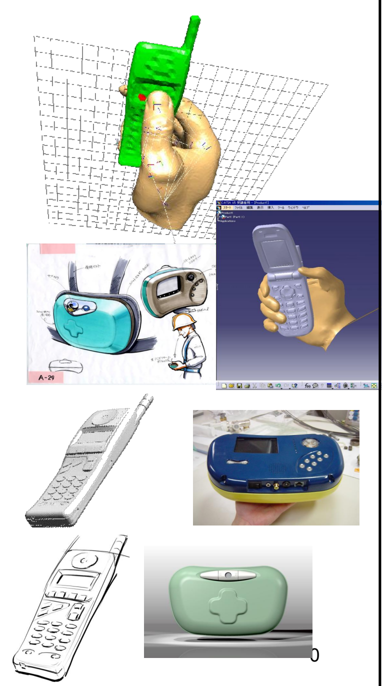
Apr. 23th,
2007 NIST "3D and 2D content rep analysis and retrieval WS"

3D Mesh Model Retrieval and 3D Human Hand Modeling for supporting Product Design

Satoshi KANAI
(kanai @ ssi.ist.hokudai.ac.jp)

Graduate School of Information Science and Technology

Hokkaido University
Sapporo JAPAN



0

Outline of Presentation

- An overview of "IT Carrozzeria " (Advanced Rapid Prototyping of Information Appliances) Project
- Content-based 3D Mesh Model Retrieval from Hand-written Sketch
- Digital Hand and Virtual Ergonomic Assessment Simulator for Styling Design

1

Market Competitiveness in Consumer Electronics

- Discriminating Hardware Functions
- User-Friendly Software
- Attractive Housing Exteriors
- Short Time to Market

2

IT-Carrozzeria Project -an Overview-

Government-funded Collaborative Research Project

Mission:

to realize Technological Fusion of Electronic Design, Style Design and Usability Assessment for Rapid Prototyping of Information Appliances.

Sponsor: MEXT (Japanese Ministry of Education, Science and Technology)

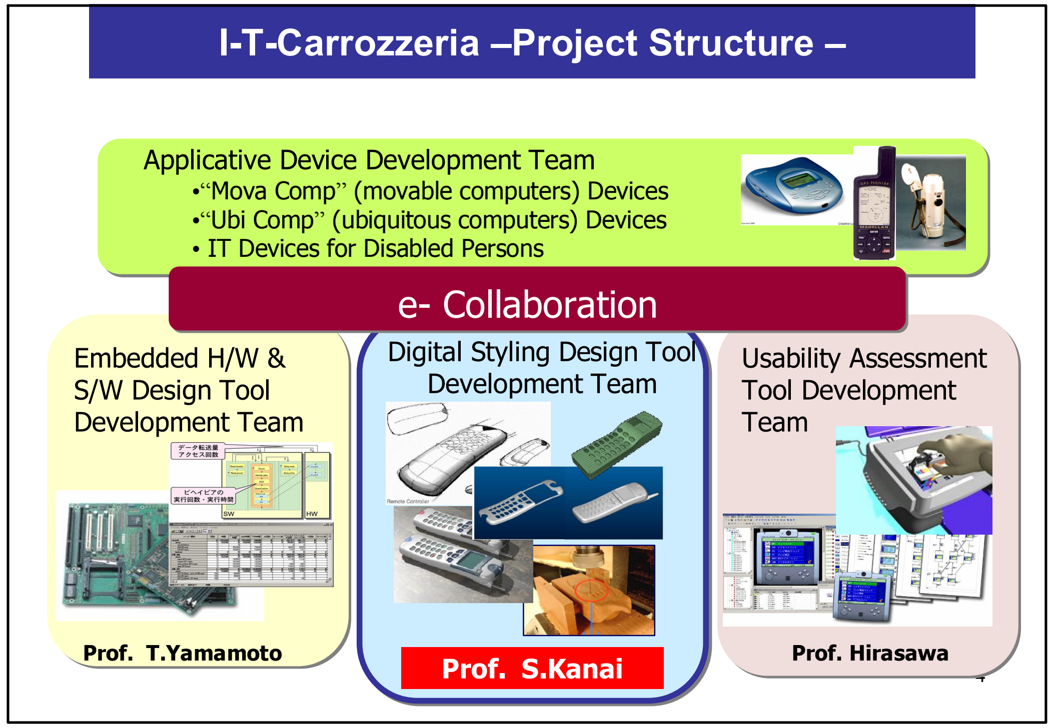
Budget: approx. 4 million USD/ year

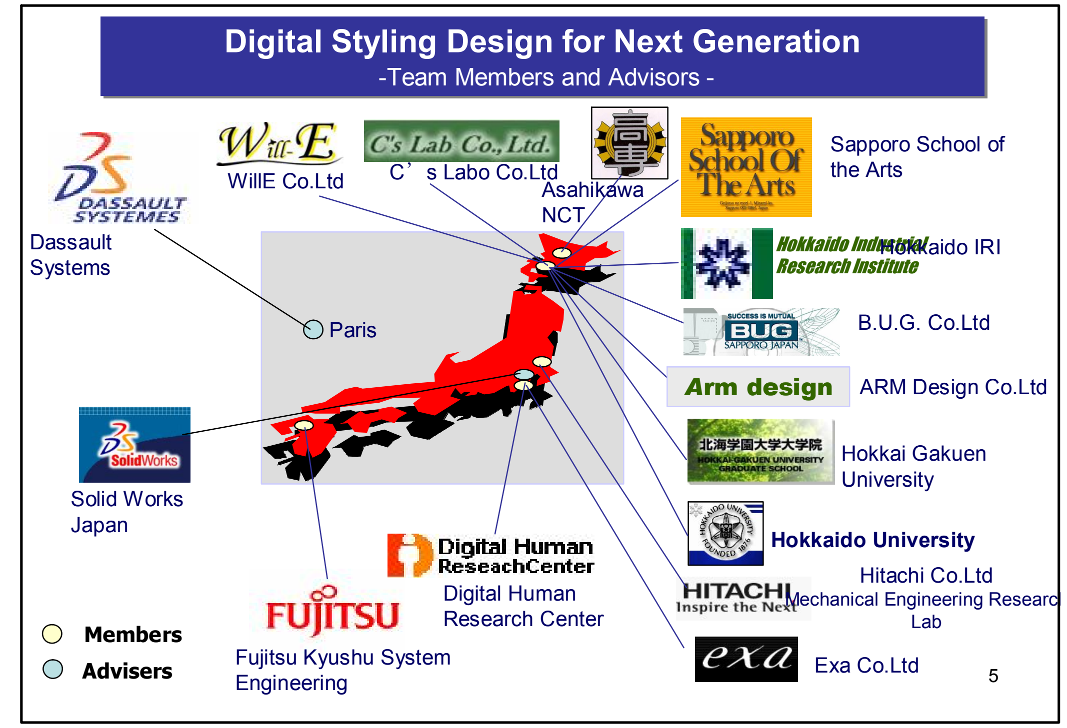
Term: Sept. 2002 ---- Mar. 2007 (5years)

Main Team members:

Hokkaido Univ., Future Univ. Hakodate, Univ. of Tokyo, Sapporo School of the Arts, Hokkaido Industrial Research Institute, Venture Companies in "Sapporo Valley", Consumer Electrics (Fujitsu, Hitachi)

3

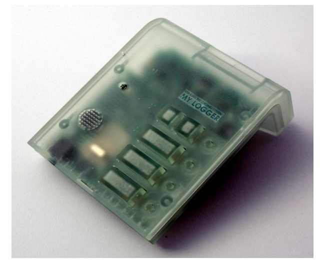

I-T-Carrozzeria –Project Structure –
Applicative Device Development Team
•"Mova Comp" (movable computers) Devices
•"Ubi Comp" (ubiquitous computers) Devices
• IT Devices for Disabled Persons
e- Collaboration
Embedded H/W & S/W Design Tool Development Team
Digital Styling Design Tool Development Team
Usability Assessment Tool Development Team
Prof. T.Yamamoto
Prof. S.Kanai
Prof. Hirasawa


Digital Styling Design for Next Generation
-Team Members and Advisors -
Dassault Systems
WillE Co.Ltd
C' s Labo Co.Ltd
Asahikawa NCT
Sapporo School of the Arts
Hokkaido IRI
B.U.G. Co.Ltd
ARM Design Co.Ltd
Hokkai Gakuen University
Hokkaido University
Hitachi Co.Ltd Mechanical Engineering Research Lab
Exa Co.Ltd
Paris
Solid Works Japan
Digital Human Research Center
Fujitsu Kyushu System Engineering
Members
Advisers
5


Sapporo-Delft Design Workshop
6


Hand-crafted and SLA-fabricated Study Models in 7days
My Logger Redesign Models
7

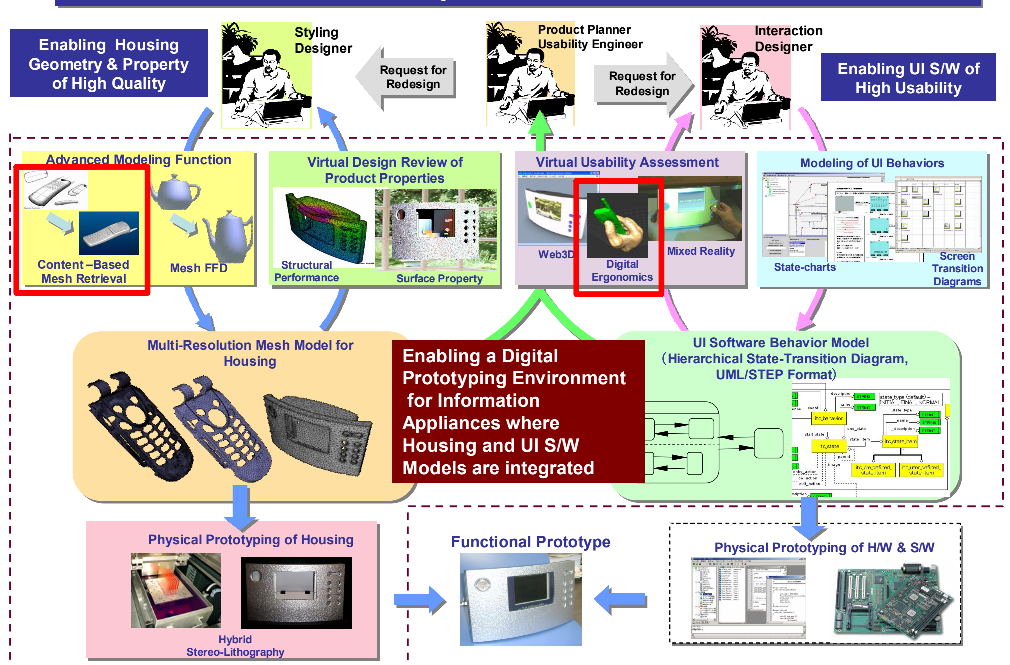
2nd Mockups (made after the workshop)



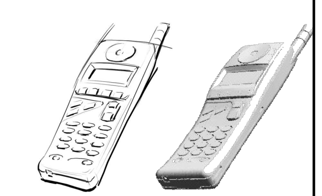
8

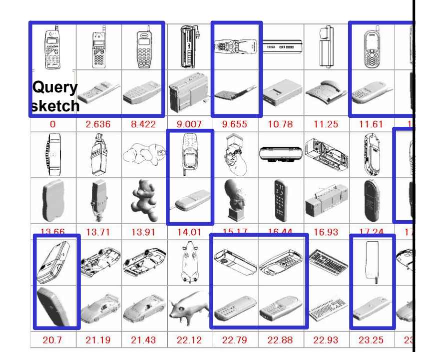
3rd Mockups (Final Mockups for preparing Commercialization) (will be released at Oct. 06)

Project Structure



Content-based 3D Mesh Model Retrieval from Hand-written Sketch





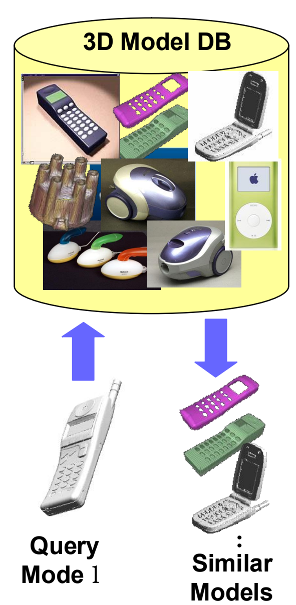
Outline

- Background & Purpose
- Overview of Approaches
- Generation of Images for Retrieval
- Descriptors for Retrieval and Dissimilarity Evaluation
- Examples and Performances
- Conclusions

- Background & Purpose
- Overview of Approaches
- Generation of Images for Retrieval
- Descriptors for Retrieval and Dissimilarity Evaluation
- Examples and Performances
- Conclusions

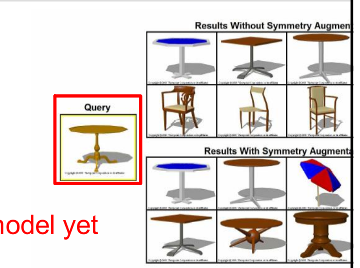
Background

- **"Flooding" of 3D models**
  - CG, CAD, CAM, CAE, 3D-Scanning, Web3D, etc..
- **Need for computer-aided retrieval functions to efficiently manage DBs of 3D models**
  - Have to provide a user with natural, simple, intuitive and friendly I/F for model retrieval
- **"Content-based" retrieval**
  - Enables a user to directly input the content data as a query
  - Enables to find a set of similar data from the DB.
  - Popular to 2D digital image retrieval
  - Retrieval of 3D models is still in the fundamental research level.

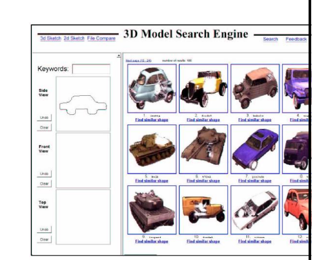


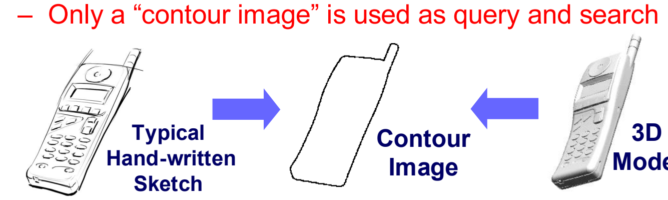
Related Works on Content-based 3D Model Retrieval

- **3D Model Retrieval from 3D Model Query**
  - Many researches
  - Feature-based: [Osada 02], [Funkhouser 02], etc.
  - Graph-based: [El-Mehalawi 03], [Hilaga 01], etc.
  - But…., a user must have a "3D model" for query
  - Impractical when a user does not have the query model yet



- **3D Model Retrieval from 2D Sketch Query**
  - Enables more simple & intuitive query to users
  - Very few research
  - [Funkhouser 03] & [Chen 03]
  - Only a "contour image" is used as query and search

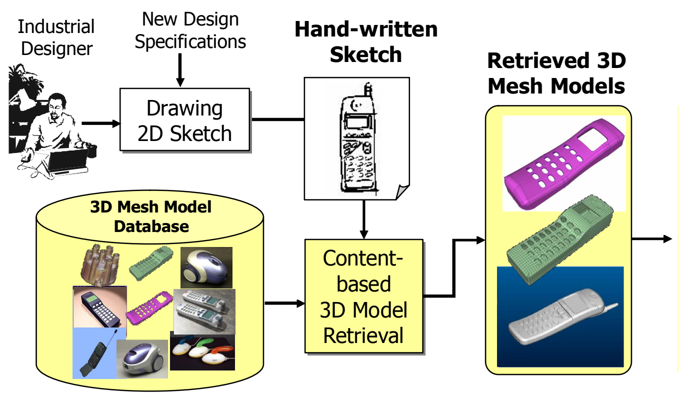




Purpose & Applications

Purpose : To develop a new algorithm of content-based 3D mesh model retrieval system from a hand-written 2D sketch query

Potential Applications in industrial design field

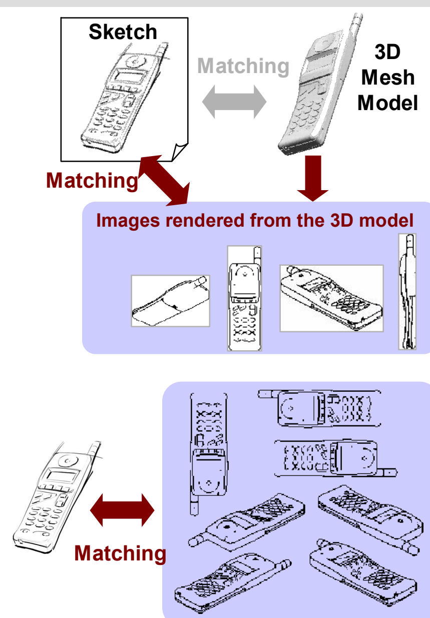


- Supporting to create New Styling Concepts
- Checking violating Design Rights
- Efficient Retrieval from 3D Parts Library

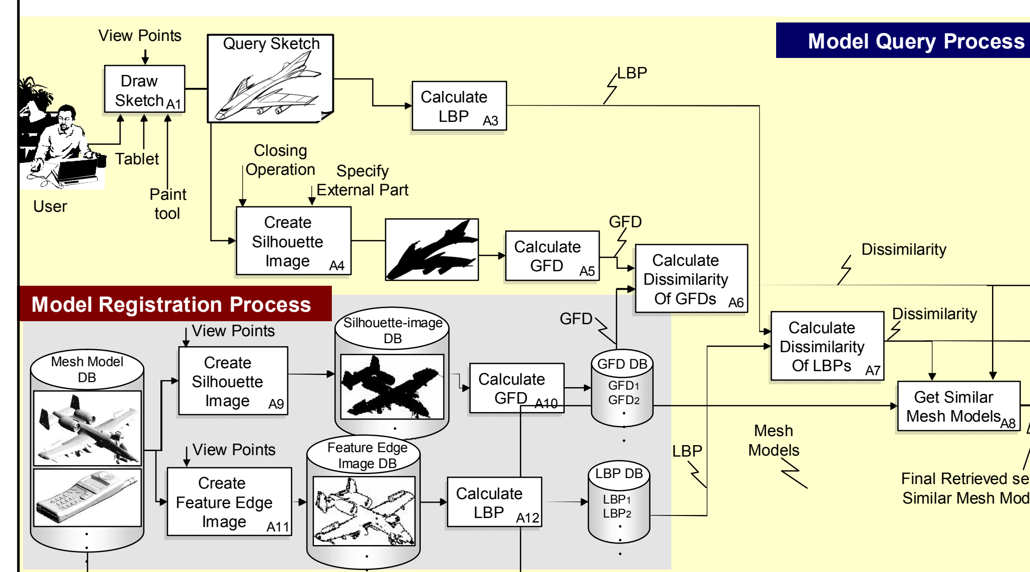
- Background & Purpose
- **Overview of Approaches**
- Generation of Images for Retrieval
- Descriptors for Retrieval and Dissimilarity Evaluation
- Examples and Performances
- Conclusions

Approaches

- A 3D model retrieval was reduced to a 2D image retrieval
  - Image-based dissimilarity evaluation between a image of input hand-written sketch and automatically rendered images of 3D mesh models.
- 2D transformation invariant image descriptors are used for the retrieval regardless of defined coord. systems
  - **Generic Fourier Descriptors (GFDs)** for silhouette images
  - **Local Binary Patterns (LBPs)** for feature edge images

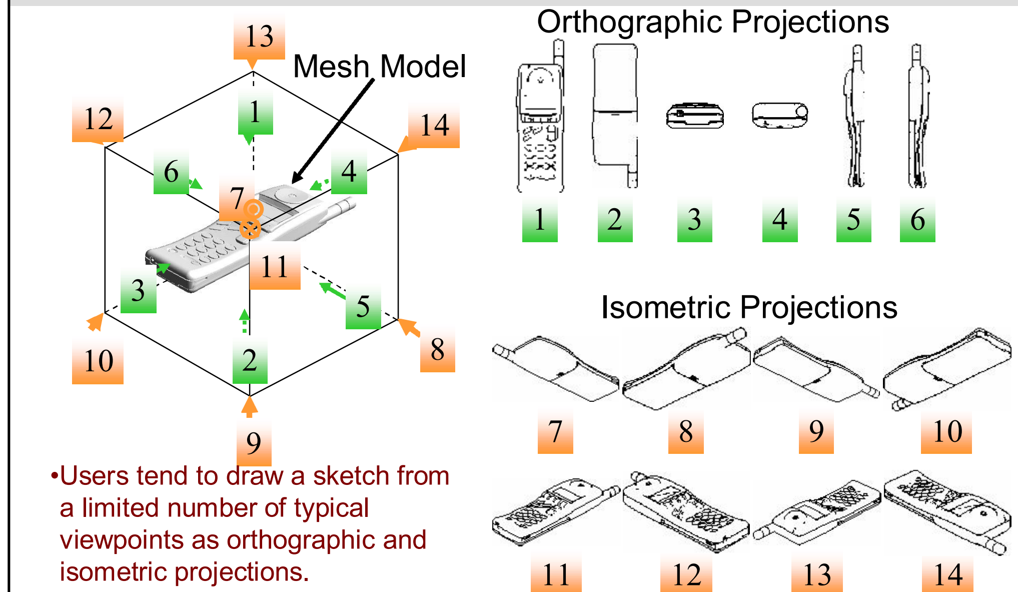


Outline of the Sketch–based 3D Mesh Model Retrieval System



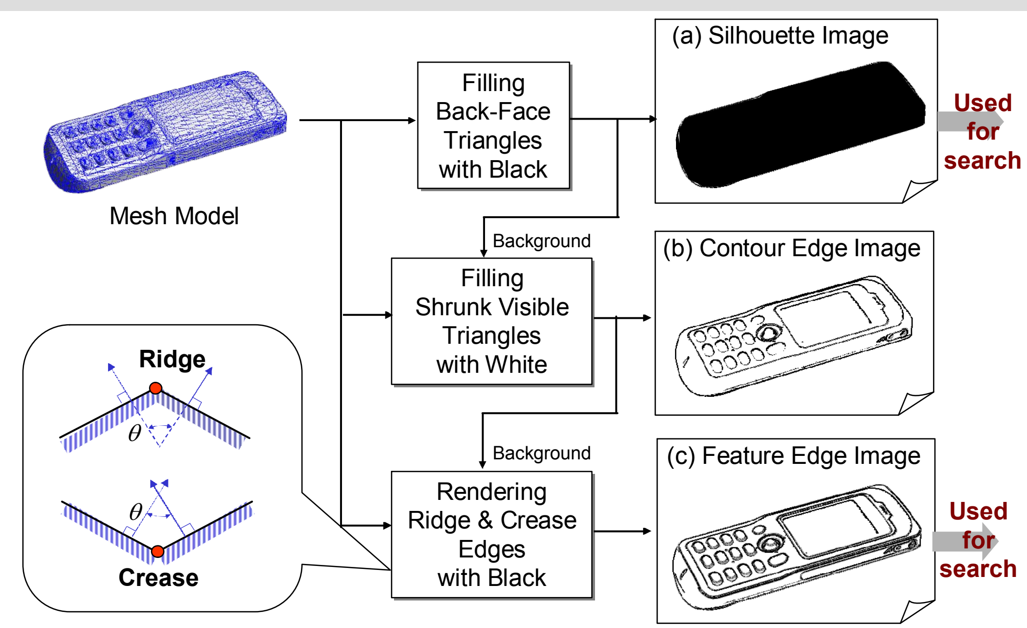
- Background & Purpose
- Overview of Approaches
- **Generation of Images for Retrieval**
- Descriptors for Retrieval and Dissimilarity Evaluation
- Examples and Performances
- Conclusions

Viewpoint settings for feature edge images and silhouette image

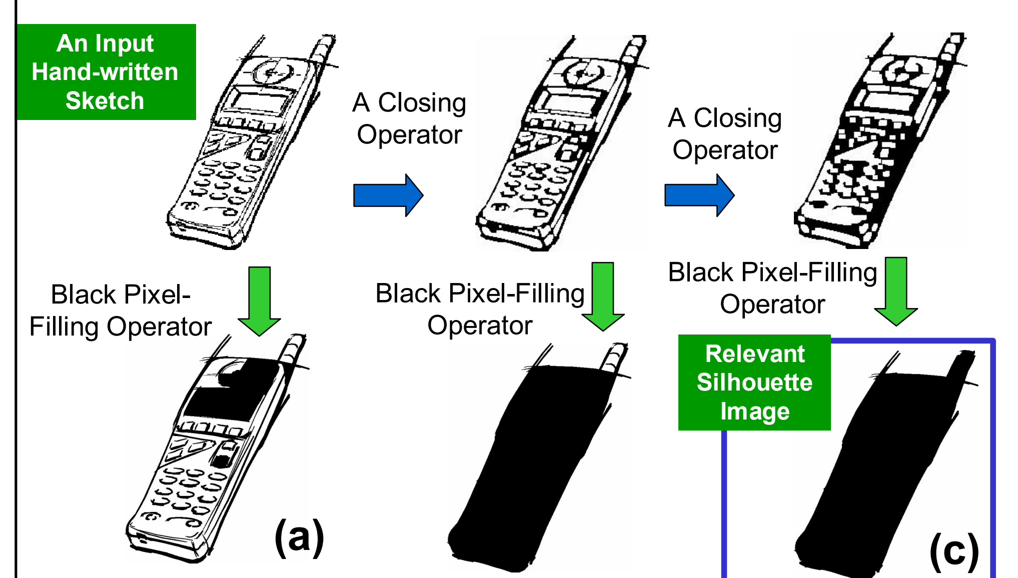


- Users tend to draw a sketch from a limited number of typical viewpoints as orthographic and isometric projections.
- **14 typical viewpoints are used.**

Rendering a silhouette image, a contour edge image and a feature edge image

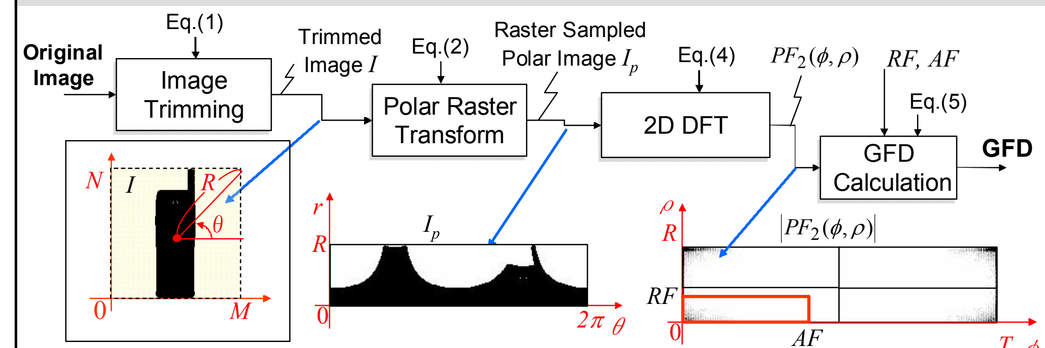


Rendering silhouette, contour edge and feature edge images for a hand-written sketch



- Background & Purpose
- Overview of Approaches
- Generation of Images for Retrieval
- **Descriptors for Retrieval and Dissimilarity Evaluation**
- Examples and Performances
- Conclusions

Generic Fourier Descriptor (GFD) (1)



$$I = \{ f(x,y) \mid 0 \le x < M, 0 \le y < N \}$$

$$I_p = \{ f(r,\theta) \mid 0 \le r < R,\ 0 \le \theta < 2\pi \} \quad \text{where} \quad R = \left\lfloor \sqrt{(M/2)^2 + (N/2)^2} \right\rfloor$$

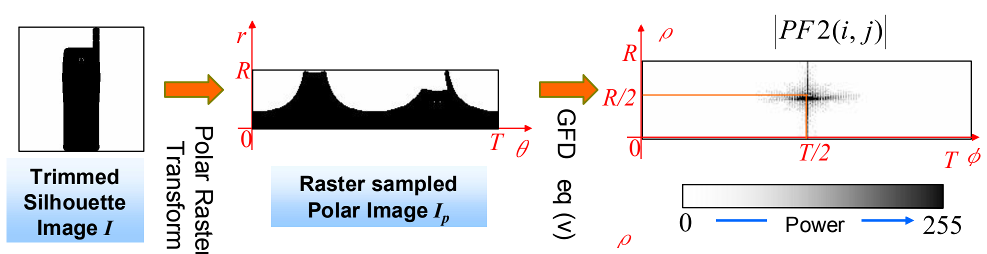
DFT for Polar Image I_p

$$PF_2(\rho,\phi) = \sum_{r}^{R-1} \sum_{i}^{T-1} f(r,\theta_i) \times \exp[-j2\pi(\frac{r}{R}\rho + \theta_i \phi)] \quad (4)$$

where $0 \le r < R$, $\theta_i = i(2\pi/T)\ (0 \le i < T)$, $0 \le \rho < R$, $0 \le \phi < T$

Generic Fourier Descriptor (GFD) (2)

- **An image descriptor for (binary) silhouette image**
- **Scaling, Translational and Rotational Invariant**



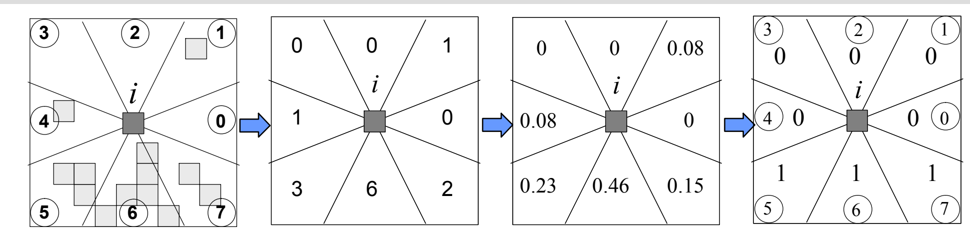
Generic Fourier Descriptor

$$\mathbf{GFD} = \left\{ \frac{|PF_2(0,0)|}{area}, \frac{|PF_2(0,1)|}{|PF_2(0,0)|}, \ldots, \frac{|PF_2(0,n)|}{|PF_2(0,0)|}, \ldots, \frac{|PF_2(m,0)|}{|PF_2(0,0)|}, \ldots, \frac{|PF_2(m,n)|}{|PF_2(0,0)|} \right\} \quad (5)$$

$$= \{ GFD(0,0), GFD(0,1), \ldots, GFD(0,n), \ldots, GFD(m,0), \ldots GFD(m,n) \} \quad (5')$$

where $area = RT$, $m = R/2$, $n = T/2$

Local Binary Patterns (LBP)

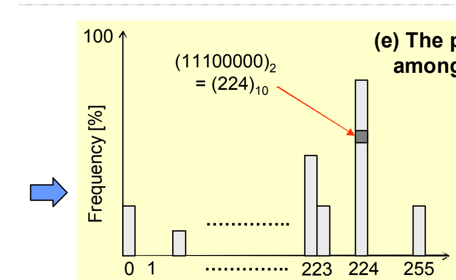


(a) Feature edge image after edge thinning
(X) : Sub-region of direction X

(b) The number of black pixels in each sub-region (c_{ix})

(c) Normalized number of black pixels in each sub-region (S_{ix})

(d) Binarized number of black pixels in each sub-region (f_{ix}) for th=0.15



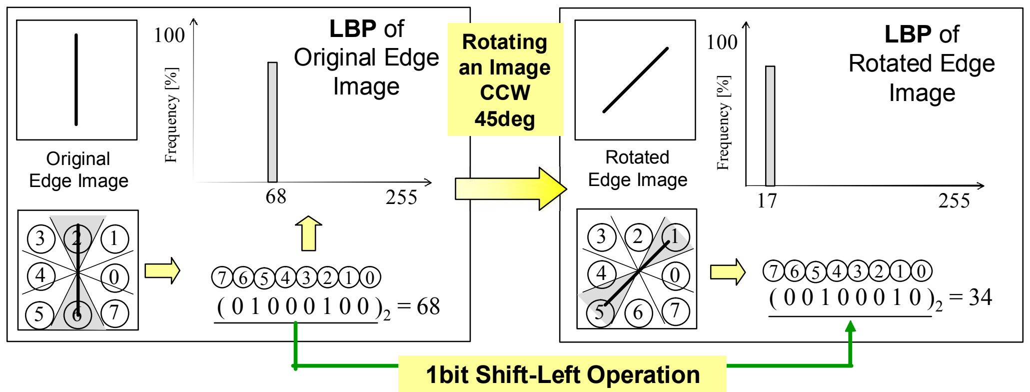
(e) The percentage of total vote for a class among 0-255 for all edge pixels

LBP = [LBP_0, LBP_1, ……… , LBP_{255}]

where $LBP_i \in$ [0,100]

Rotational & Reflective Invariance for LBP

- LBP itself is translational & scaling invariant, and is NOT rotational and reflective invariant
- Rotational and Reflective invariance for LBP can be realized by simple Bitwise operations for an original LBP



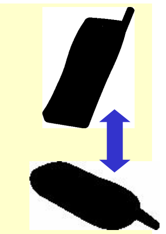
45deg CCW Rotation of Image = 1-bit Shift-left Operation of the LBP

Dissimilarity Evaluation by combining GFD with LBP

- **A Dissimilarity between GFDs** (D_{GFD})

$$D_{GFD}(\mathbf{GFD}_Q, \mathbf{GFD}_{Ix}) = \sqrt{\sum_{k=0}^{RF}\sum_{l=0}^{AF}\left\{GFD_Q(k,l) - GFD_{Ix}(k,l)\right\}^2}$$

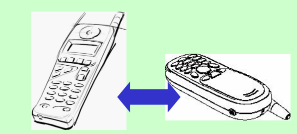
$GFD_Q(k, l)$: a GFD component of a silhouette image of a query sketch
$GFD_{Ix}(k, l)$: a GFD component of a silhouette image x in the DB



- **A Dissimilarity between LBPs** (D_{LBP})

$$D_{LBP}(\mathbf{LBP}_Q, \mathbf{LBP}_{Ix}) = \min_{p \in \{1,2,\dots,P\}} \left\langle \sqrt{\sum_{j=0}^{255}\left\{l^Q_{j'(p,j)} - l^{Ix}_j\right\}^2} \right\rangle$$

$l^Q_{j'(p,j)}$: $j'(p, j)$-th component of LBP of a query sketch
l^{Ix}_j : j-th component of LBP of a feature edge image in the DB

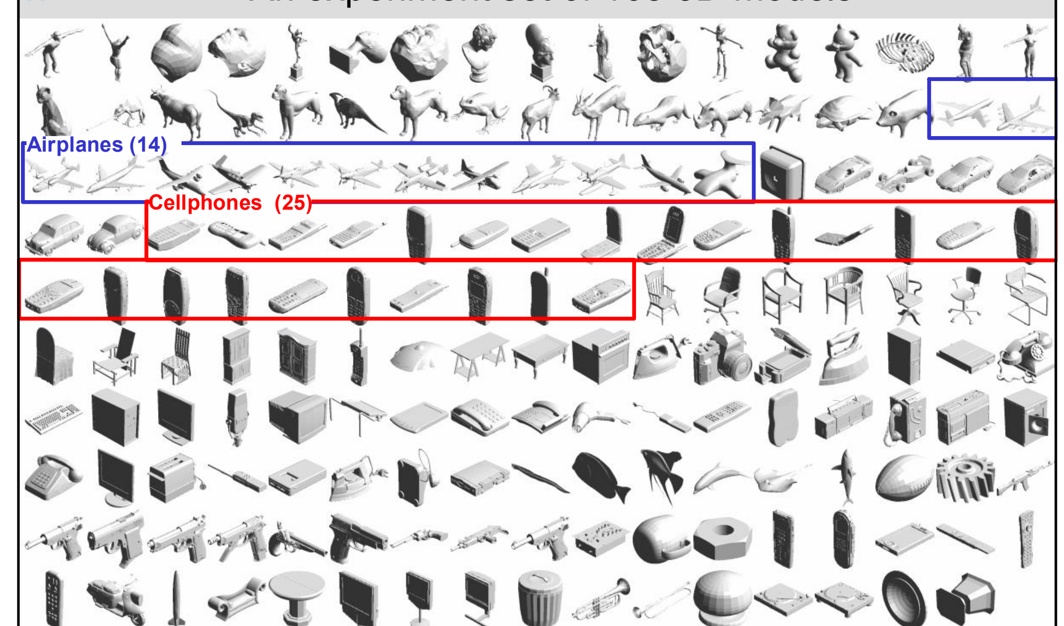


p : # of bitwise operations (rotations) on LBP

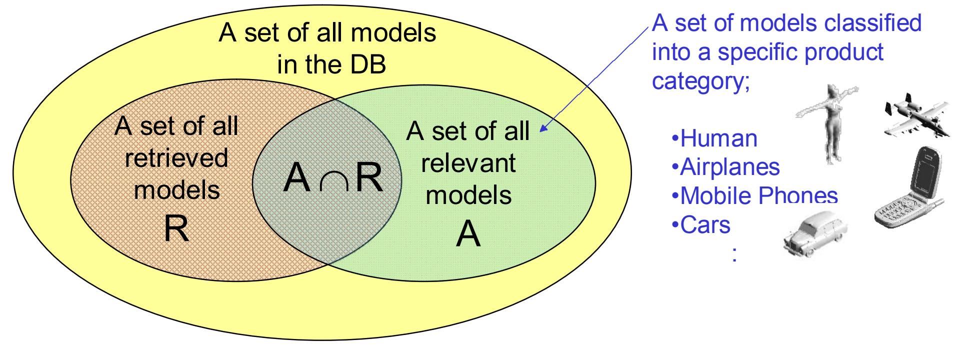
- **2-tier Searching Strategy**
  1. **Pre-filtering by GFD :** Generating a Candidate retrieval set using GFDs
  2. **Re-arrangement by LBP :** Finding a Final retrieval set by rearranging the places of the models in the Candidate set using LBPs

- Background & Purpose
- Overview of Approaches
- Generation of Images for Retrieval
- Descriptors for Retrieval and Dissimilarity Evaluation
- Examples and Performances
- Conclusions

An experiment set of 168 3D models



Retrieval performance measures



◆ **Recall**

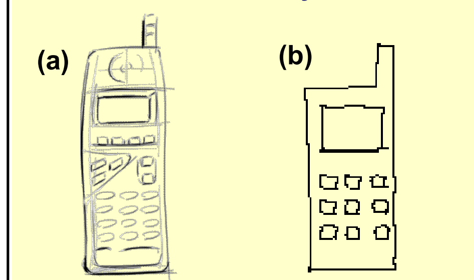
a measure how much the retrieved set contains models in a relevant set ➡ $\text{Recall} = \frac{|A \cap R|}{|A|}$

◆ **Precision**

a measure how much the retrieved set does not contain irrelevant models ➡ $\text{Precision} = \frac{|A \cap R|}{|R|}$

Hand-written sketches for query and retrieval conditions

Hand-written Query sketches



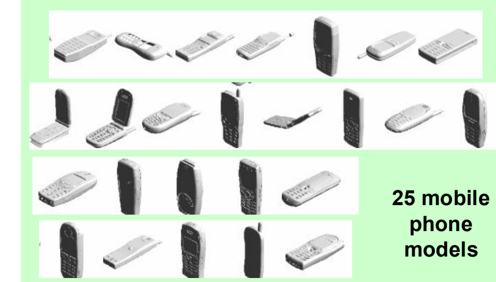
(a) A rough sketch written by an industrial designer

(b) A scribble sketch written by a student (without industrial design skills)

Retrieval Conditions

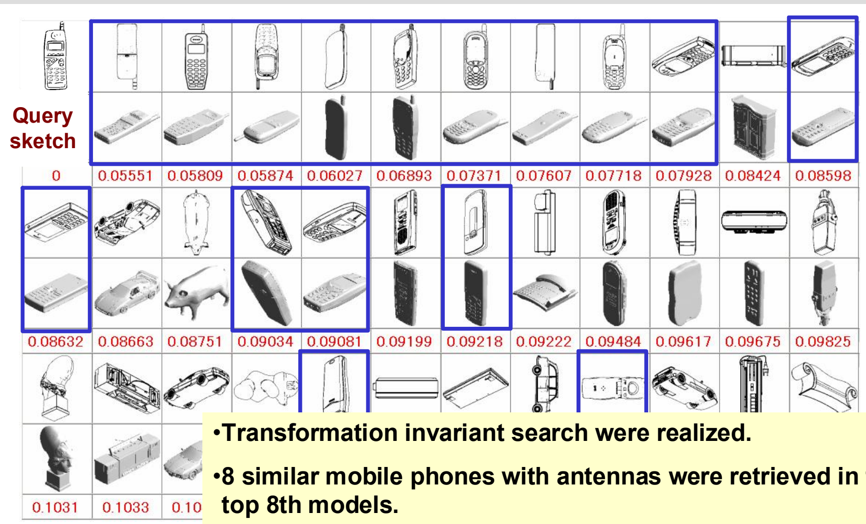
- **# of models in the retrieval set = 35 models**

A relevant model set = A set of Mobile phones (25 models)



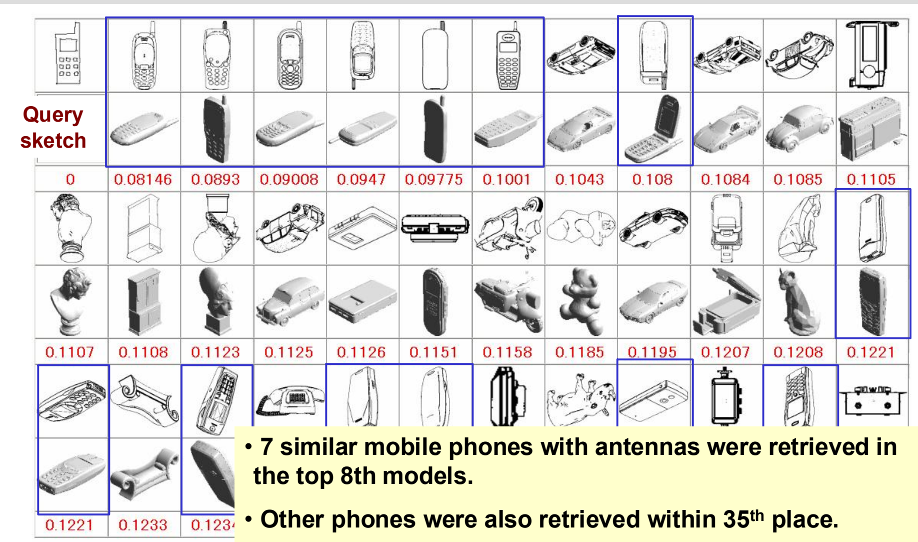
25 mobile phone models

A retrieval result for a rough sketch only using pre-filtering by GFD



- **Transformation invariant search were realized.**
- **8 similar mobile phones with antennas were retrieved in the top 8th models.**
- **Other phones were also retrieved within 35th place.**
- **The similar models in the top 8th still had dissimilar feature edge shapes (without push button surface)**

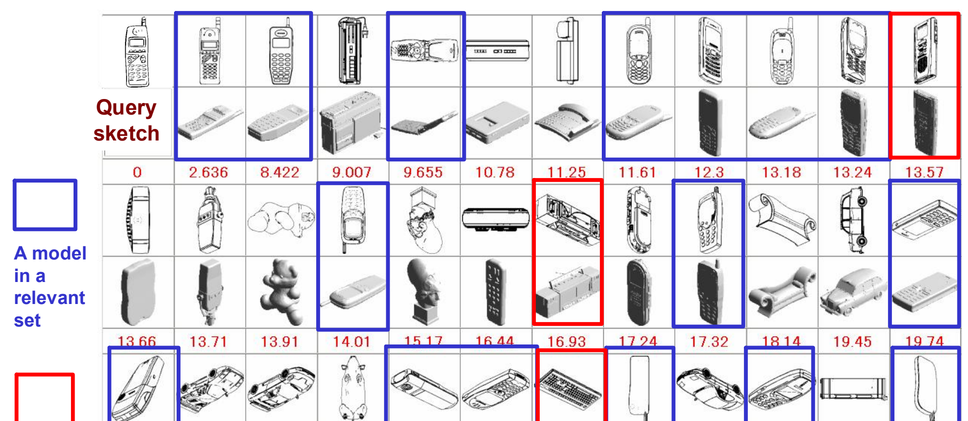
A retrieval result for a scribble using pre-filtering only by GFD



A model in a relevant set

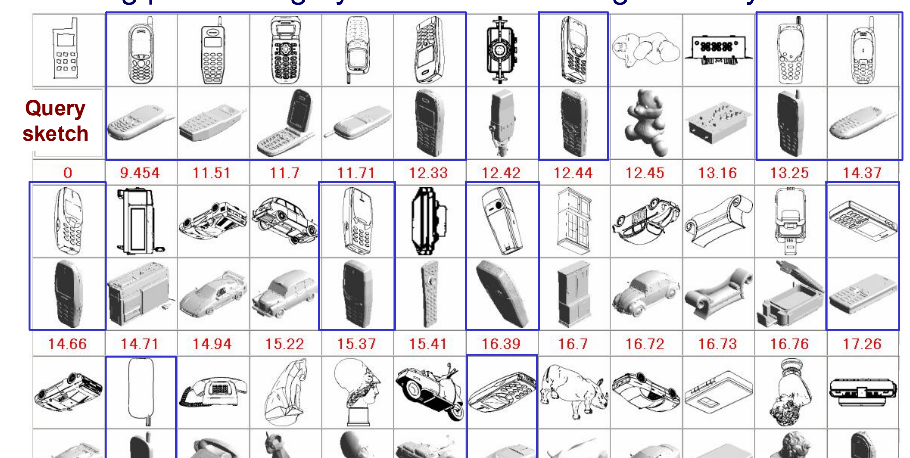
- **7 similar mobile phones with antennas were retrieved in the top 8th models.**
- **Other phones were also retrieved within 35th place.**
- **Similar satisfactory results to the former one were obtained.**

A retrieval result for a rough sketch using pre-filtering by GFD and re-arrangement by LBP



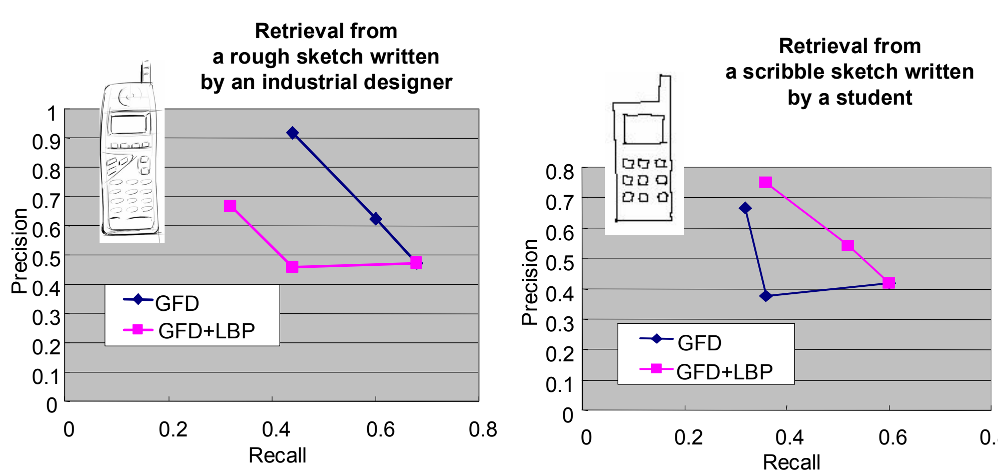
- The phones with similar silhouettes and similar feature edges (button surfaces) appeared in higher places than the case only using GFD.
- Some models in different categories but resembling to the sketch (keyboard, digital recorders, audio set, etc.) also appeared.
- The proposed 2-tier search strategy worked well

A retrieval result for a scribble using pre-filtering by GFD and re-arrangement by LBP



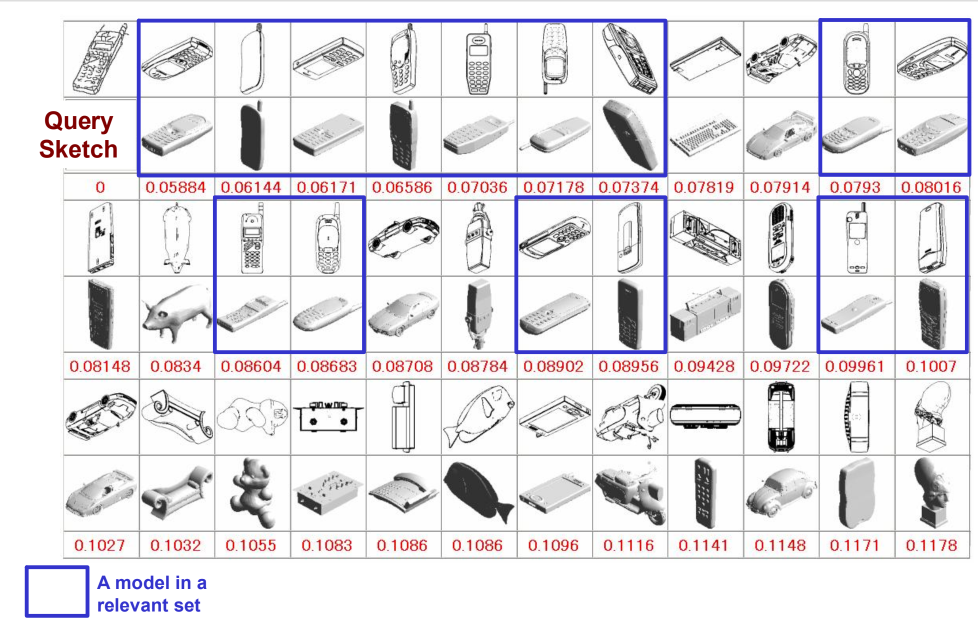
- The phones with similar silhouettes and similar feature edges (button surfaces) still appeared in higher places than the case only using GFD.
- The proposed 2-tier search strategy worked well

Plots of Precision-Recall for two retrieval results



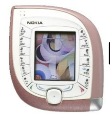
- 2-tier search strategy using pre-filtering by GFD and re-arrangement by LBP could improve the retrieval performance especially in the case of using a simple sketch as a query.

A retrieval result for another rough sketch using pre-filtering by GFD

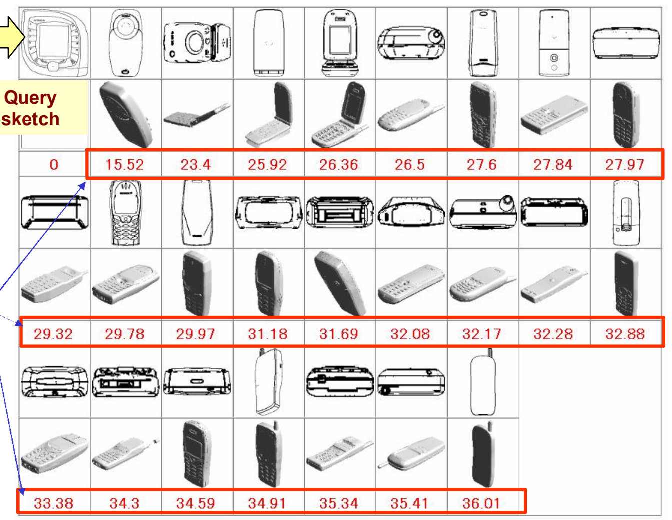


A result of retrieval for a unconventional mobile phone sketch

A mobile phone having an unconventional housing shape



Query sketch



- **The models with similar to the query were not retrieved.**
- **Dissimilarity values increased a few hundreds as large as the ones in the case that the similar shapes were found.**

The mobile phone of the query has a strikingly original exterior.

Conclusions

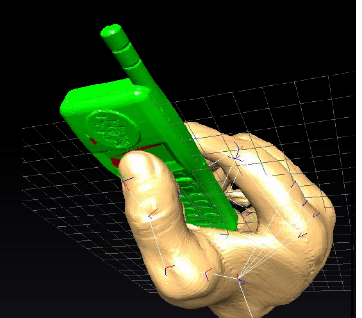
(1) A new algorithm of content-based 3D mesh model retrieval system from a hand-written 2D sketch query was proposed.

- Generic Fourier Descriptor and Local Binary Patterns enabled a model retrieval function invariant to rotational, translational and reflective transformations for a sketch and mesh models.

(2) Retrieval performances were evaluated as the Precision-Recall

- An effectiveness of the Pre-filtering by GFD and re-arrangement by LBP were indicated by the examples of industrial design.

Digital Hand and Virtual Ergonomic Assessment Simulator for Styling Design



Satoshi KANAI
Yui ENDO

Hokkaido University, JAPAN

Natsuki MIYATA
Makiko KOUCHI
Masaaki MOCHIMARU

Digital Human Research Center, AIST, JAPAN

Introduction

Ergonomic Assessment for Handheld Information Appliances

- Ease of grasping the housing
- Ease of operating the user-interfaces
- Ease of using the embedded software

Process of Ergonomic Assessment

Current Ergonomic Assessment
- Uses physical mockups and real human subjects
- Costs a lot of time and money
- Not done in some cases of development of handheld information appliances

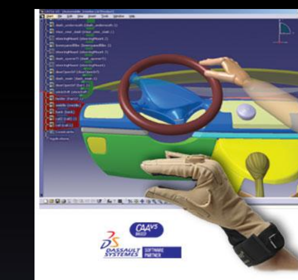
Virtual Ergonomic Assessment
- Uses digital mockups and digital hand models
- Easily generates the digital hand models with various dimensions
- Saves the cost

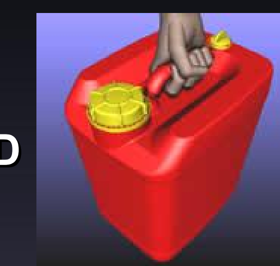
Related Works (1)

Digital Human Modeling
- SANTOS (Univ. Iowa)
- INRETS Model
- HUMOSIM (Univ. Michigan)

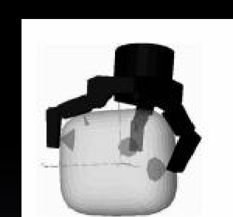
Computer Graphics
- Univ. Toronto
- MPI Informatik
- Hitachi

Commercial Add-ons for 3D-CAD
- Virtual Hand （USA, Immersion） （for CATIA）
- Handy-Works (NZ, ZeeTec) （for SolidWorks）





Related Works (2)



GraspIt! - [Miller 05]
- A grasp planning system for robotic hands

Virtual Reality - [Wan04] etc.
- Enables to grasp a virtual object with a digital hand controlled by a data glove

Disadvantages of related works
- Digital hand geometries with low-fidelity
- Improper grasp posture generation for the information appliances
- Insufficient grasp assessment functions experimentally verified.

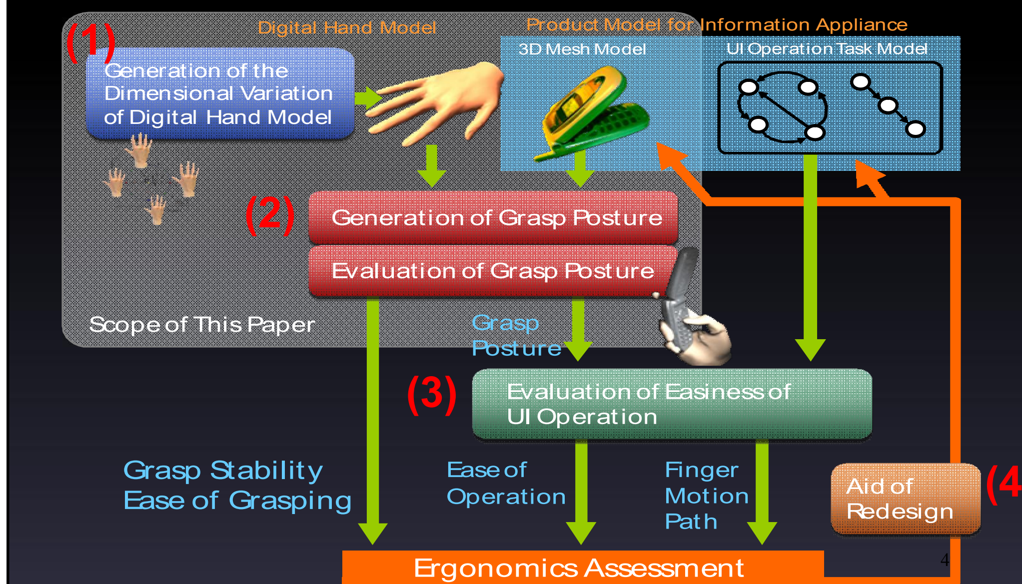
Research Purpose

To develop a software for ergonomics design, which enables ergonomic assessment for a handheld information appliance without “real” subjects and physical mockups by integrating a digital hand with a digital mockup of the product
- Virtual grasp assessment

Features

- Hand geometries with high fidelity
- Appropriate grasp posture generation of information appliances
- Virtual grasp assessment function whose ability is experimentally verified
  - Grasp Stability – Force closure & Grasp Quality
  - Ease of Grasping – EOG map

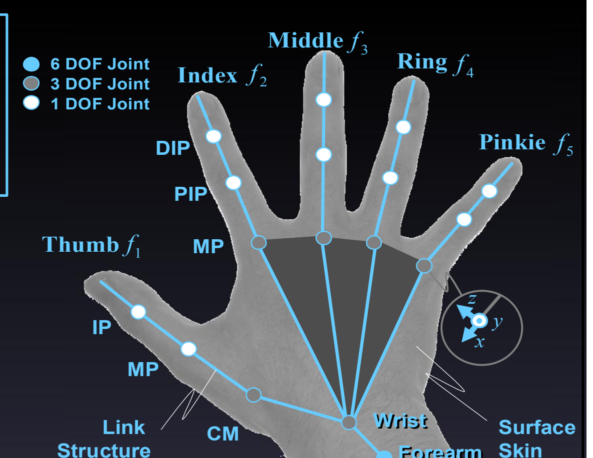
Overview of our system



Digital Hand Model

Dhaiba-Hand by [Kouchi 05]

Personal or average size of
1) Link structure model
2) Static surface skin model



Digital Hand Model

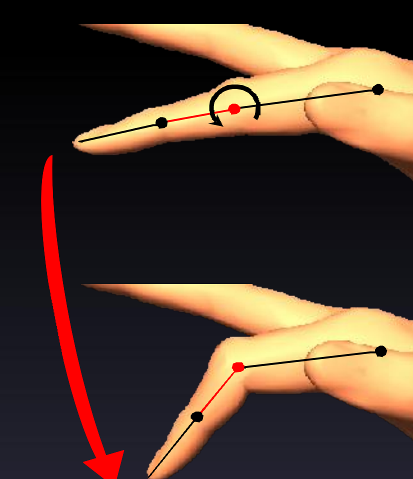
Dhaiba-Hand by [Kouchi 05]

Personal or average size of
1) Link structure model
2) Static surface skin model

+

Our developed model

3) Surface skin deformation algorithm
4) Finger closing motion sequencer (FCMS)



Digital Hand Model

Dhaiba-Hand by [Kouchi 05]

Personal or average size of
1) Link structure model
2) Static surface skin model

+

Our developed model

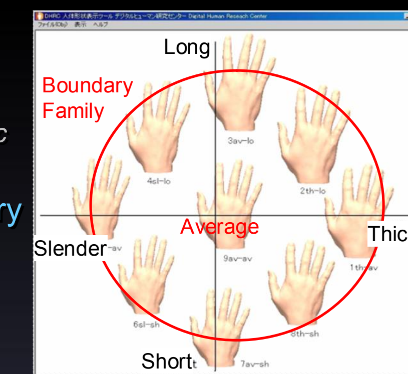
3) Surface skin deformation algorithm
4) Finger closing motion sequencer (FCMS)

52

Dimensional Variation of Digital Hand

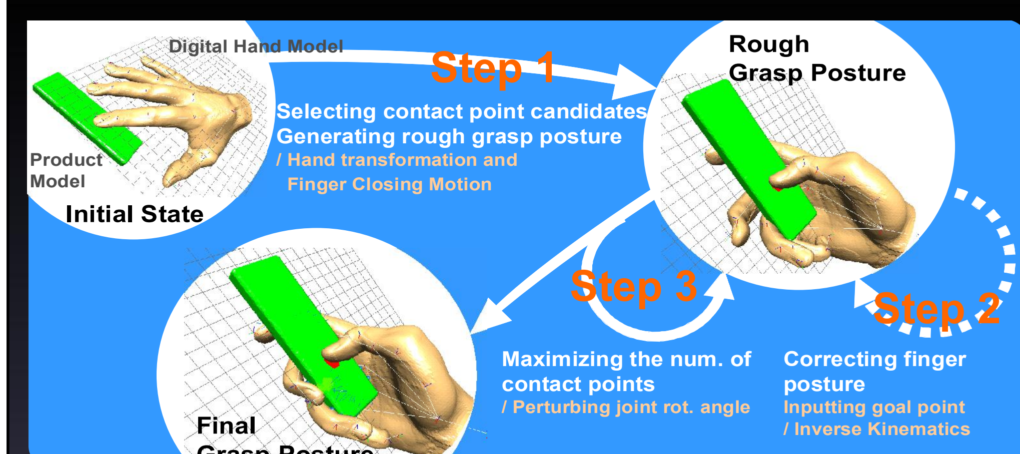
Dhaiba-Hand [Kouchi03]

- A specified subject's hand
  - Generated by inputting 82 measurements and deforming *generic hand model*
- Average dimension and 8 boundary family of Japanese adults
  - Factor analysis of hand dimensions
    - 103 subjects (Japanese adults)
    - 82 measurements
  - Includes 95% of distribution in boundary family circle



53

Generation of the Grasp Posture

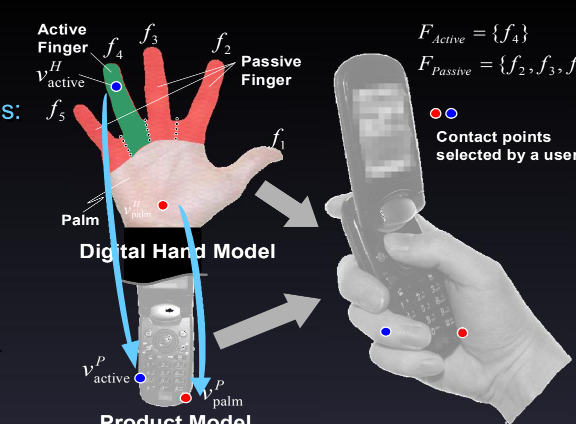


54

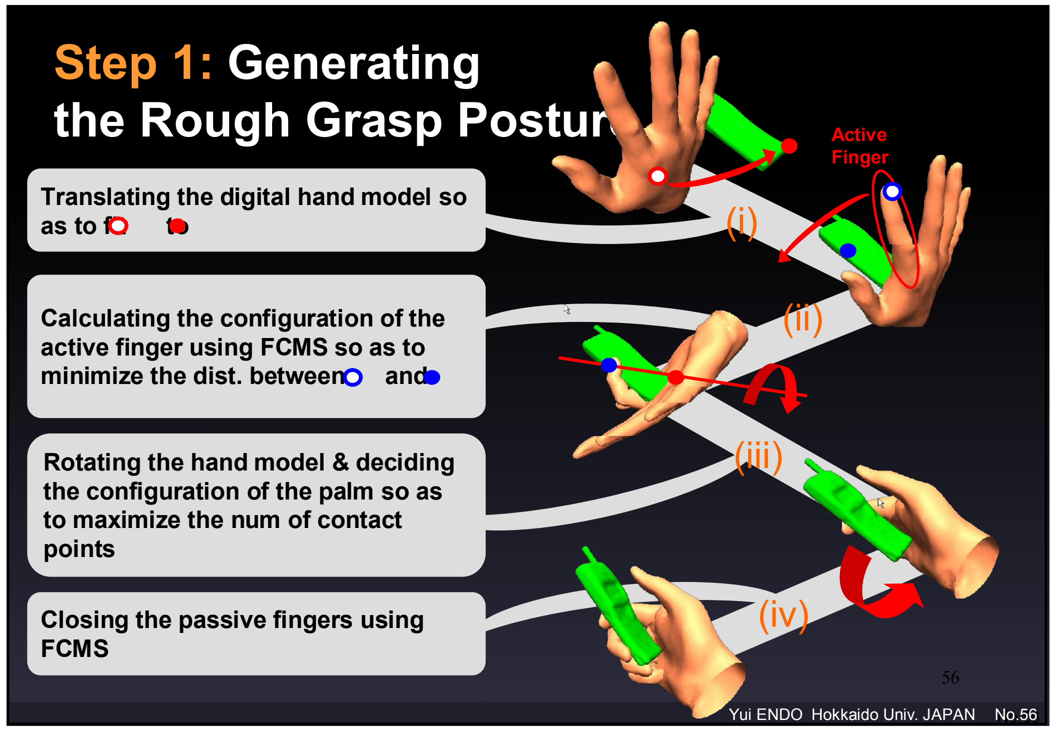
Step 1: Generating the Rough Grasp Posture

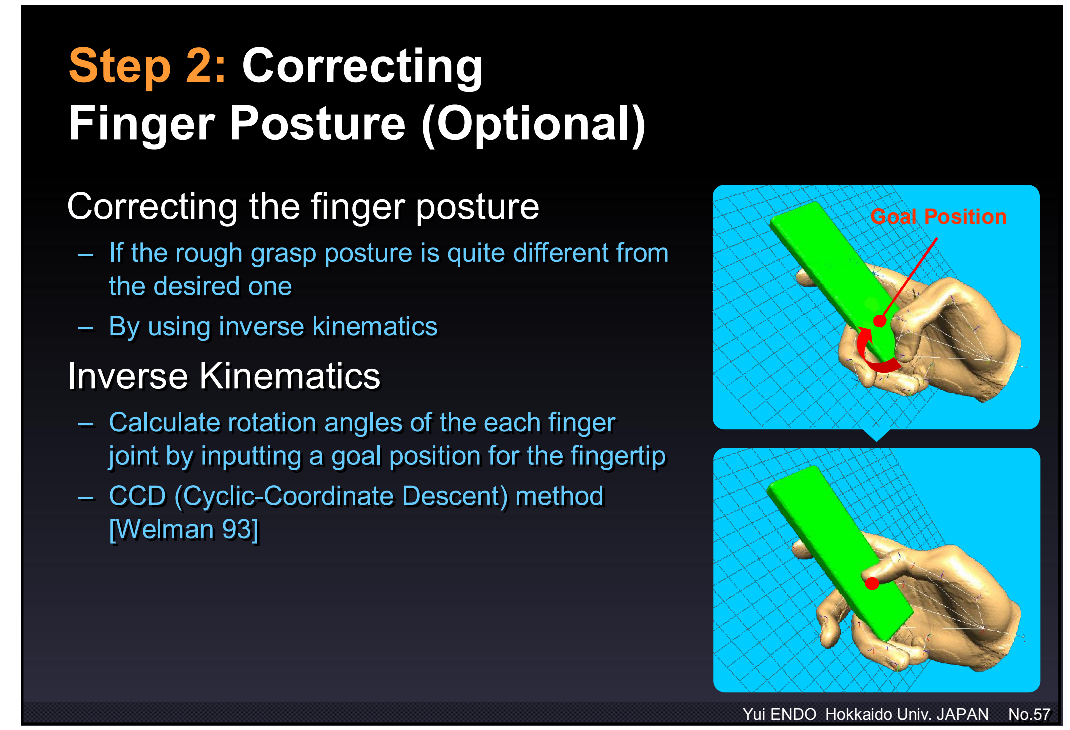
Selecting contact point pair candidates

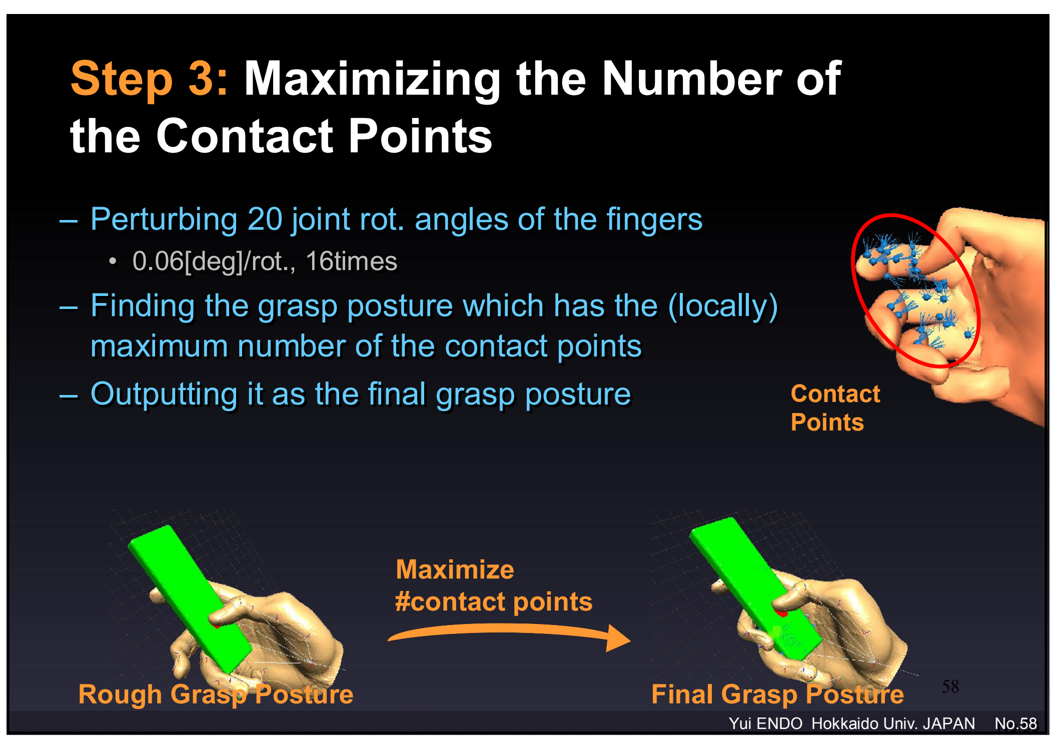
- Classifying fingers into two types:
  - Active finger
  - Passive finger
- Selecting contact point candidates
  - One vertex on the palm and its relative vertex of the product
  - One vertex on the Active finger and its relative vertex of the product

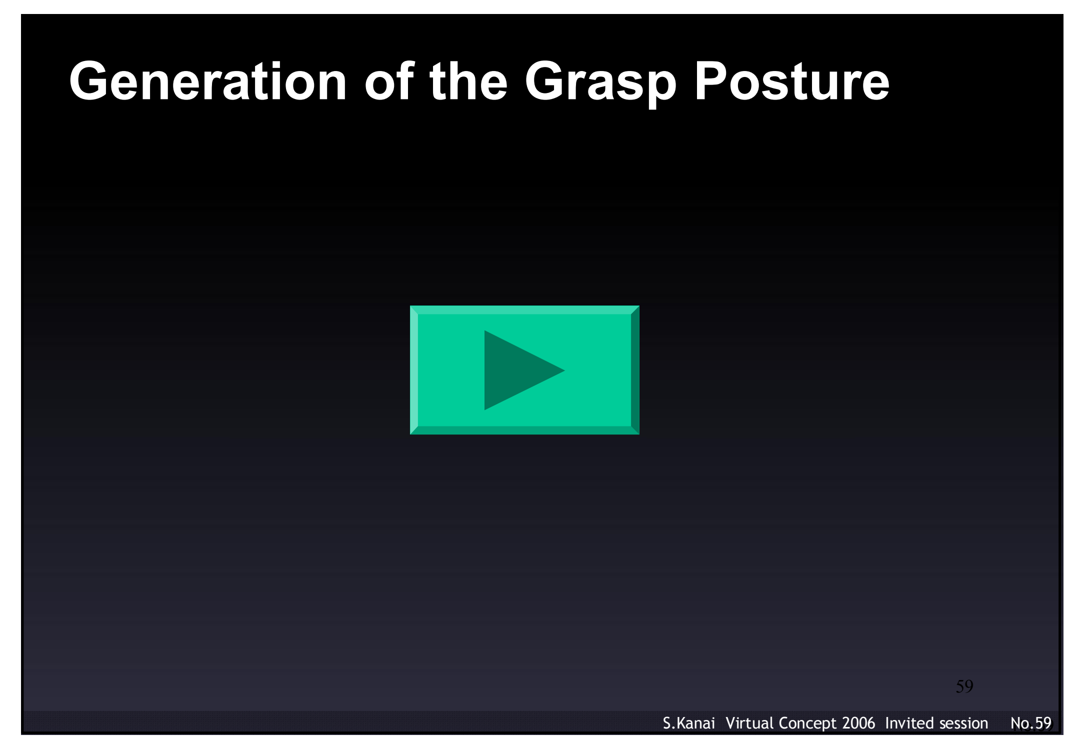


55


Step 1: Generating the Rough Grasp Posture
Translating the digital hand model so as to fit to
Calculating the configuration of the active finger using FCMS so as to minimize the dist. between and
Rotating the hand model & deciding the configuration of the palm so as to maximize the num of contact points
Closing the passive fingers using FCMS
Active Finger
(i)
(ii)
(iii)
(iv)
56
Yui ENDO Hokkaido Univ. JAPAN No.56


Step 2: Correcting Finger Posture (Optional)
Correcting the finger posture
– If the rough grasp posture is quite different from the desired one
– By using inverse kinematics
Inverse Kinematics
– Calculate rotation angles of the each finger joint by inputting a goal position for the fingertip
– CCD (Cyclic-Coordinate Descent) method [Welman 93]
Goal Position
Yui ENDO Hokkaido Univ. JAPAN No.57


Step 3: Maximizing the Number of the Contact Points
– Perturbing 20 joint rot. angles of the fingers
• 0.06[deg]/rot., 16times
– Finding the grasp posture which has the (locally) maximum number of the contact points
– Outputting it as the final grasp posture
Contact Points
Maximize #contact points
Rough Grasp Posture
Final Grasp Posture
58
Yui ENDO Hokkaido Univ. JAPAN No.58


Generation of the Grasp Posture
59
S.Kanai Virtual Concept 2006 Invited session No.59

Grasp Stability Evaluation

Force-Closure

- Indicates whether the digital hand can grasp the product model stably at the contact points set

Grasp Quality

- Defined only when the force-closure condition is satisfied
- Expresses how stably the hand can hold the product at the posture
  - Larger Grasp Quality means stabler grasp

60

Grasp Stability Evaluation

Wrench $\mathrm{w}(c) \in \mathrm{R}^6$

- A vector of contact force and torque at a contact point c

$$\mathbf{w}(c) \equiv \begin{bmatrix} \mathbf{f}_c \\ \mathbf{f}_c \times \mathbf{p}(c) \end{bmatrix} \qquad (1)$$

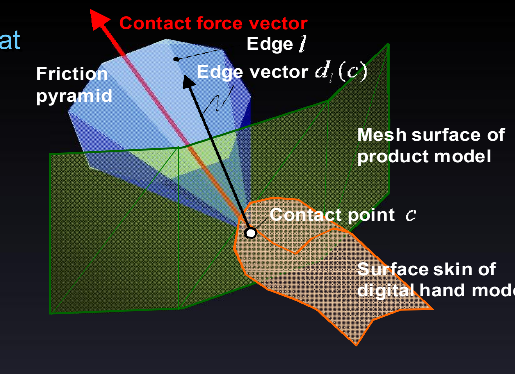
$\mathbf{f}_c$: contact force vector at c

$\mathbf{p}(c)$: position vector of c

- Expressed as a linear combination of $\mathrm{w}_l(c)$

$$\mathbf{w}(c) = \sum_{l=1}^{L} \alpha_l(c)\mathbf{w}_l(c) \qquad (2)$$

$$\mathbf{w}_l(c) \equiv \begin{bmatrix} \mathbf{d}_l(c) \\ \mathbf{p}(c) \times \mathbf{d}_l(c) \end{bmatrix} \qquad (3)$$



L : #edges of friction pyramid

$\mathbf{d}_l(c)$: l – th unit edge vector of the pyramid at c

$\alpha_l(c)$: a set of nonnegative coefficient

μ : friction coefficient

61

Grasp Stability Evaluation

Force-Closure

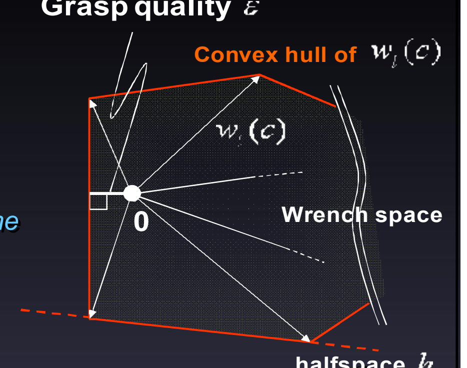
- *the state to resist any external wrench by applying positive forces at the contacts*

$$\mathbf{0} \in \mathrm{Interior}\left(\mathrm{ConvexHull}\left\{\bigcup_{c=1}^{N}\bigcup_{l=1}^{L}\mathbf{w}_l(c)\right\}\right) \qquad (4)$$

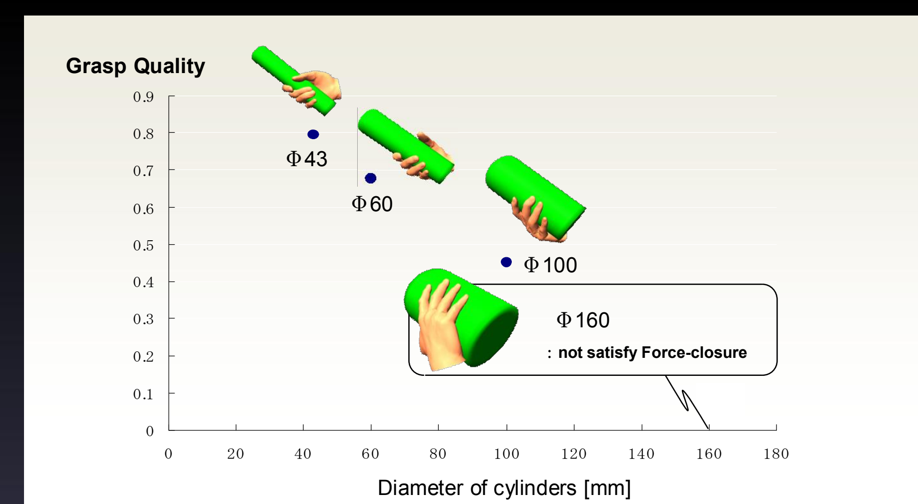
Grasp Quality

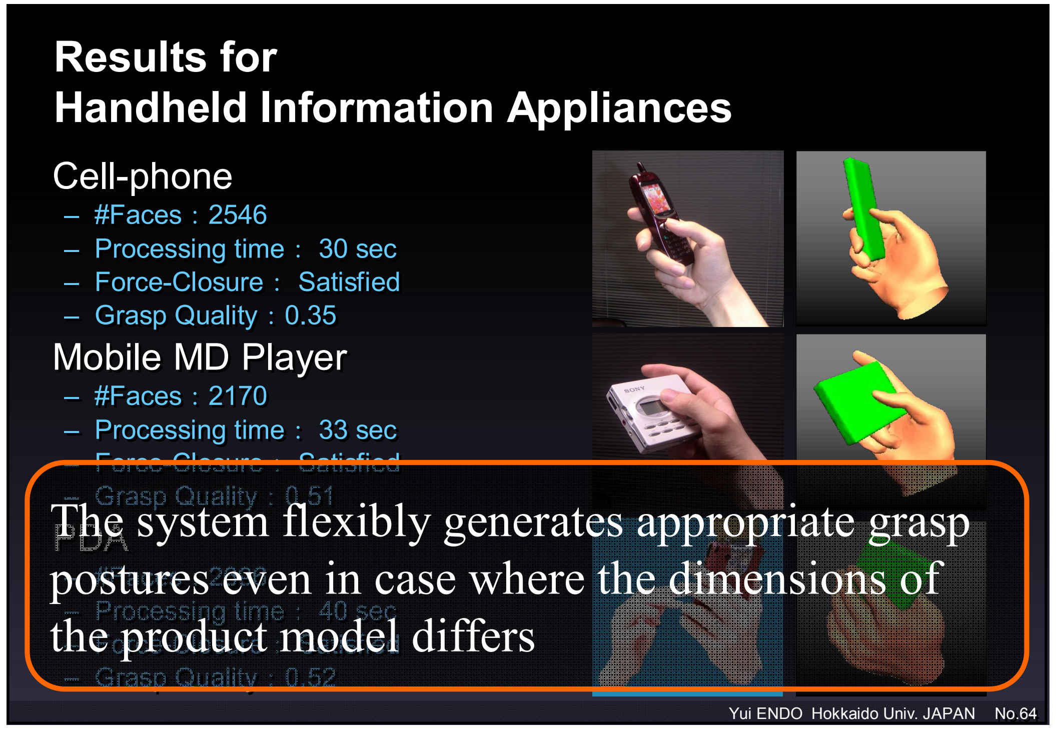
- *the reciprocal of the sum of magnitudes of contact normal forces required to achieve the worst case wrench*

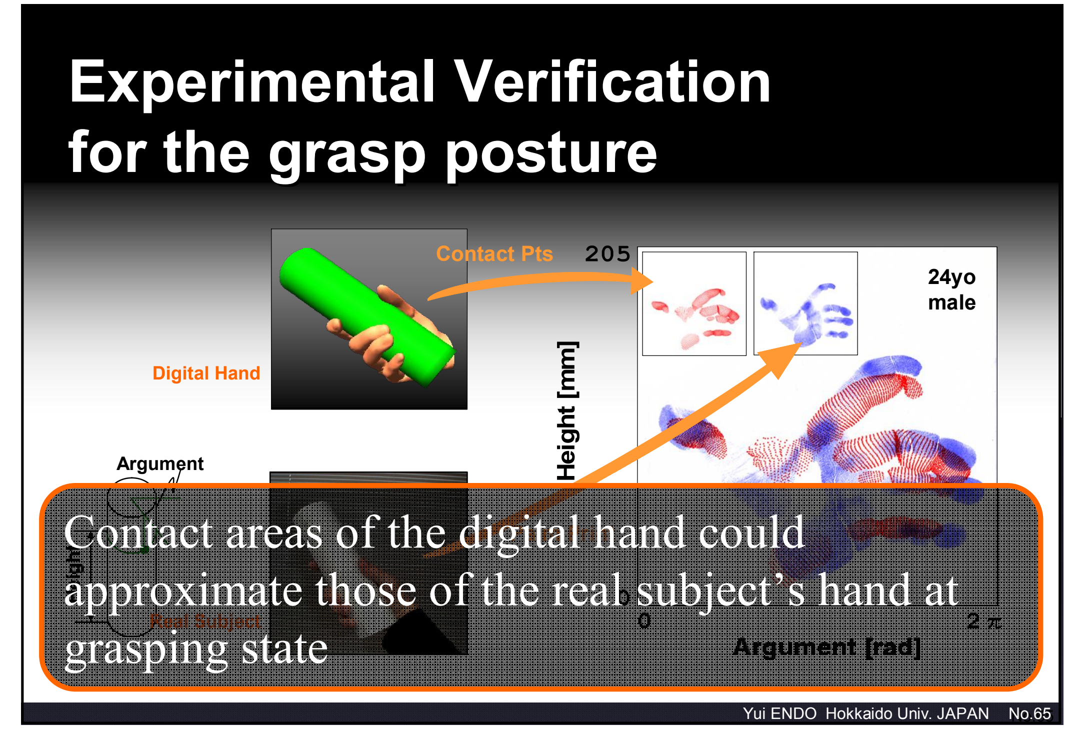
$$\varepsilon = \min_{h \in H}\left(\mathrm{dist}(\mathbf{0}, h)\right) \qquad (\varepsilon \in [0,1]) \qquad (5)$$

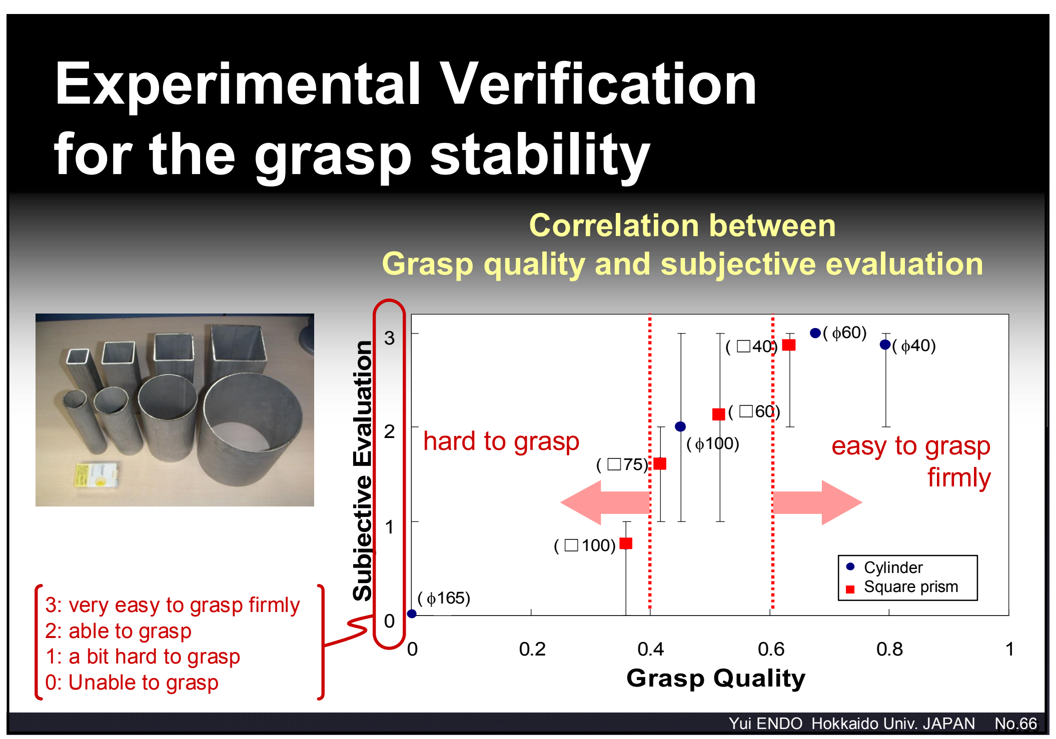


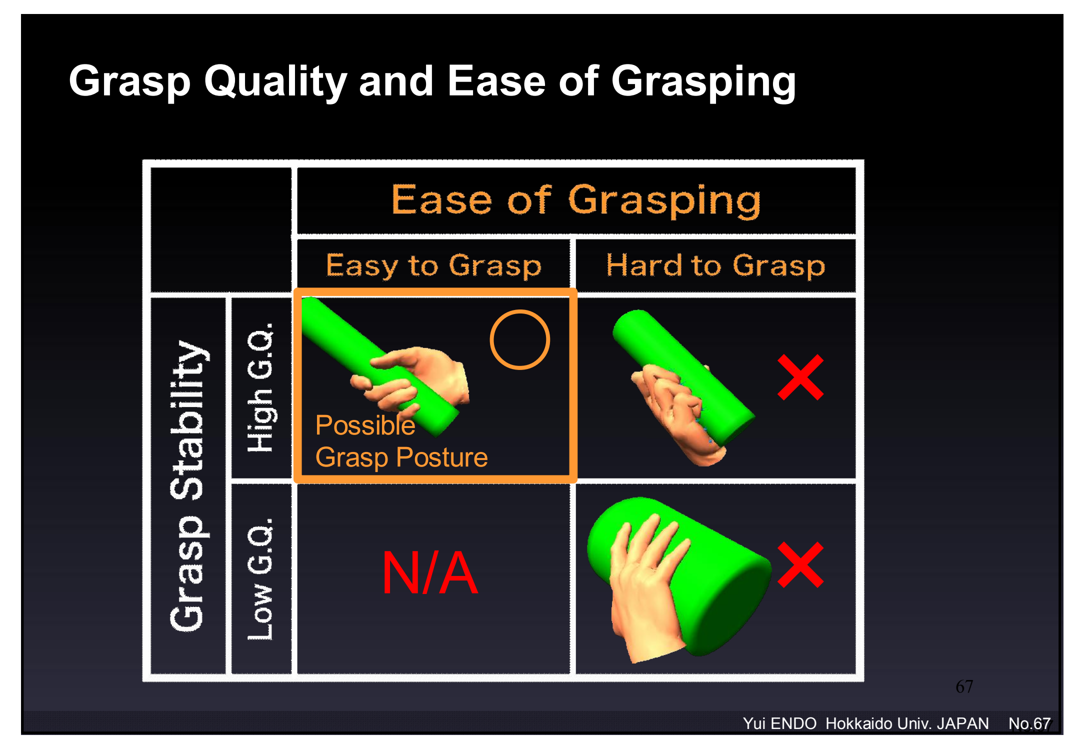
Results of Grasp Posture and Grasp Stability for Cylinders




Results for
Handheld Information Appliances
Cell-phone
– #Faces : 2546
– Processing time : 30 sec
– Force-Closure : Satisfied
– Grasp Quality : 0.35
Mobile MD Player
– #Faces : 2170
– Processing time : 33 sec
– Force-Closure : Satisfied
– Grasp Quality : 0.51
PDA
– Processing time : 40 sec
– Grasp Quality : 0.52
The system flexibly generates appropriate grasp postures even in case where the dimensions of the product model differs
Yui ENDO Hokkaido Univ. JAPAN No.64

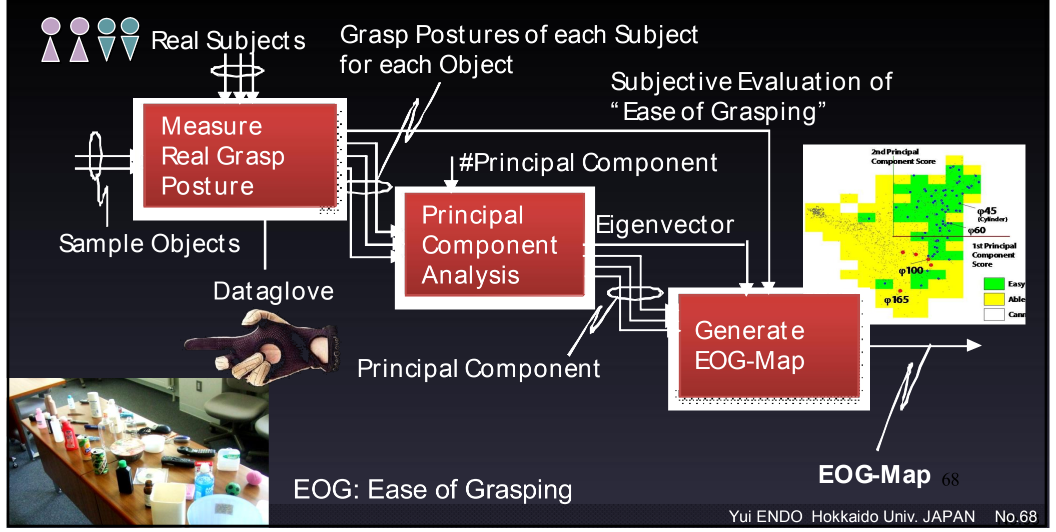

Experimental Verification
for the grasp posture
Contact Pts
205
24yo
male
Digital Hand
Height [mm]
Argument
Real Subject
0
2π
Argument [rad]
Contact areas of the digital hand could approximate those of the real subject's hand at grasping state
Yui ENDO Hokkaido Univ. JAPAN No.65


Experimental Verification
for the grasp stability
Correlation between
Grasp quality and subjective evaluation
Subjective Evaluation
Grasp Quality
hard to grasp
easy to grasp
firmly
(φ165)
(□100)
(□75)
(φ100)
(□60)
(□40)
(φ60)
(φ40)
Cylinder
Square prism
0
0.2
0.4
0.6
0.8
1
3: very easy to grasp firmly
2: able to grasp
1: a bit hard to grasp
0: Unable to grasp
Yui ENDO Hokkaido Univ. JAPAN No.66


Grasp Quality and Ease of Grasping
Ease of Grasping
Easy to Grasp
Hard to Grasp
Grasp Stability
High G.Q.
Low G.Q.
Possible
Grasp Posture
N/A
67
Yui ENDO Hokkaido Univ. JAPAN No.67

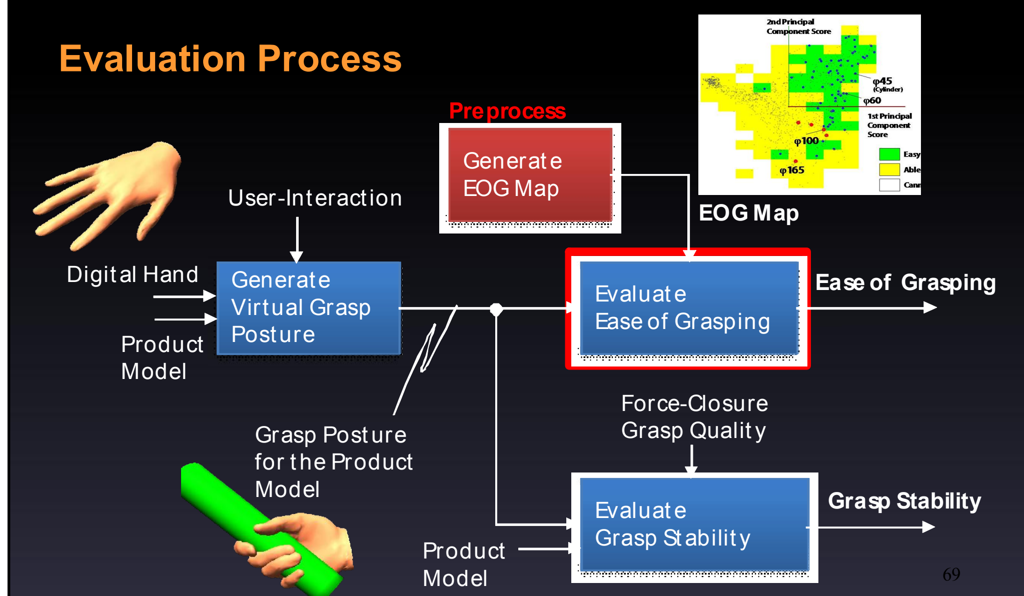
Overview of EOG Evaluation

Preprocess



Overview of EOG Evaluation

Evaluation Process



Grasp Posture Measurement for Real Subjects

Experiment

- 8 subjects
- 58 daily products and 12 cylinders and square prisms
- "CyberGlove" with 19 sensors

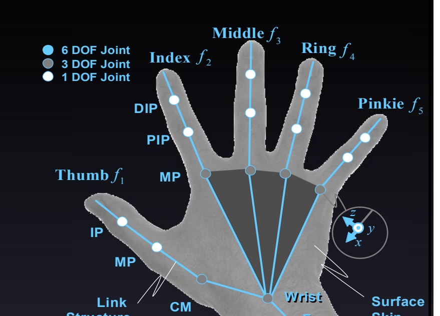
Recorded Data for Each Objects

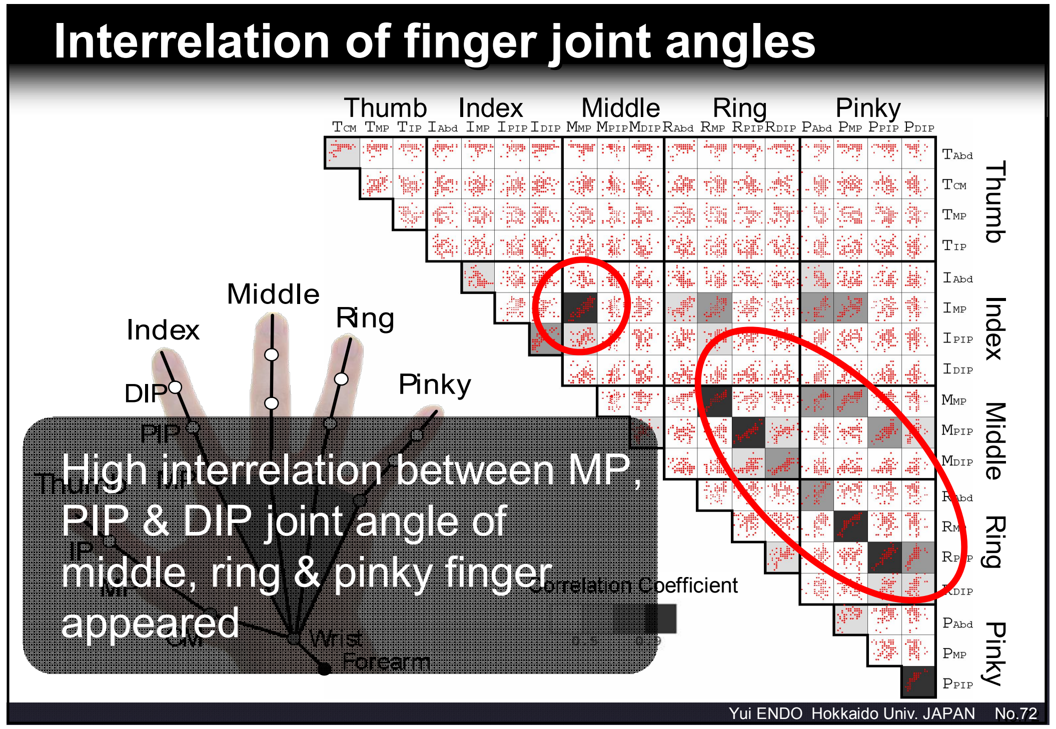
- a time sequence of finger joint angles from the opened state to the grasping state
- two-level subjective evaluation for the grasp postures
  - Easy to Grasp / Not Easy to Grasp

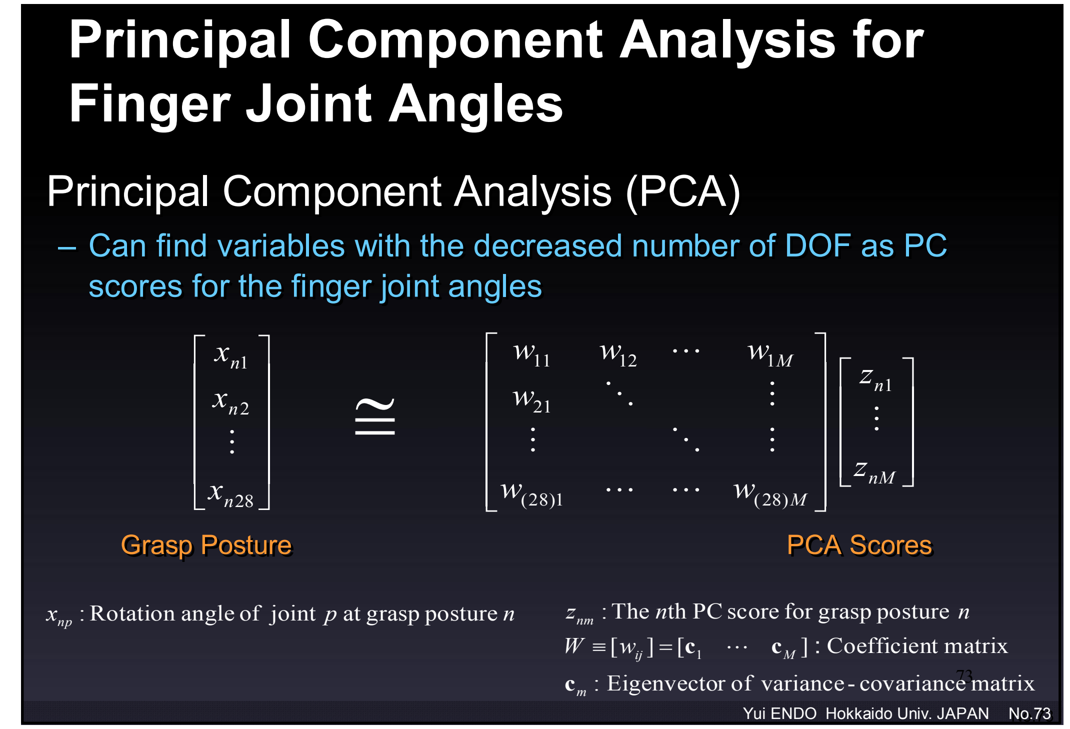
Principal Component Analysis for Finger Joint Angles

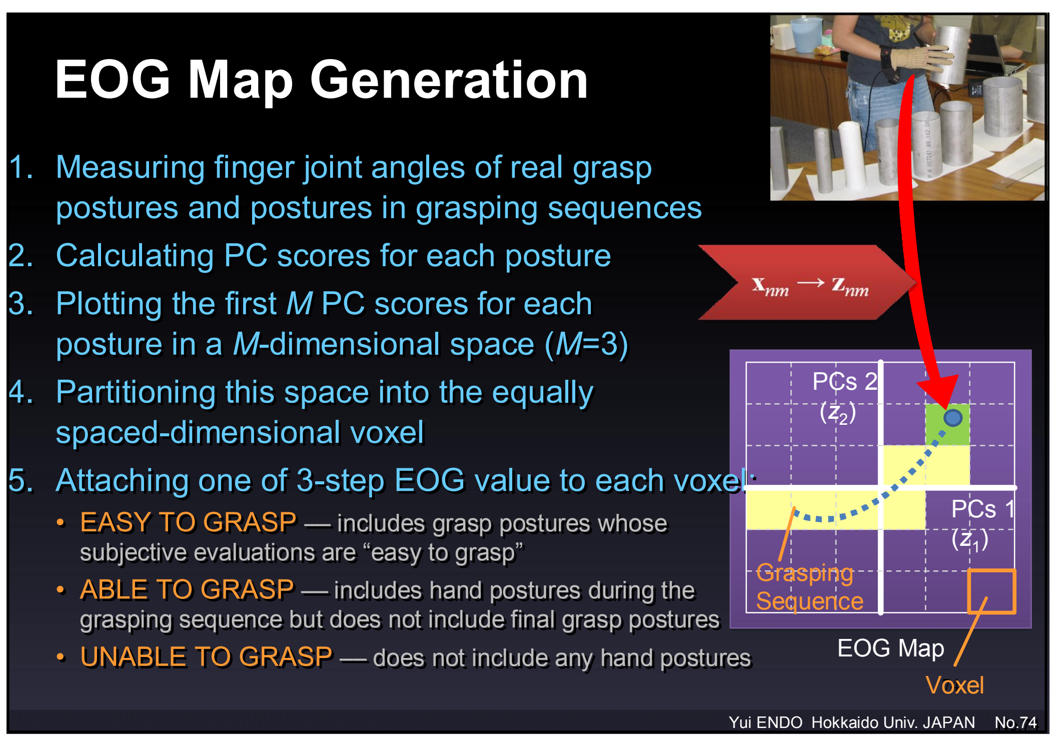
Background

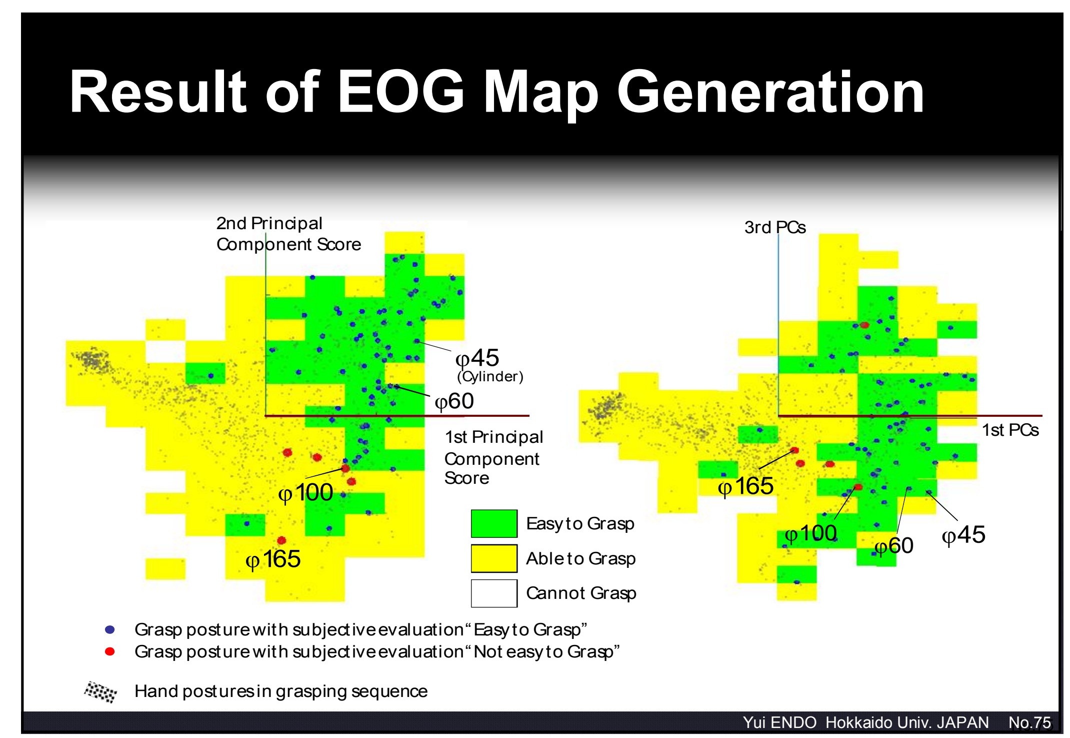
- Hand fingers have more than 25 DOF
- To calculate an index value from the combination of finger angle values is difficult
- Finger joint angles are strongly interrelated with each other at holding state [Santello1998]
- This interrelation of the finger joint angles can be applied to decrease the DOF of the hand fingers




Interrelation of finger joint angles
Thumb
Index
Middle
Ring
Pinky
Index
Middle
Ring
Pinky
DIP
PIP
High interrelation between MP, PIP & DIP joint angle of middle, ring & pinky finger appeared
Correlation Coefficient
Wrist
Forearm
Yui ENDO Hokkaido Univ. JAPAN No.72

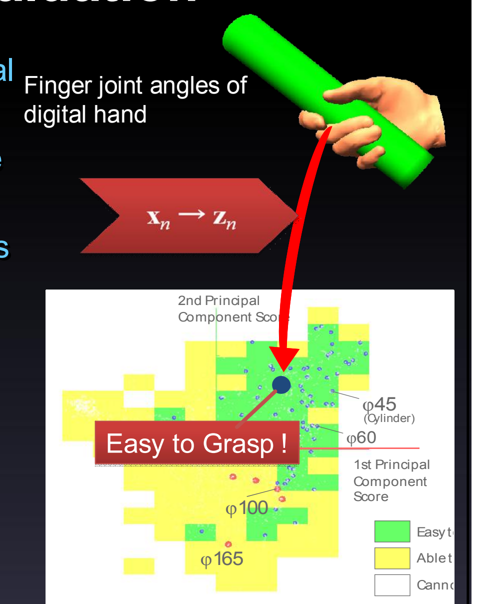

Principal Component Analysis for Finger Joint Angles
Principal Component Analysis (PCA)
– Can find variables with the decreased number of DOF as PC scores for the finger joint angles
$\begin{bmatrix} x_{n1} \\ x_{n2} \\ \vdots \\ x_{n28} \end{bmatrix} \cong \begin{bmatrix} w_{11} & w_{12} & \cdots & w_{1M} \\ w_{21} & \ddots & & \vdots \\ \vdots & & \ddots & \vdots \\ w_{(28)1} & \cdots & \cdots & w_{(28)M} \end{bmatrix} \begin{bmatrix} z_{n1} \\ \vdots \\ z_{nM} \end{bmatrix}$
Grasp Posture
PCA Scores
x_{np} : Rotation angle of joint p at grasp posture n
z_{nm} : The nth PC score for grasp posture n
$W \equiv [w_{ij}] = [\mathbf{c}_1 \ \cdots \ \mathbf{c}_M]$: Coefficient matrix
$\mathbf{c}_m$: Eigenvector of variance-covariance matrix
Yui ENDO Hokkaido Univ. JAPAN No.73


EOG Map Generation
1. Measuring finger joint angles of real grasp postures and postures in grasping sequences
2. Calculating PC scores for each posture
3. Plotting the first M PC scores for each posture in a M-dimensional space (M=3)
4. Partitioning this space into the equally spaced-dimensional voxel
5. Attaching one of 3-step EOG value to each voxel
• EASY TO GRASP — includes grasp postures whose subjective evaluations are "easy to grasp"
• ABLE TO GRASP — includes hand postures during the grasping sequence but does not include final grasp postures
• UNABLE TO GRASP — does not include any hand postures
$\mathbf{x}_{nm} \rightarrow \mathbf{z}_{nm}$
PCs 2 (z_2)
PCs 1 (z_1)
Grasping Sequence
EOG Map
Voxel
Yui ENDO Hokkaido Univ. JAPAN No.74

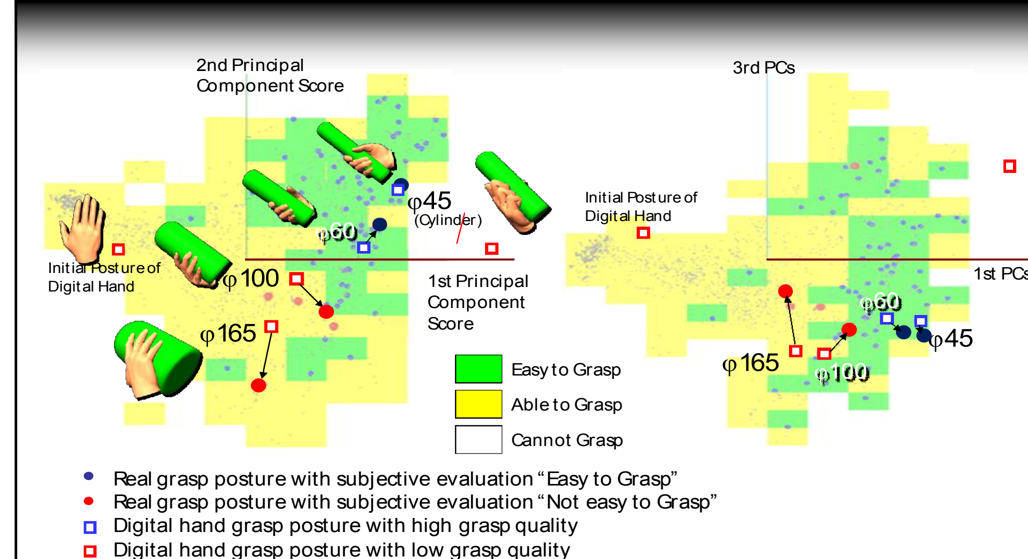

Result of EOG Map Generation
2nd Principal Component Score
φ45 (Cylinder)
φ60
1st Principal Component Score
φ100
φ165
3rd PCs
1st PCs
φ165
φ100
φ60
φ45
Easy to Grasp
Able to Grasp
Cannot Grasp
Grasp posture with subjective evaluation "Easy to Grasp"
Grasp posture with subjective evaluation "Not easy to Grasp"
Hand postures in grasping sequence
Yui ENDO Hokkaido Univ. JAPAN No.75

Ease of Grasping Evaluation

- Generating a grasp posture of digital hand
- Calculate PC scores for the posture
- Plotting the point to EOG map and finding a voxel where this point exits
- Outputting EOG value of the volxel



Verification of EOG Evaluation



Conclusions

1) A software of ergonomic assessment for handheld information appliances was developed

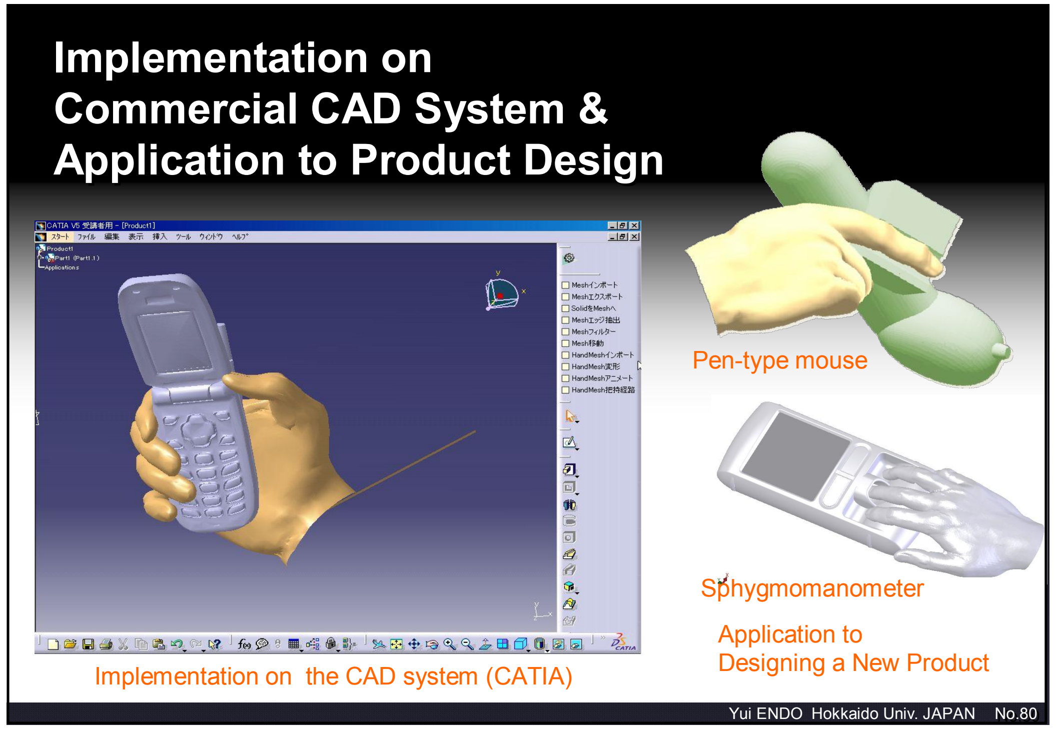
- Could generate an appropriate grasping posture for the appliance by minimum user-interactions
- Evaluate grasp stability for the appliance by using force-closure and grasp quality
- Evaluate ease of grasping of the grasp posture by using EOG map

2) The validity of these grasping postures and their ergonomic assessment indices derived from our system with one from "real" subjects was experimentally verified

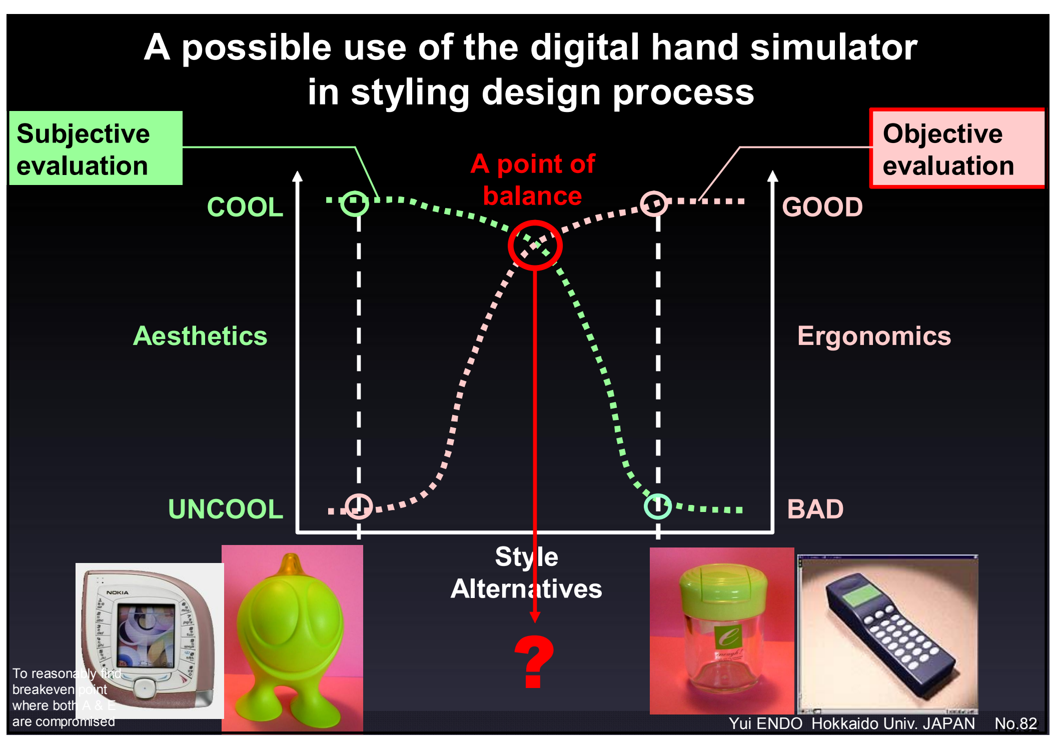
Future works

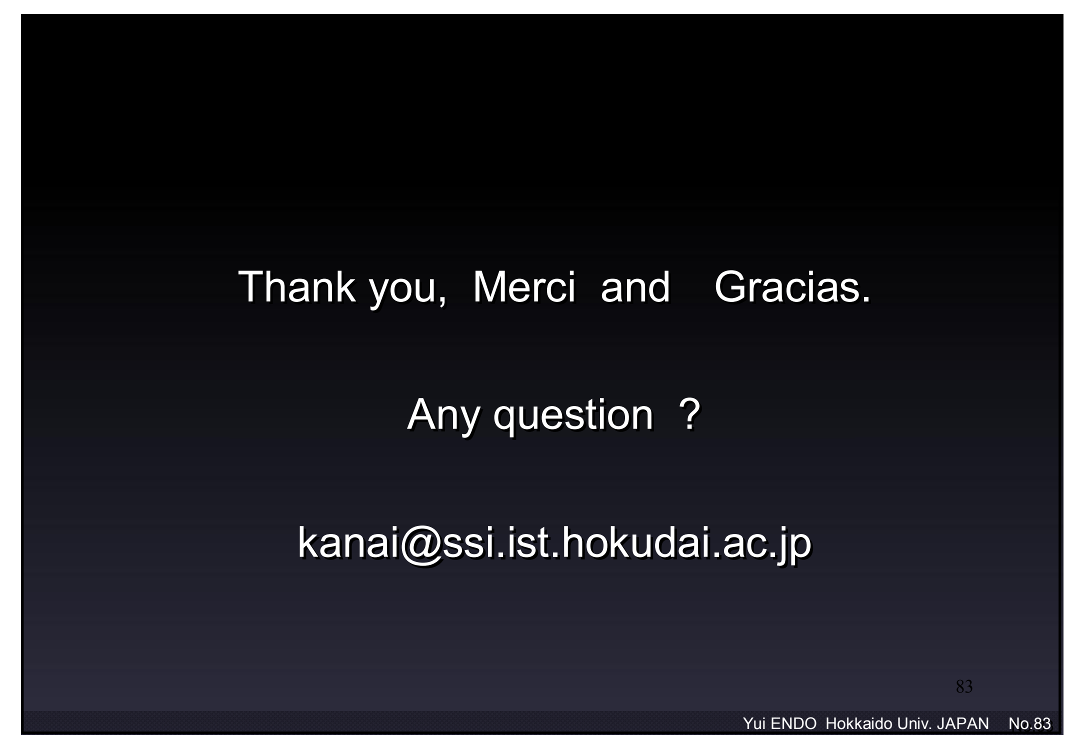
New Functions for our system

- Evaluation of the ease of finger operation for the use-interface of a product
- Aid the designers in redesigning the housing shapes and the user-interfaces in a product model


Implementation on
Commercial CAD System &
Application to Product Design
Pen-type mouse
Sphygmomanometer
Application to
Designing a New Product
Implementation on the CAD system (CATIA)
Yui ENDO Hokkaido Univ. JAPAN No.80


Implementation on
Commercial CAD System &
Application to Product Design
Nikon
Collaborative
research with
Nikon Corp.
Application of Industrial Design for Digital SLR / Compact Cameras
Yui ENDO Hokkaido Univ. JAPAN No.81


A possible use of the digital hand simulator
in styling design process
Subjective
evaluation
Objective
evaluation
A point of
balance
COOL
GOOD
Aesthetics
Ergonomics
UNCOOL
BAD
Style
Alternatives
?
Yui ENDO Hokkaido Univ. JAPAN No.82


Thank you, Merci and Gracias.
Any question ?
kanai@ssi.ist.hokudai.ac.jp
Yui ENDO Hokkaido Univ. JAPAN No.83