subjects used multiple fingers or their palms without instruction.

Evaluation of FEELEX 2
Recognition Performance of Palpation

Task: Invisible hard objects are displayed (3 patters).

Subjects are asked to draw position and size of the hard object on a piece of paper.



Evaluation of FEELEX 2

Subjects:

9 university students (7 males, 2 females)
ranged in age from 22 to 24.

Procedure:

We prepared three trials for each pattern.

The three patterns are displayed in random order, and thus each subject completed a total of 9 trials.

The subjects were asked to draw the object that th ey perceived for each trial.

Result of Evaluation (1)
Size of perceived objects

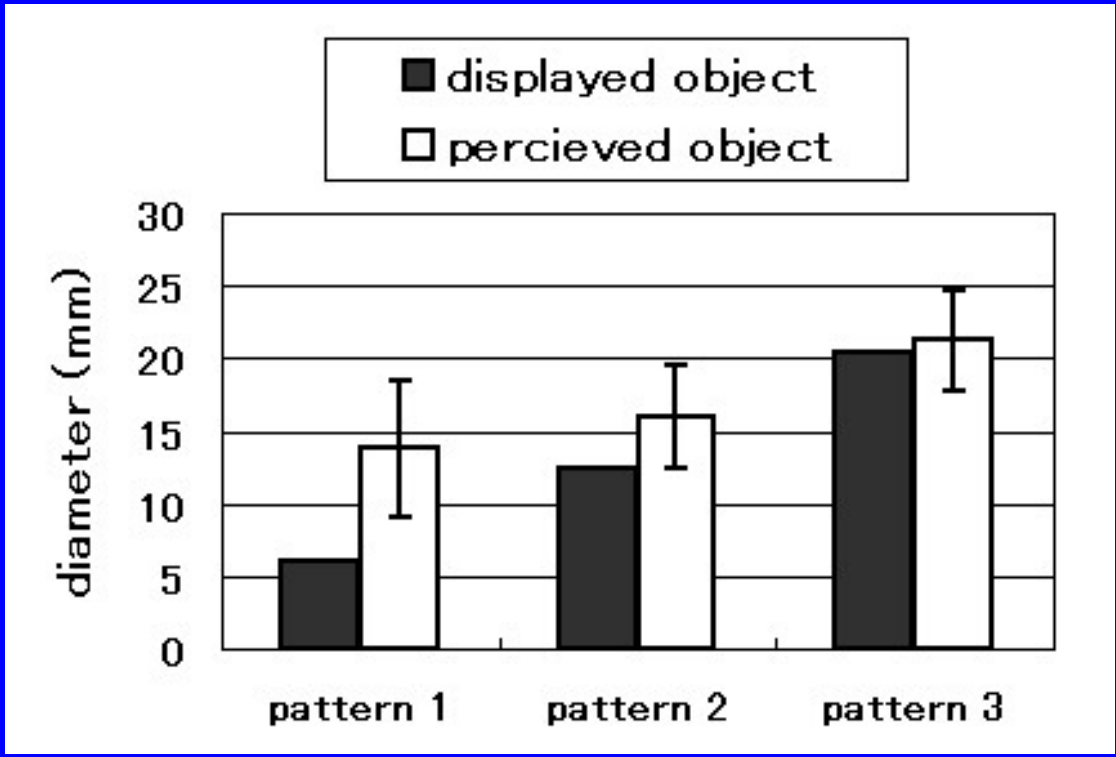
The size of a perceived object is represented by the approximated diameter of the figure drawn by th e subjects.

$$d = \sqrt{4S/\pi}$$

Where

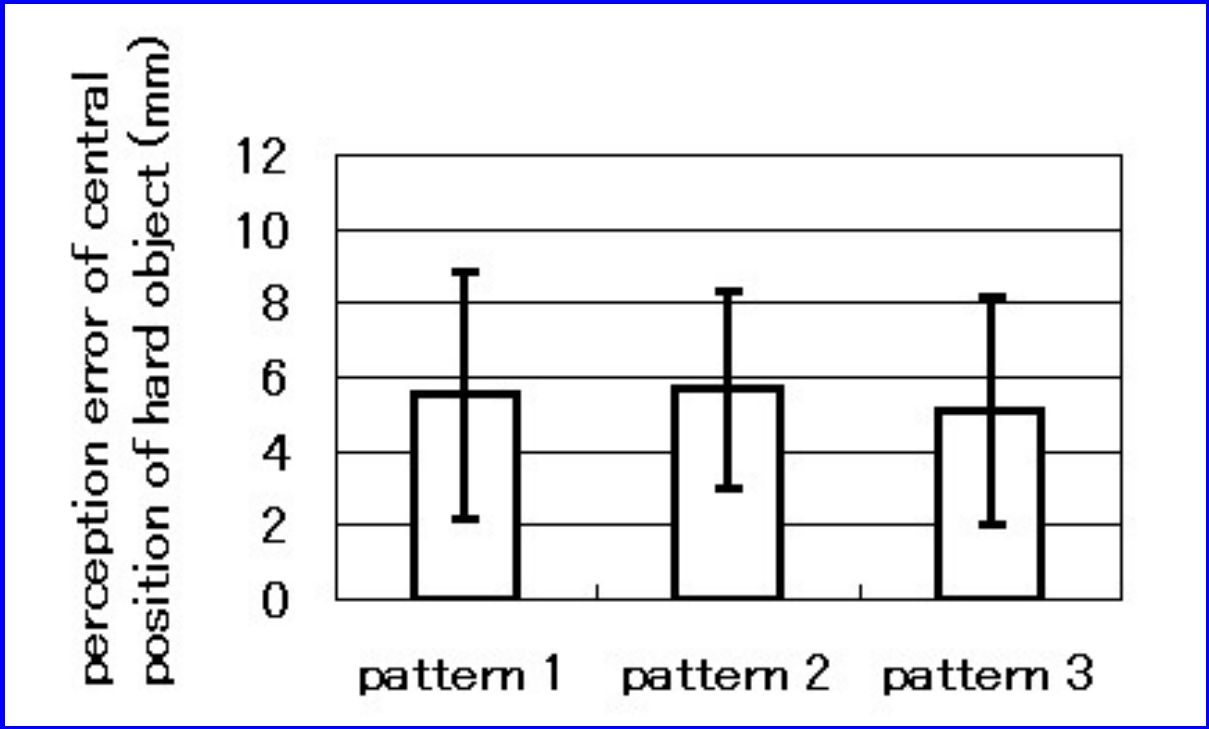
d = approximate diameter

S = measured area



Result of Evaluation (2) position of perceived objects

We calculated the central position (center of mass) of each perceived object.



Discussion for the Experiments

(1) Perception error of size
ranged from 1mm to 8 mm
→ much smaller than finger,
enough for palpation

Over estimation is caused by rubber sponge that covers the rods.

(2) Perception error of position
less than 6mm
→ reasonable error compared to rod distance (8mm)

General Discussion for the FEELEX

(1) advantages

- natural interaction

success in long term exhibition in a museum

- safety

free from vibration or unwanted force

(2) disadvantages

- difficulty in hardware implementation
- limitation of simulated shape

sharp edge, backside of object

Applications for the FEELEX

- Palpation

  training simulator, tele-medicine

- 3D shape modeling

  virtual clay for rough design task

- Touch screen

  barrier-free solution

- Art

  interactive sculpture

Conclusion

Prototype FEELEX provides natural haptic in teraction.

Effectiveness is tested through exhibition an d palpation experiments.

Future Work

Development of new mechanism

- ability to simulate various shapes
- low-cost, easy to fabricate, mechanically robust