

***On-line Korean Sign Language  
Recognition System  
using FMMN Network and Feature Analysis***

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November 17, 1995

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  - Rehabilitation engineering
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## Co-workers

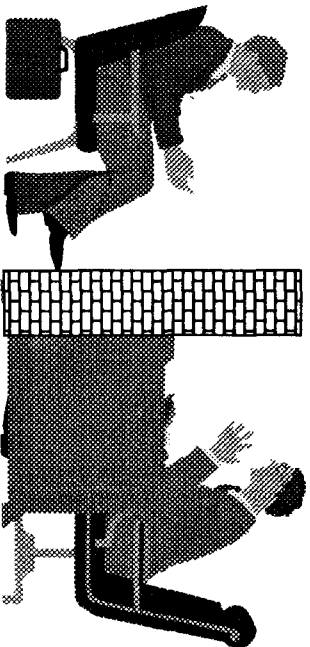
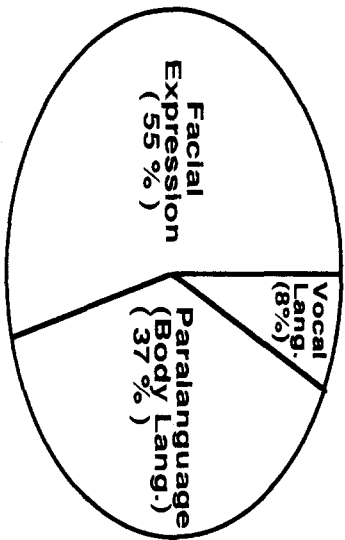
- **Jong-Sung Kim, EE, KAIST**
  - KSL Recognition System
- **Gyu-tae Park, EE, KAIST**
  - Text-to-Sign Generation System
- **Supporting Organization**
  - Samsung Elec.

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# Human Machine Interface



*Prof. Zeugnam Bien, EE, KAIST*





## Definition of Service Robot

*IEEE R&A T.C. on Service Robots*

- Service Robots = NON Industrial Robots
- Robot working in public area interacting with human
- It is not easy to give a competent definition for what service robots are.
- Reprogrammable, sensor-based mechatronic device which performs useful service to human activities

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5

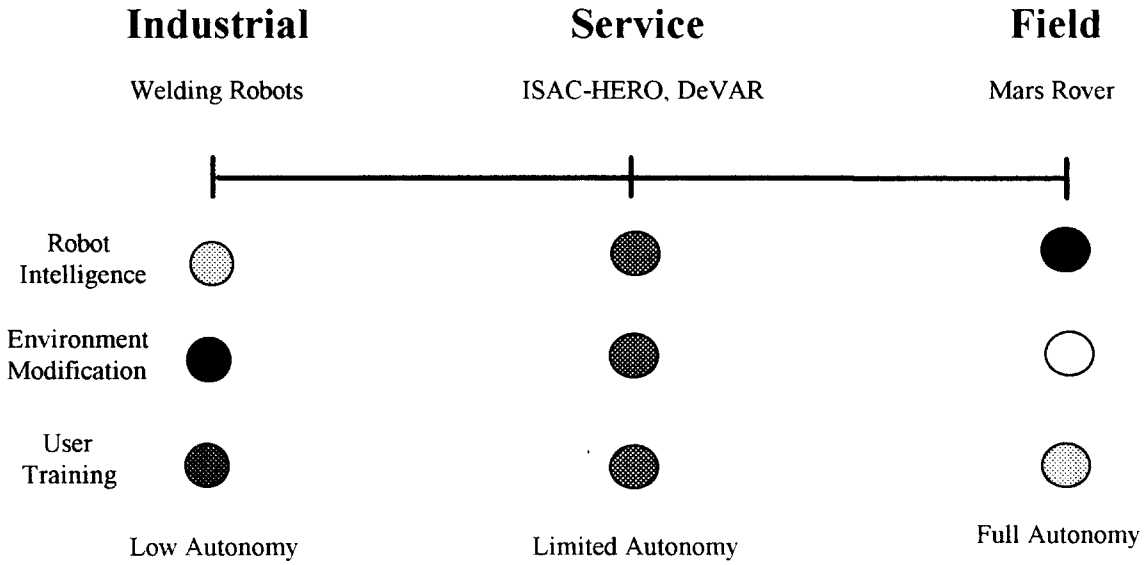


Fig. 1 Spectrum for robot development [57]

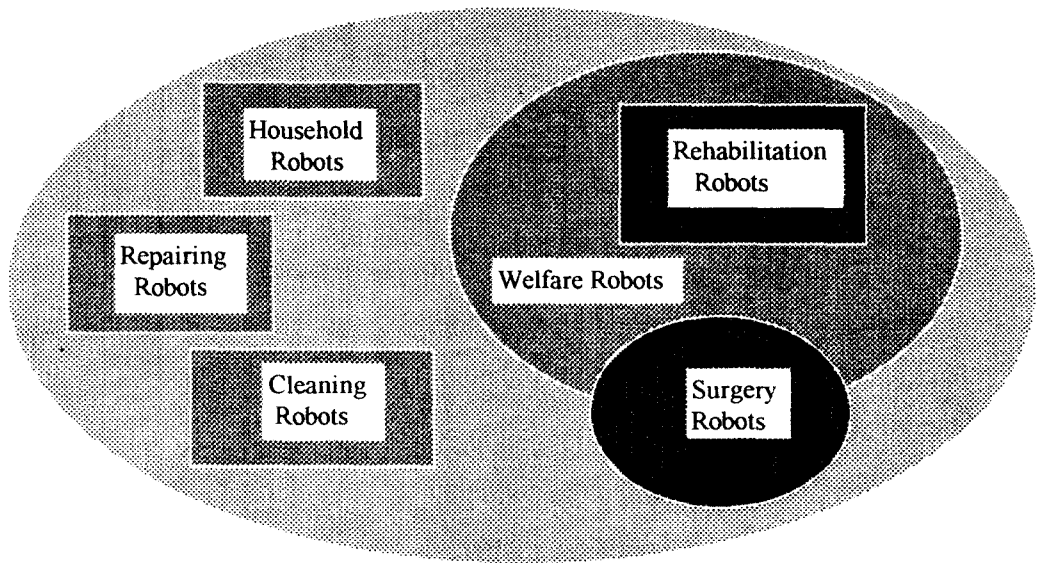


Fig.2 Family of service robots

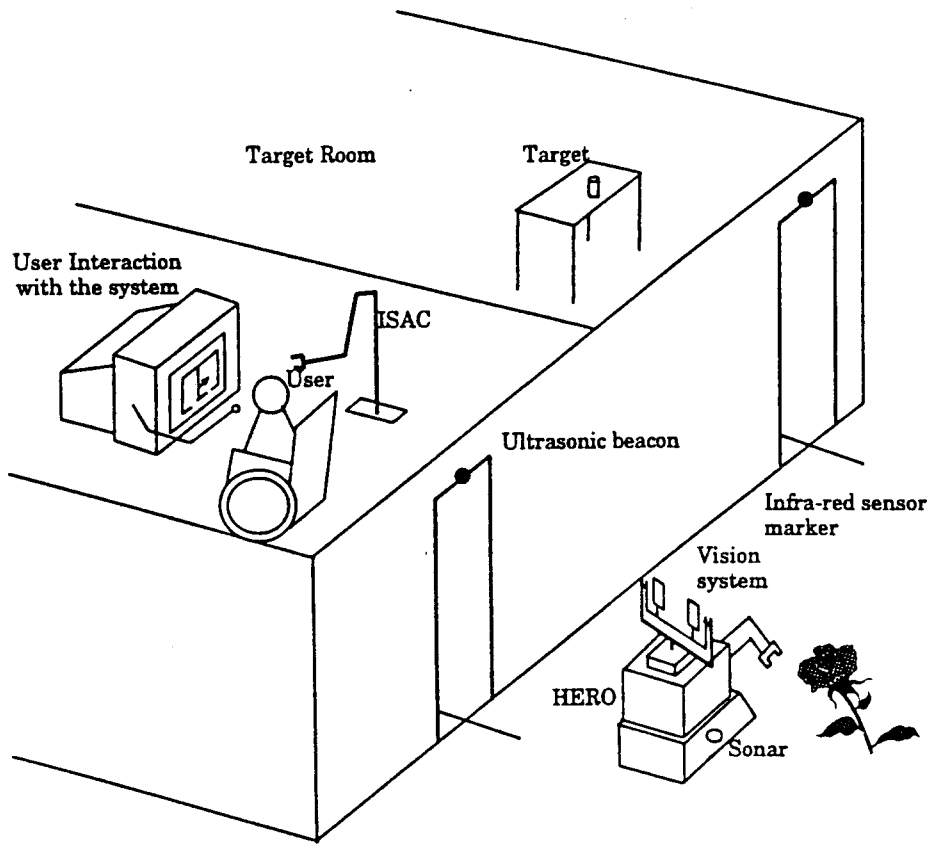
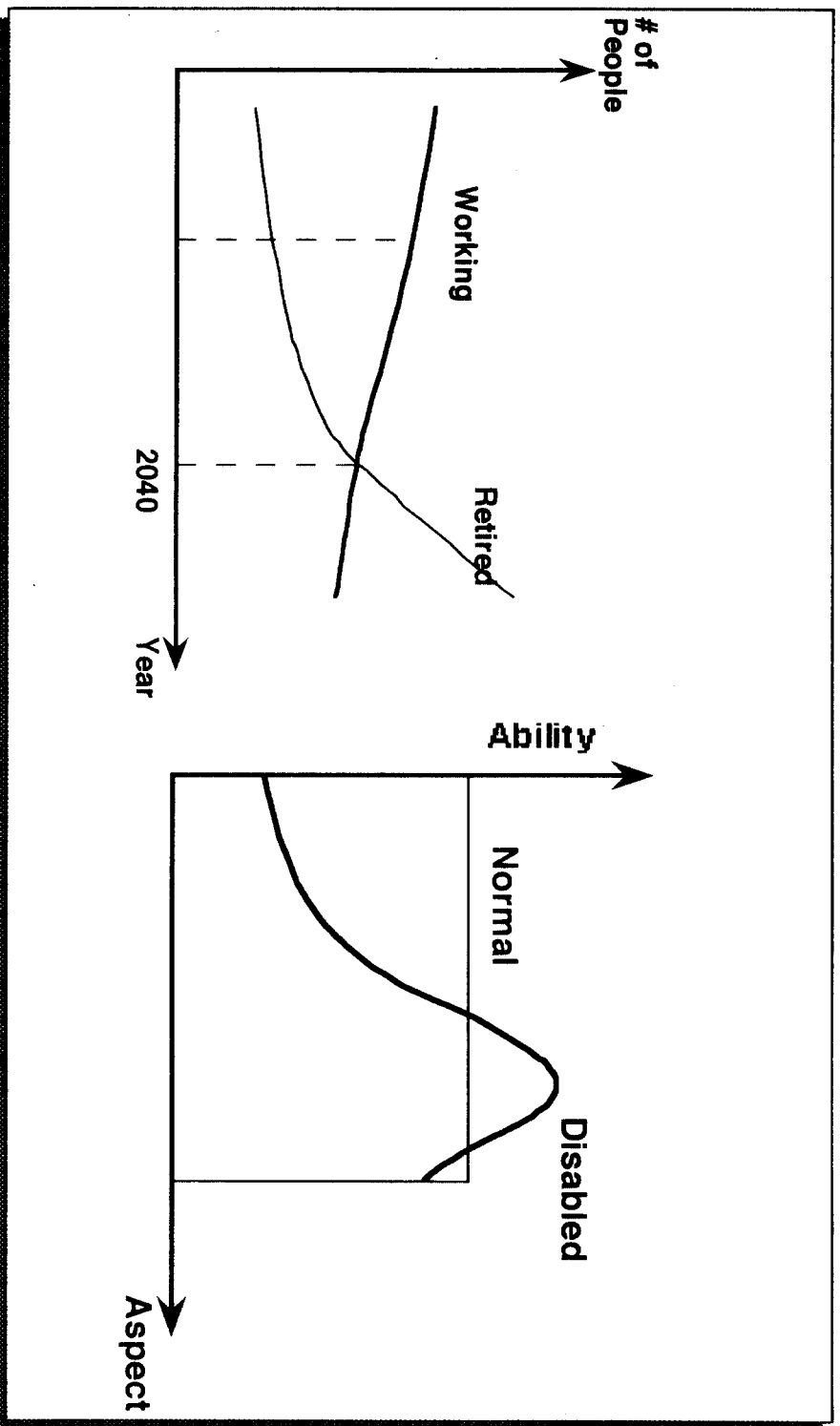


Figure 2: ISAC-HERO Service Robot System



# Rehabilitation



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## Rehabilitation Robots

- Table mounted arm
- Wheelchair mounted arm
- Robotic workstation
- *Integrated platform*
  - CCD Video Cameras
  - Radio Communication devices

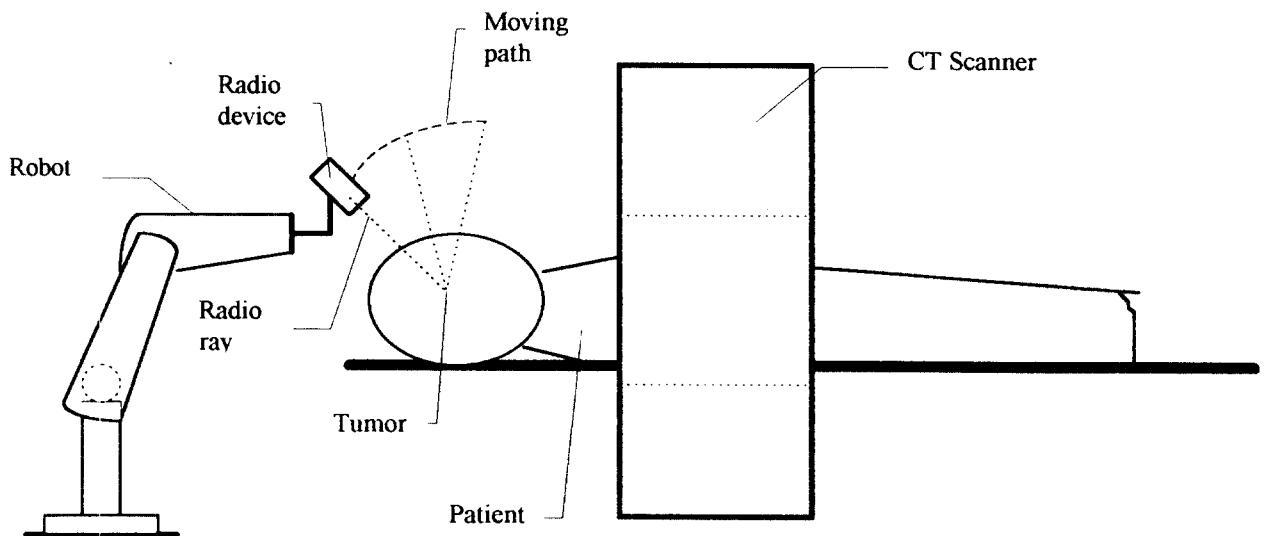


# Neuro-surgery

- Brain surgery

  - Positioning

  - Trajectory tracking



- Precise Operation

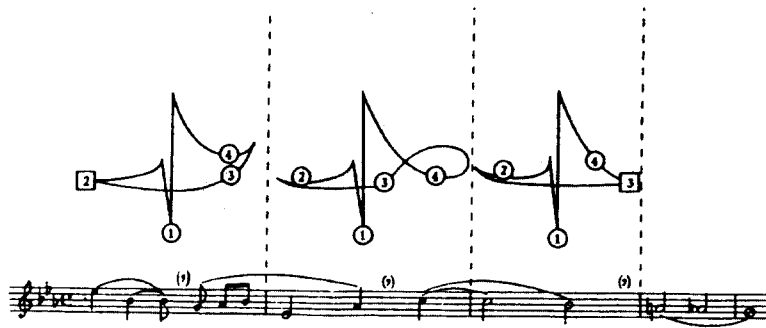
without damaging healthy tissues



## KSL for the Deaf

- **Hand Gestures in Life(Predefined gesture action)**
  - Traffic cop's hand gesture
  - In auction room
  - Music Conductor's motion
  - In the construction industry
  - Simple gestures(750 gestures/day)
- **Sign Language : Stylized language system**
  - the best example of communication via gestures
  - For hearing-impaired persons
  - Many hand gestures are expressed



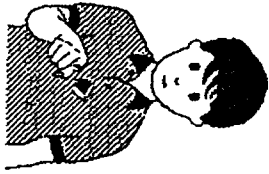


(a) Conducting Diagram

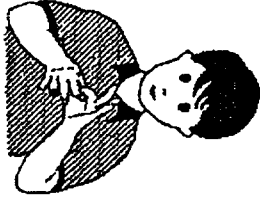


(b) Dynamic Hand gesture in concert

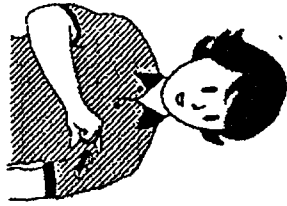
Figure 1.1: An example of dynamic hand gesture : conductor's motion



당신



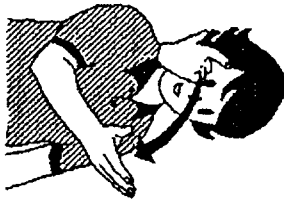
의



이름은



무엇



업니까?

# Dynamic Gesture



- **Hand-Gesture Recognition**
  - **Static Posture Recognition**
    - » **Space domain**
    - » **Recog. of hand shape**
    - » **Specific value of D.O.F. of the hand**
  - **Dynamic Gesture Recognition**
    - » **Time + space domain**
    - » **Motion of the fingers & hands**
    - » **From continuous features**





## Related Works

### ■ Yamaguchi, Japan

- Gesture recognition using color vision
- Using model-based approach
- 16 gestures for the JSL

### ■ Fels, Canada

- back-propagation N-N
- 66 root words/ 203 words from the ASL
- many training time

### ■ M. Waldron, America

- 14 ASLs
- Self Organizing Map







## Related Works

- **Vision sensor or Hand-Tracker device**
  - Vision : Many data & Much processing time
  - Hand-Tracker device : real-time processing
- **Recognition of Specific Gestures**
  - Addition of new gesture : difficult
  - many variations on time, space, signers





## Goal

- **Recognition of Dynamic gesture**
  - The Korean Sign Language
  - On-line Recognition
  - Many Data Sets exist
  - Start & Stop position of gesture
  - Different physical dimension in different person



# Sensing Device

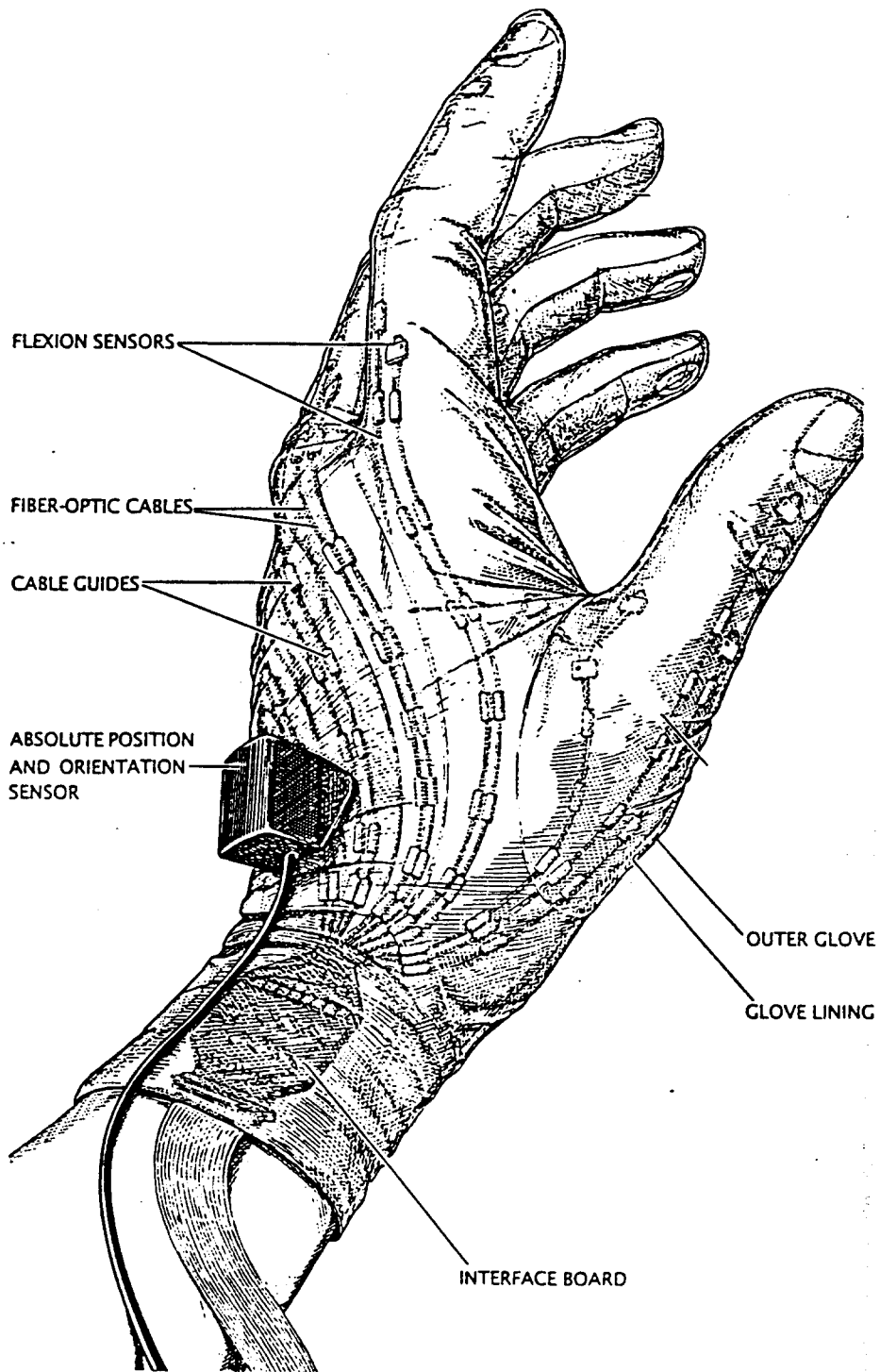


## ■ Data Glove

- VPL Research Inc.
- Get 32 Data from hand every 1/15 sec.
- Flex Sensor(using optical fiber) : 10 joints
- 3D Magnetic Sensor
  - » position(x,y,z)
  - » orientation(yaw, pitch, roll)

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데이터 장갑의 외형



# The Korean Sign Lang.

## ■ The KSL

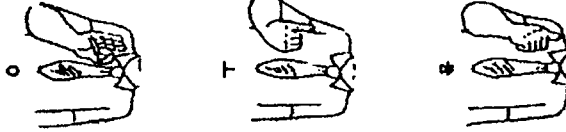
- a method of communication for Deaf person
- using both hands and finger
  - » Dynamic Gestures : express words
- Many Words : about 6,000 vocabularies(many compound word)
- different sign lang. in different countries
  - » A(merican)SL, J(apanese)SL, I(talian)SL, ...



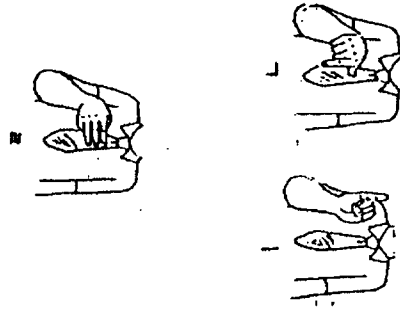
나는



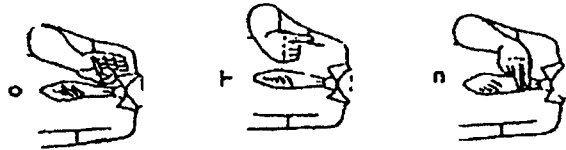
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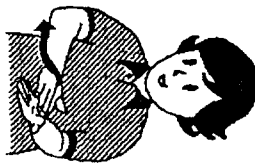
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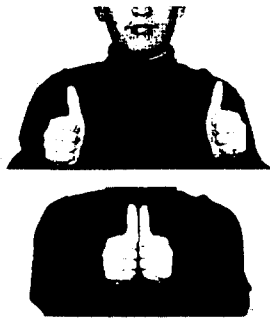


등



입니다.

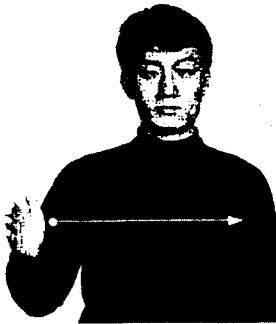




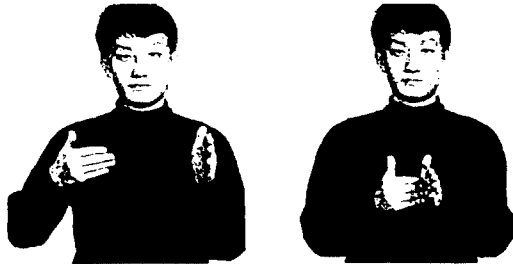
(a) 남자(man)



(b) 여자(woman)



(c) 부터(from)



(d) 까지(till)

Figure 2.2: Examples of the Korean Sign Language



## Dynamic Gesture in the KSL

- Based on shape of object
- specified dynamic hand gesture
- motion of two hands and 10 fingers
  - right hand : main motional action
  - left hand : auxiliary action







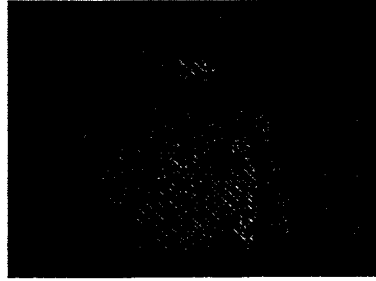
## 4 Categories in KSL

- **Multi-gesture type : compound words**
- **Symmetric gesture : most of the KSL**
- **Double hand-shape gesture : multiple hand posture**
- **Nonsymmetric gesture : different postures of both hands**

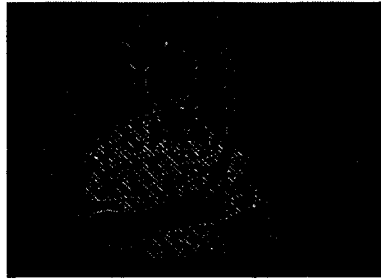




(a) Compound Word  
( '생일(Birthday)' )



(b) Symmetric Gesture  
( '만나다(Meet)' )



(c) Multiple Motion  
( '미안합니다(I'm sorry)' )



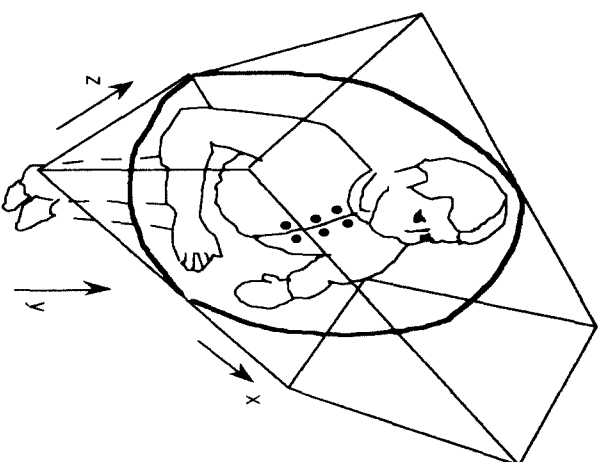
(d) Nonsymmetric Gesture  
( '계절(Season)' )

Figure 2.5: Examples of 4 categories in the KSL

# Principles of the KSL



- The neutral position for starting gesture
- The boundary of hand motion
  - recognizable gesture region





# Scope

## ■ Recognition of the Korean Sign Language

– Dynamic Hand Gesture :

$$G_k = (x_k, y_k, t_k, F_{ki}), \quad 1 \leq k < K : \text{time step}$$





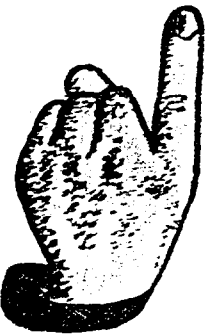
## Recognition of the KSL

- **Recognition of dynamic gestures in the KSL**
  - **No compound words**
  - **No double shaped hand motion**
  - **Dynamic Hand Gesture**
- **Basic Elements in the KSL**
  - » **14 Basic Postures**
  - » **14 Basic Directions**



# 수 화

## 1



교 육 부

서울 선 회 학 교  
1종도서연구개발위원회

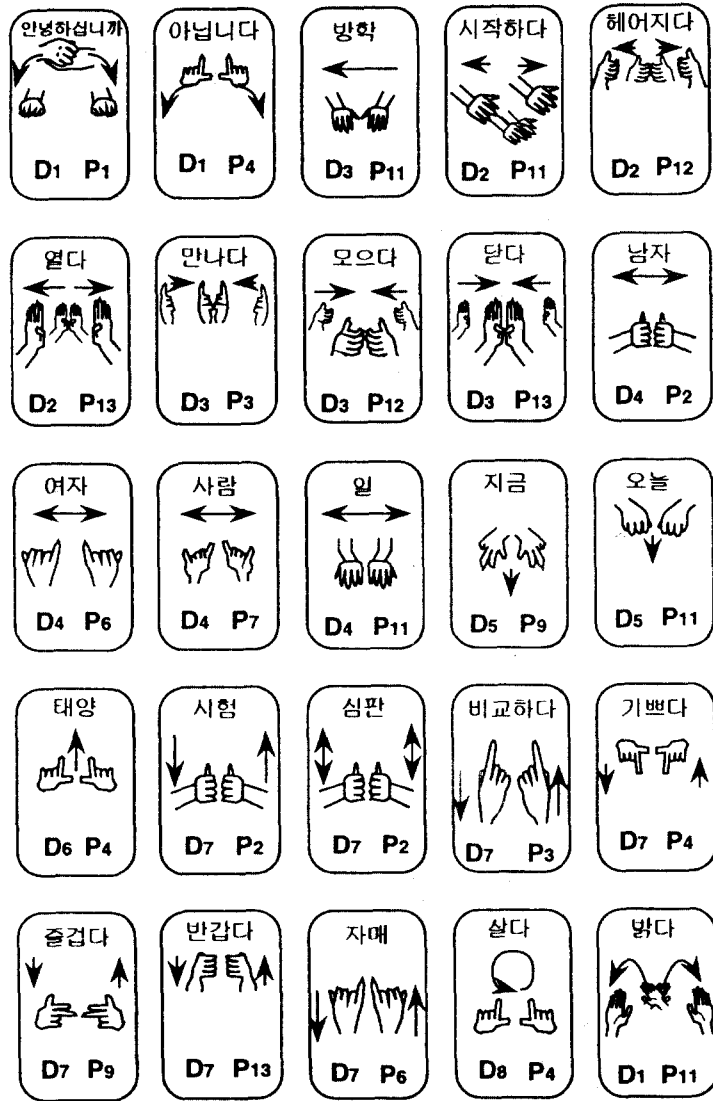


Figure 2.10: Type I : Symmetric Motion

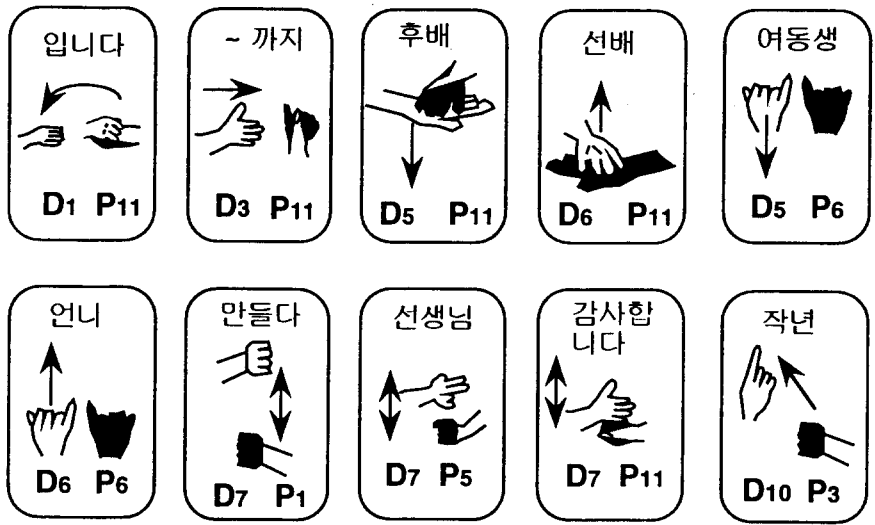


Figure 2.12: Type III : Left-Static/Right-Dynamic Motion



Figure 2.13: Type IV : Back & Forth Motion





Figure 2.11: Type II : Only Right Hand Motion

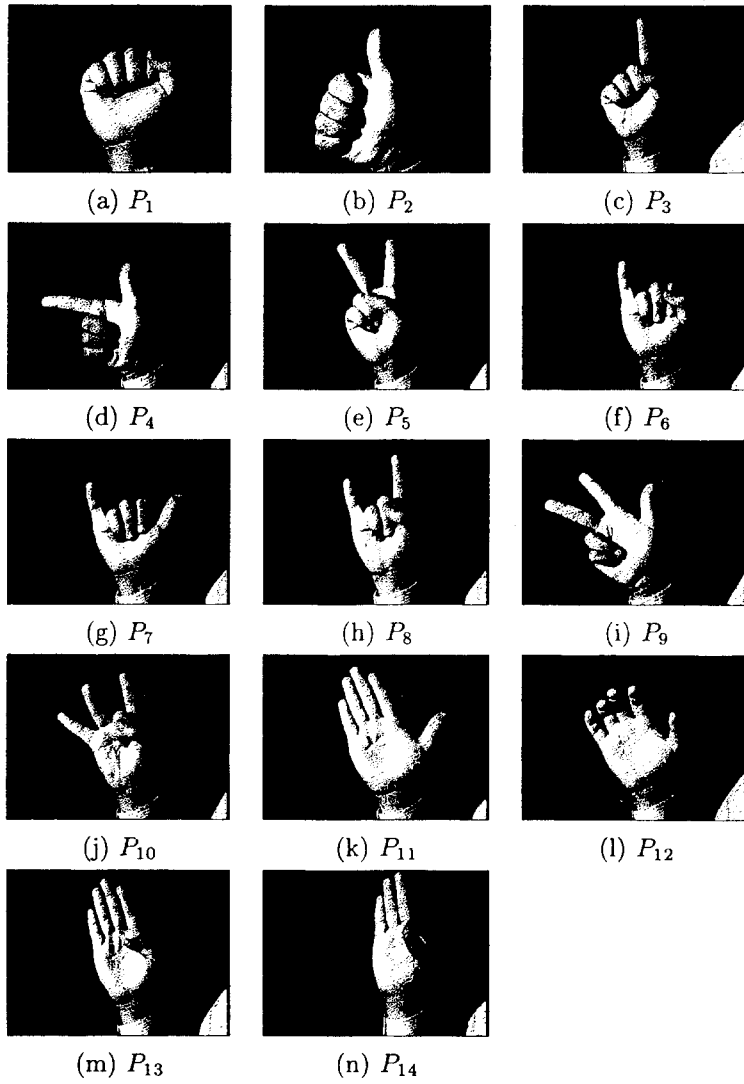
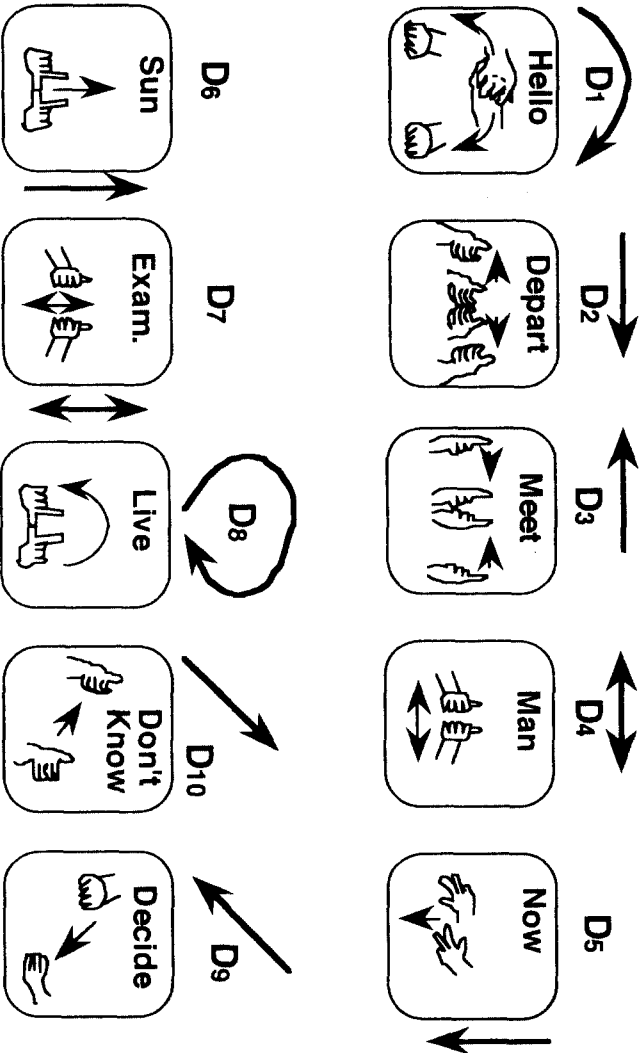


Figure 2.15: 14 Basic hand postures

# 14 Basic Directions



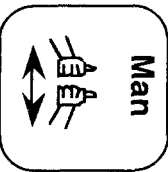
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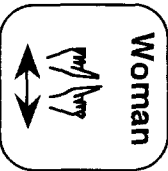


# Dynamic gestures in the KSL

## Same Direction & Different Posture

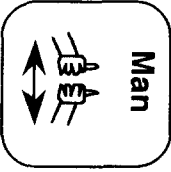


D<sub>4</sub> P<sub>2</sub>



D<sub>4</sub> P<sub>6</sub>

## Different Direction & Same Posture

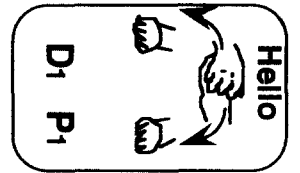


D<sub>4</sub> P<sub>2</sub>



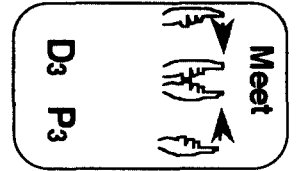
D<sub>7</sub> P<sub>2</sub>





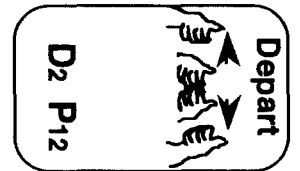
Hello

D1 P1



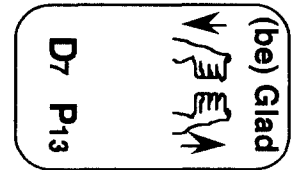
Meet

D3 P3



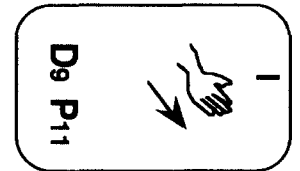
Depart

D2 P12



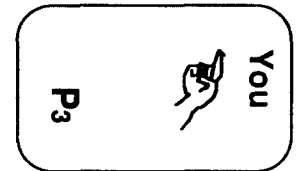
(be) Glad

D7 P13



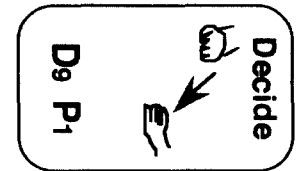
I

D9 P11



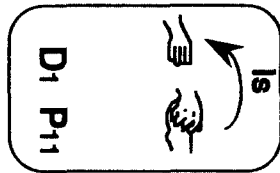
You

P3



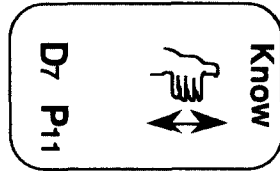
Decide

D9 P1



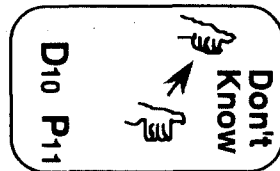
Is

D1 P11



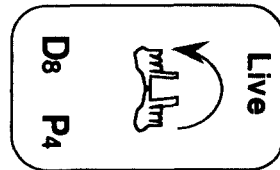
Know

D7 P11



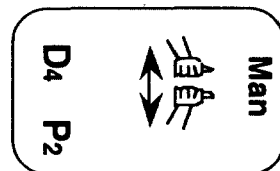
Don't Know

D10 P11



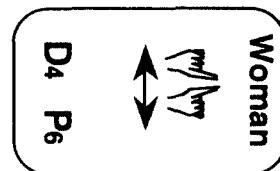
Live

D8 P4



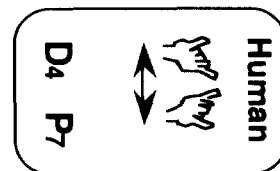
Man

D4 P2



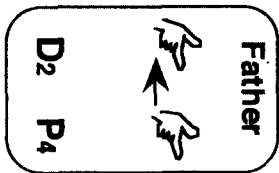
Woman

D4 P6



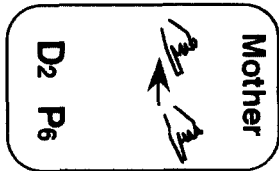
Human

D4 P7



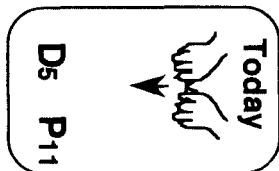
Father

D2 P4



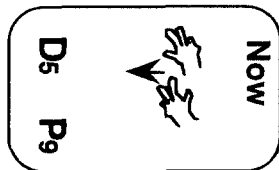
Mother

D2 P6



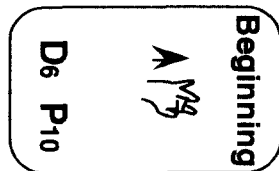
Today

D5 P11



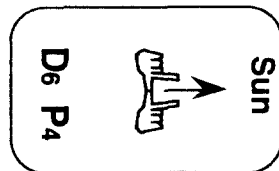
Now

D5 P9



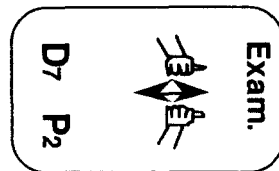
Beginning

D6 P10



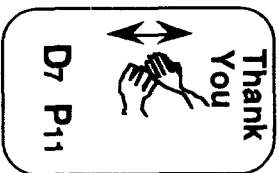
Sun

D6 P4



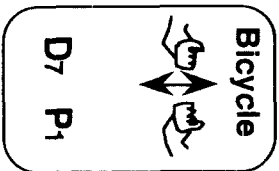
Exam.

D7 P2



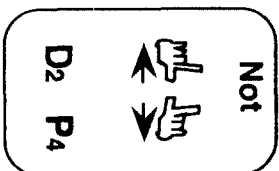
Thank You

D7 P11



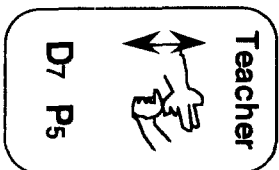
Bicycle

D7 P1



Not

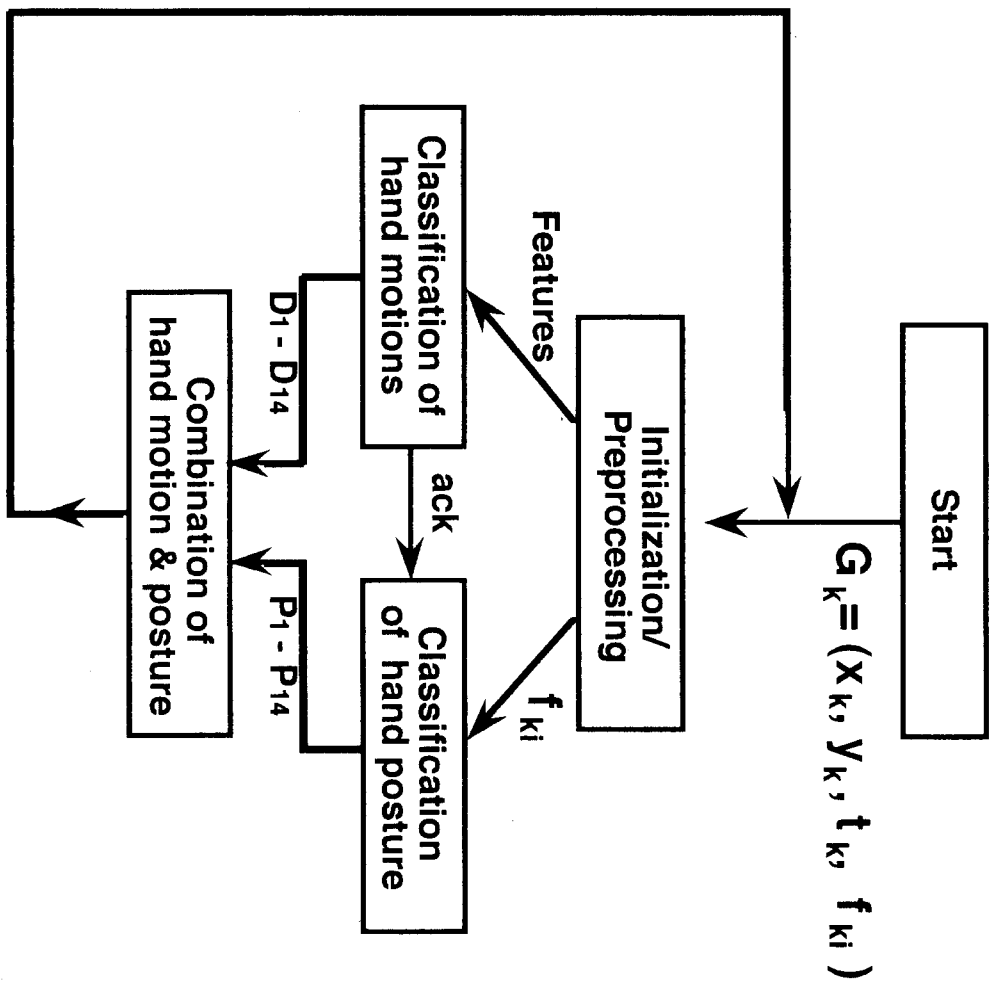
D2 P4



Teacher

D7 P5

# Flow Chart of the KSL Recog. System





## KSL Recognition

- **Dynamic gestures in the KSL**
  - Hand Posture + Hand Motion
- **Classification of Hand Posture by FMNN**
- **Classification of Hand Motion by Feature Analysis**



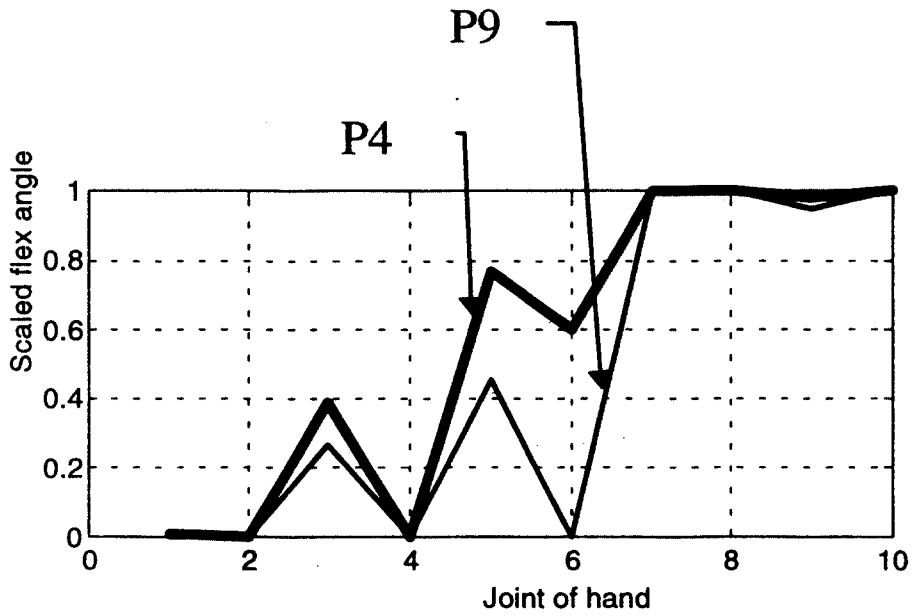


## Hand Posture

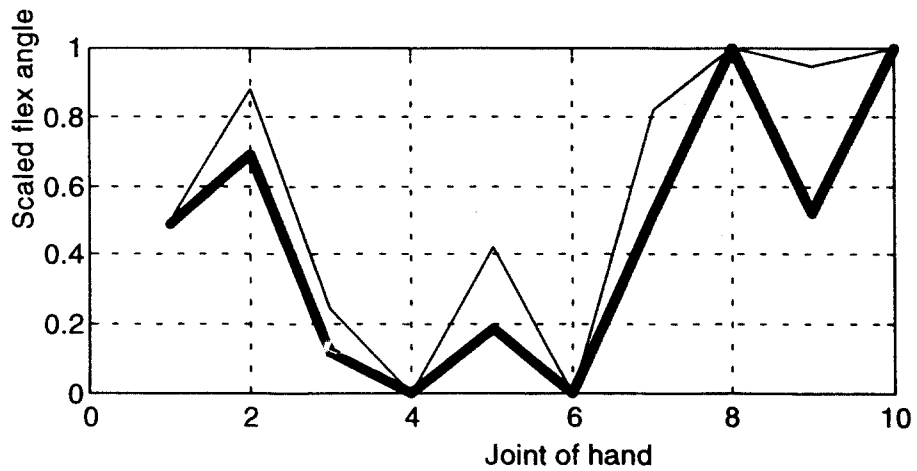
- Variation of Flex angles
- Different humans have different hands & fingers in physical dimension
- Time Varying
  - e.g) Vibration







Different Posture P4 and P9



Posture P5 by the other person

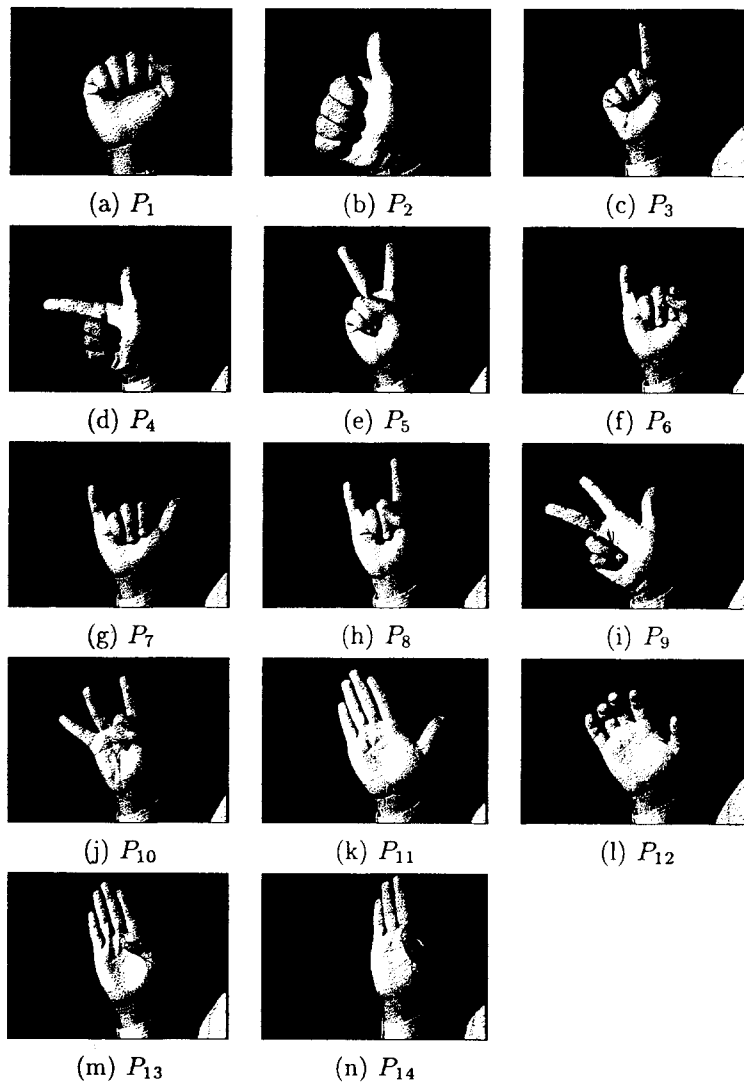
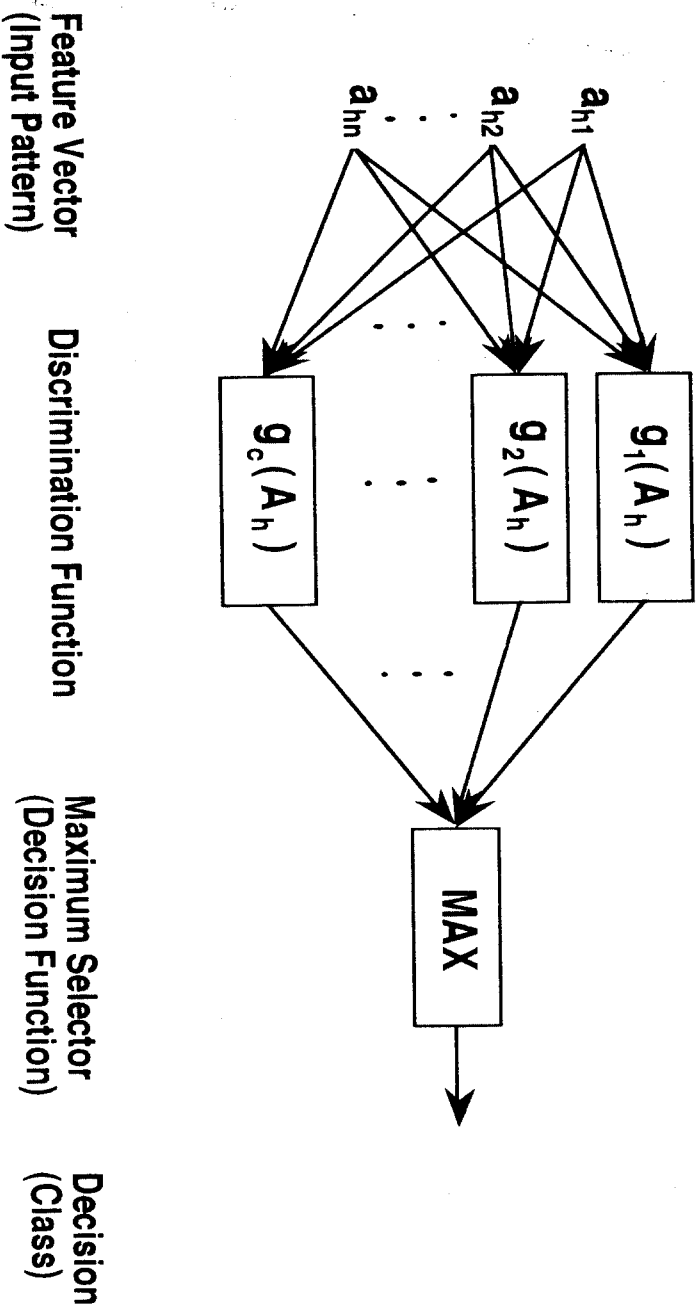


Figure 2.15: 14 Basic hand postures

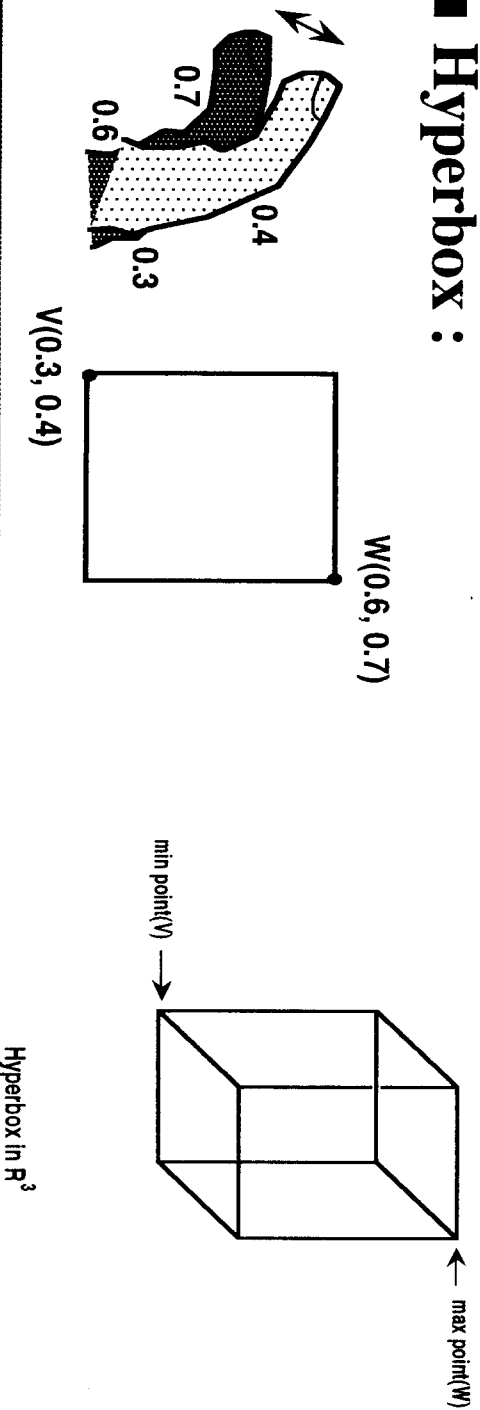
# A Pattern Classifier



# FMMNN Classifier

- On-line supervised learning classifier
- Fuzzy system
- Applicable to a high dimensional input vector

## ■ Hyperbox :



# FMMNN Classifier



- fuzzy rules with variable fuzzy regions(hyperboxes)

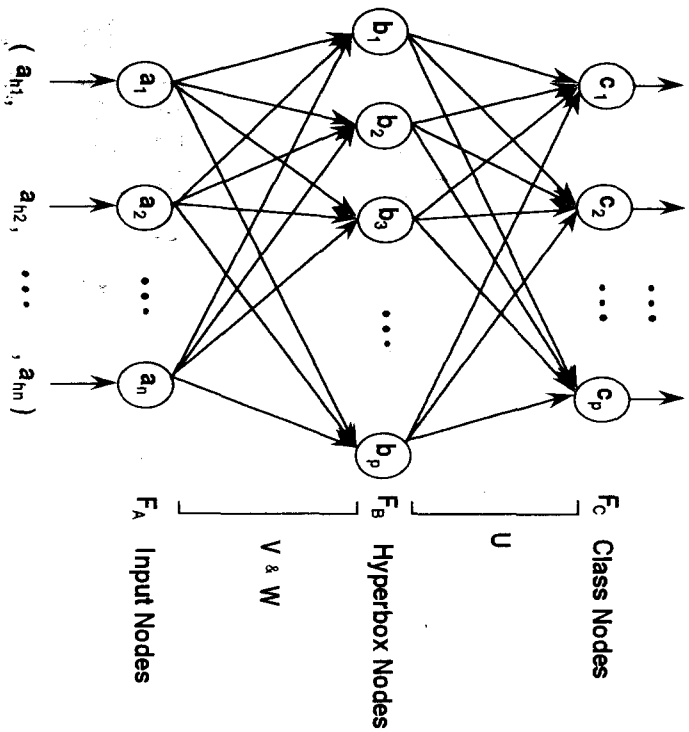
$$b_j(A_h) = \frac{1}{2n} \sum_{i=1}^n [\max(0, 1 - \max(0, \gamma \min(1, a_{hi} - w_{ji}))) + \max(0, 1 - \max(0, \gamma \min(1, v_{ji} - a_{hi})))]$$

P. Simpson, "Fuzzy Min-Max Neural Networks", IEEE Trans. on Neural Network, vol3, no. 5, Sept., 1992

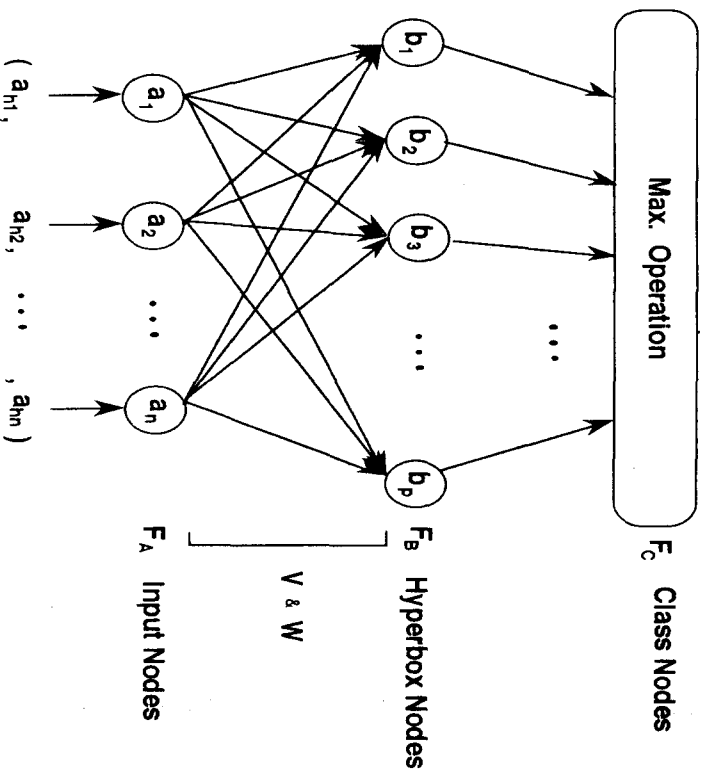


# FMNN Classifier

## FMNN Classifier



## Simplified Version





## ■ Learning Algorithm

- Expansion Process

$$\sum_{i=1}^n (\max(w_{ji}, a_{hi}) - \min(v_{ji}, a_{hi})) \leq i * \theta$$

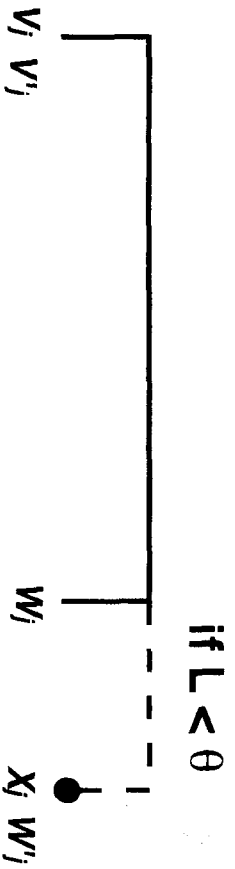
$$v_{ji}^{new} = \min(v_{ji}^{old}, a_{hi}), \forall i = 1, 2, \dots, n,$$

$$w_{ji}^{new} = \max(w_{ji}^{old}, a_{hi}), \forall i = 1, 2, \dots, n,$$

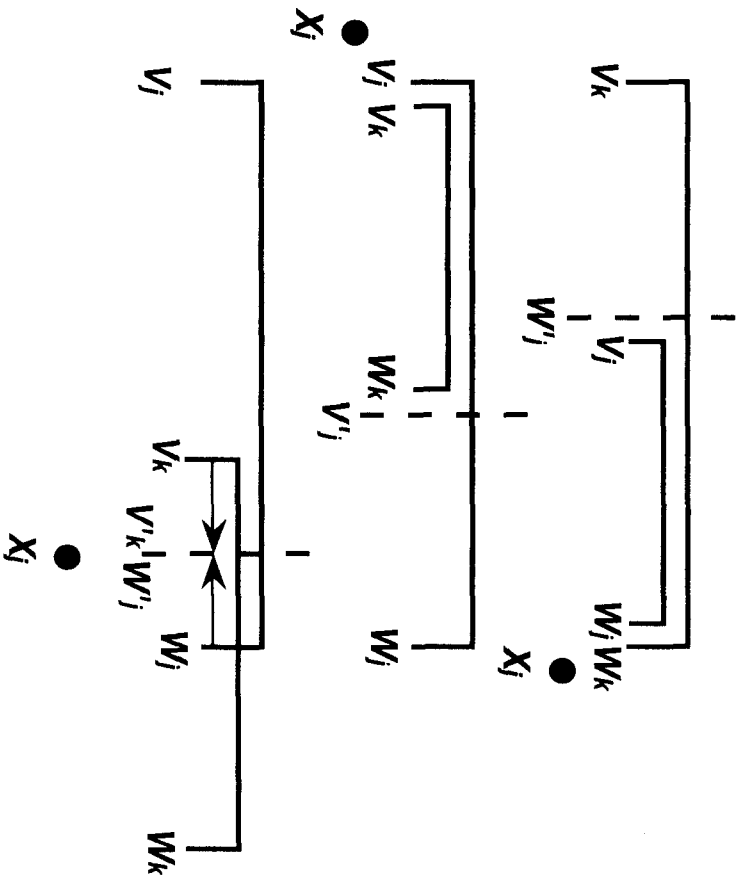
- Overlap Test
- Contraction Process



## Expansion



## Contraction





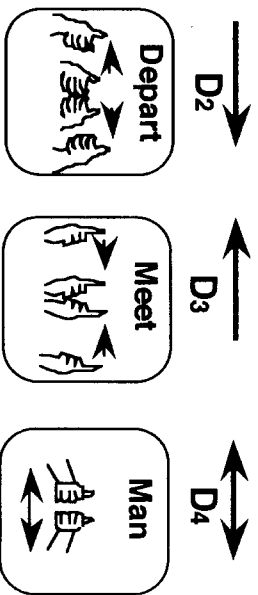
# Hand Posture in KSL

$$b_j(F_h, V_j, W_j) = \frac{1}{20} \sum_{i=1}^{10} [\max(0, 1 - \max(0, \gamma \min(1, F_i - w_{ji}))) + \max(0, 1 - \max(0, \gamma \min(1, v_{ji} - F_i)))]$$

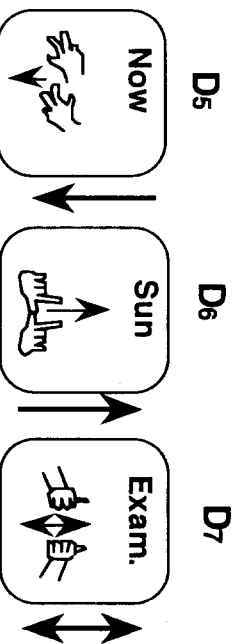


# 4 types hand motion

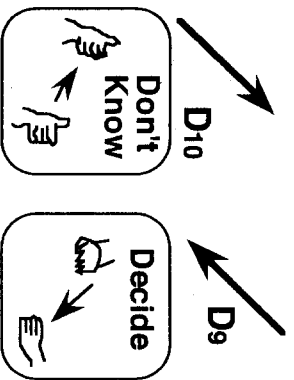
## (1) Horizontal Motion



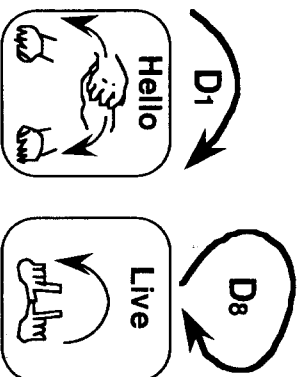
## (2) Vertical Motion



## (3) Slant Motion



## (4) Circular Motion





# Classification of Hand Motion

## ■ Preprocessing

i) Reduction of hand trembling

$$l(k) = \sqrt{dx(k)^2 + dy(k)^2}$$

$$dx(k) = x(k) - x(k-1)$$

$$dy(k) = y(k) - y(k-1)$$

ii) Reduction of magnetic interference

» data distortion due to ferrous metallic substances  
in Polhemus 3-D sensor system





## Classification of Hand Motion

### ■ 4 types of hand motions

- Horizontal motion(H)
  - » D<sub>4</sub> : Left & right motion
- Vertical motion(V)
  - » D<sub>7</sub> : Up & down motion
- Slant motion(S)
- Circular motion(C)
  - » D<sub>1</sub>



# Features in hand motion

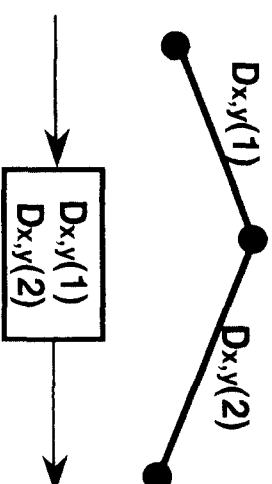
## (1) Sampled latest 3 points

$$D_x(1) = dx(m), \quad D_x(2) = dx(m-1)$$

$$D_y(1) = dy(m), \quad D_y(2) = dy(m-1)$$

## (2) Cumulative Length

$$L(m) = \sum_{m=1}^M \|l(m)\|$$



## Features in hand motion



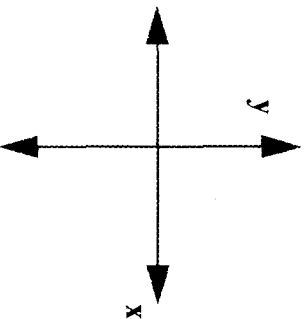
### (3) Difference of both position (left & right)

$$dbx(m) = rx(m) - lx(m)$$

$$dby(m) = ry(m) - ly(m)$$

### (4) Current Phase

$$CP(m) = \tan^{-1} \left( \frac{y(m)}{x(m)} \right)$$

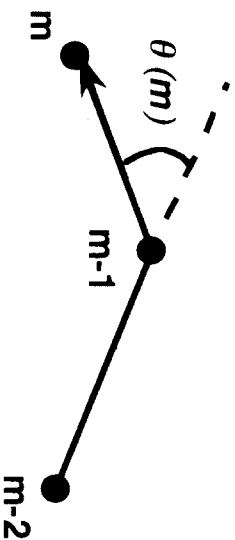


# Features in hand motion

## (5) Cumulative Direction Change in radians

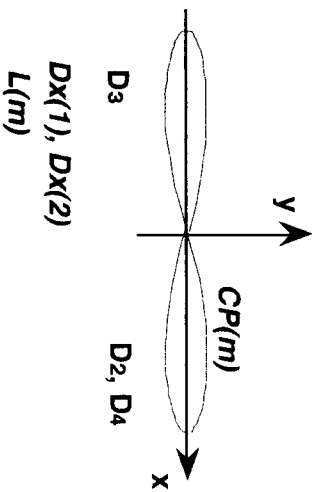
$$\theta(m) = \tan^{-1} \frac{y(m) - y(m-1)}{x(m) - x(m-1)} - \tan^{-1} \frac{y(m-1) - y(m-2)}{x(m-1) - x(m-2)}$$

$$\sum_{m=1} \theta(m)$$



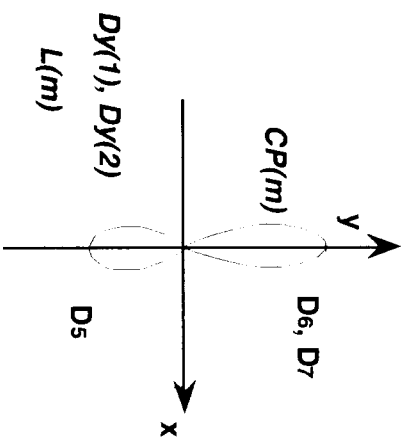
# ■ Feature Analysis

(1) Horizontal Type :  $D_2, D_3, D_4$

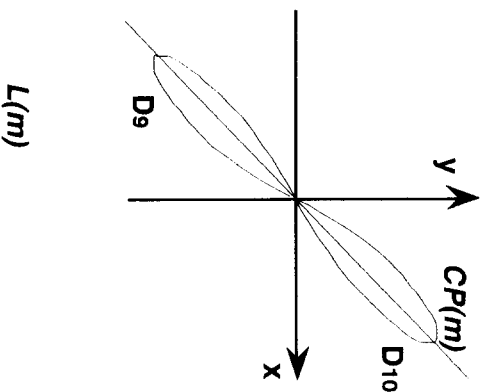


$dby(m) > \text{Threshold}$

(2) Vertical Type :  $D_5, D_6, D_7$



(3) Slant Type :  $D_9, D_{10}$



(4) Circular Type :  $D_1, D_8$

$\Sigma\theta(m)$   
 $L(m)$



## Feature Analysis

- **CP(m) : Classification of H, V, S**
- **L(m) : Recognizable region**
- **Dx,Dy : each motion in each H,V,S**
- **dbym(m) : D4**
- **Cumulative direction change : C**



# Recognition of Dynamic gestures in the KSLs

<p>Hello</p> <p>D1 P1</p>	<p>Meet</p> <p>D3 P3</p>	<p>Depart</p> <p>D2 P12</p>	<p>(be) Glad</p> <p>D7 P13</p>	<p>I</p> <p>D9 P11</p>	<p>You</p> <p>P3</p>	<p>Decide</p> <p>D9 P1</p>
<p>Is</p> <p>D1 P11</p>	<p>Know</p> <p>D7 P11</p>	<p>Don't Know</p> <p>D10 P11</p>	<p>Live</p> <p>D8 P4</p>	<p>Man</p> <p>D4 P2</p>	<p>Woman</p> <p>D4 P6</p>	<p>Human</p> <p>D4 P7</p>
<p>Father</p> <p>D2 P4</p>	<p>Mother</p> <p>D2 P6</p>	<p>Today</p> <p>D5 P11</p>	<p>Now</p> <p>D5 P9</p>	<p>Beginning</p> <p>D6 P10</p>	<p>Sun</p> <p>D6 P4</p>	<p>Exam.</p> <p>D7 P2</p>
<p>Thank You</p> <p>D7 P11</p>	<p>Bicycle</p> <p>D7 P1</p>	<p>Not</p> <p>D2 P4</p>	<p>Teacher</p> <p>D7 P5</p>			





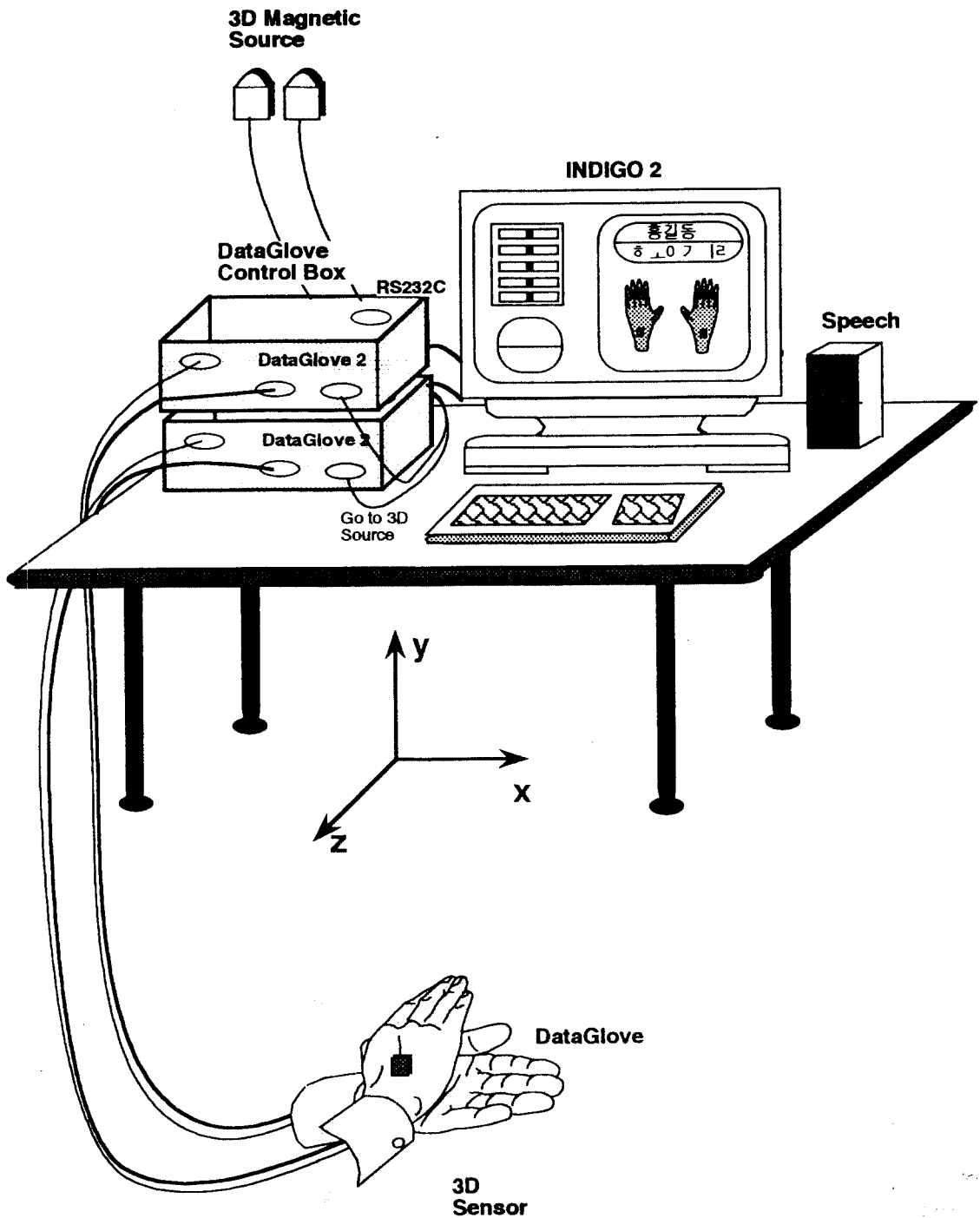
## Experimental Results

- Two VPL Data Gloves
- Main Computer : Sun Sparc-Station 10
- RS232C with 19,200 baud rates
- Sampling time : 1/15 second

*Prof. Zeungnam Bien, EE, KAIST*







# Korean Sign Language Recognition System

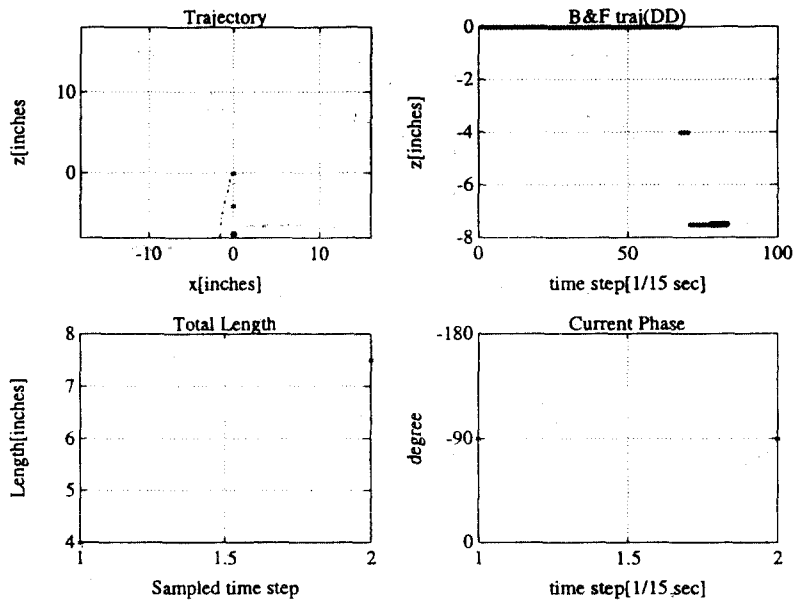
# Experimental Results



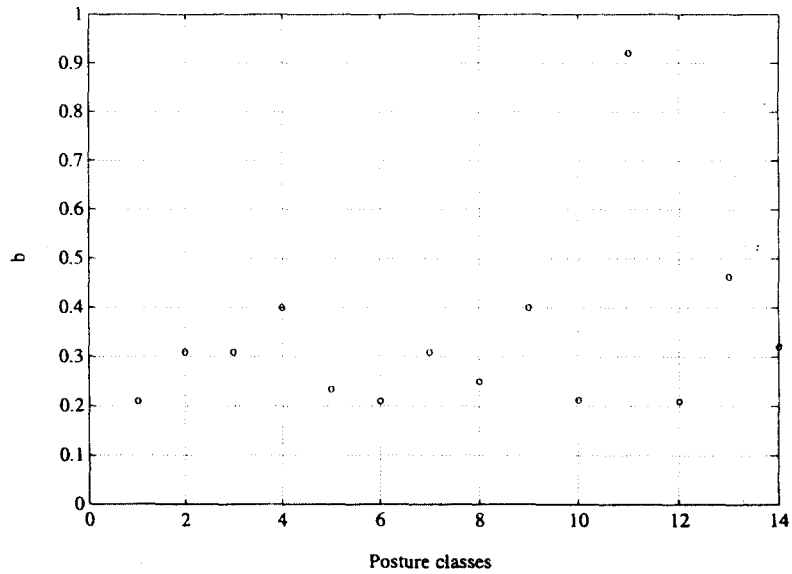
## ■ KSL Recognition System

- Recognition of dynamic gestures in the KSL based on the basic elements
- 75 % Recognition Rate
- 14 basic direction classification
- 14 posture classification



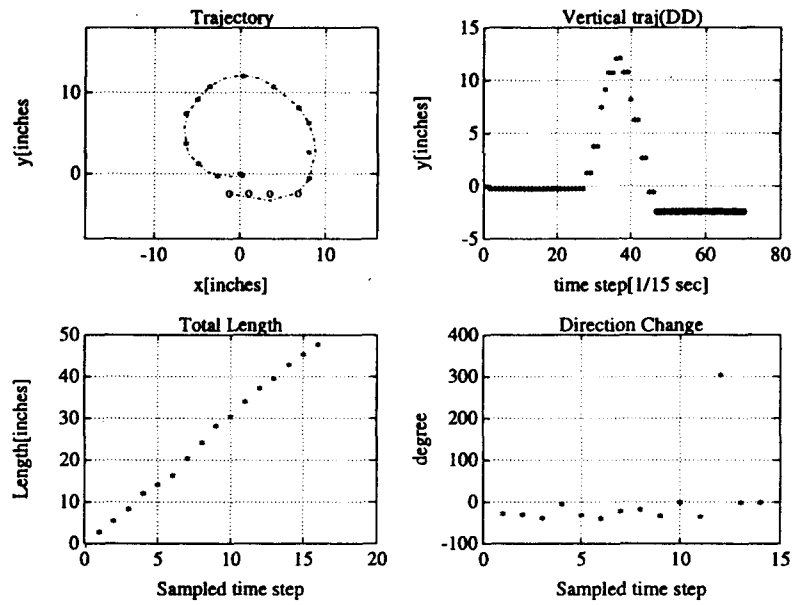


(a) Direction  $D_{11}$

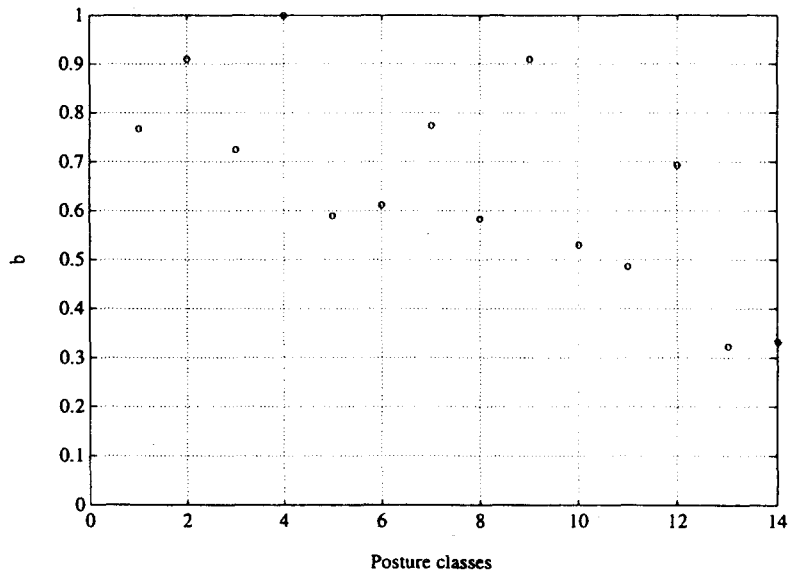


(b) Posture  $P_{11}$

Figure 4.16: Experimental Result: gesture '주다(give)'



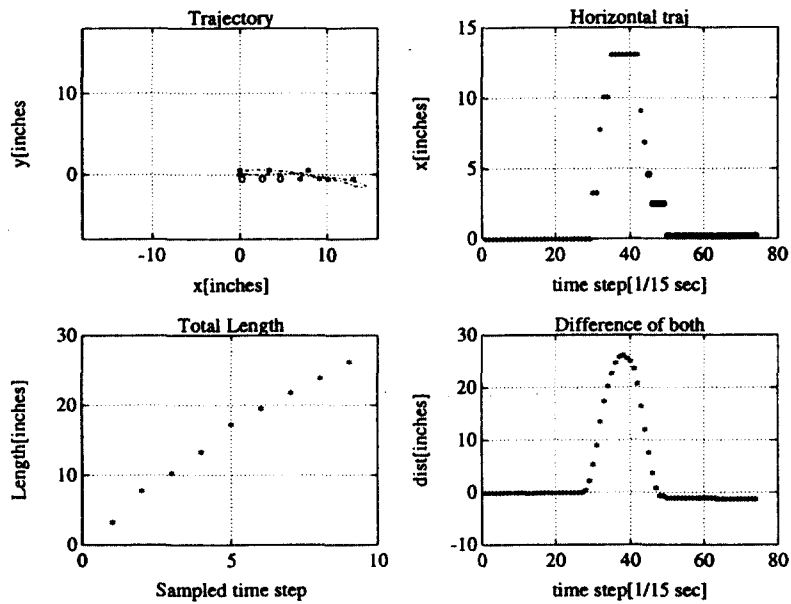
(a) Direction  $D_8$



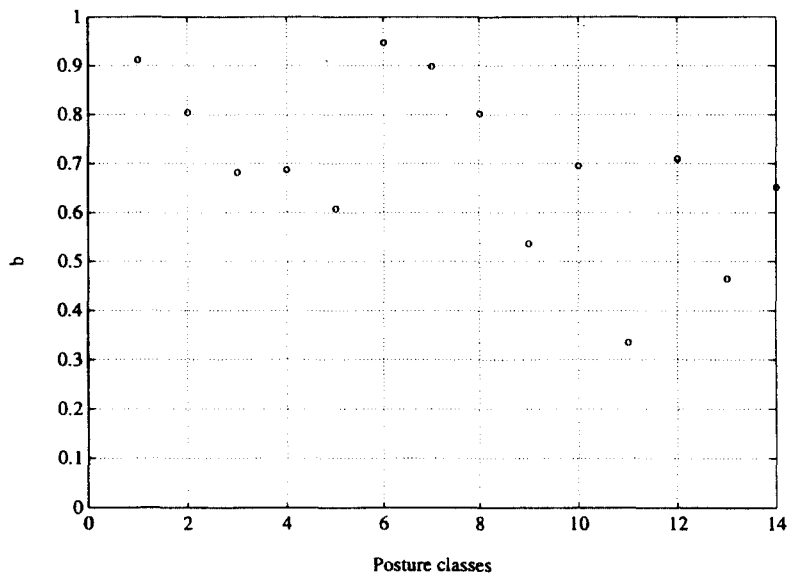
(b) Posture  $P_4$

Figure 4.10: Experimental Result: gesture '살다(live)'





(a) Direction  $D_4$



(b) Posture  $P_6$

Figure 4.8: Experimental Result: gesture '여자(woman)'

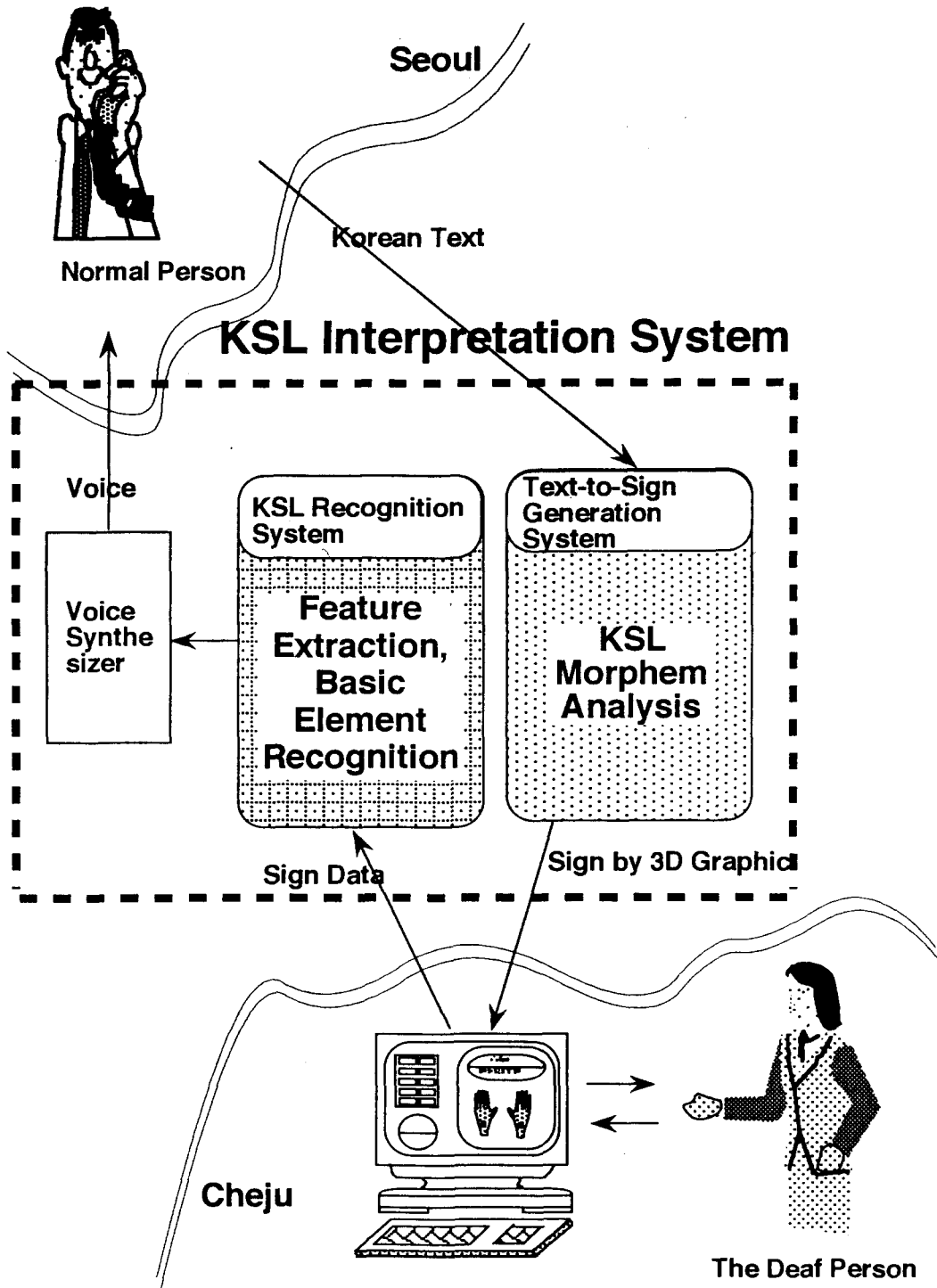




## Conclusion

- **Human's Hand Gesture**
- **On-line Recognition of the dynamic Gestures**
  - Recognition of dynamic gestures in the KSL based on the basic elements, directions & postures
- **Communication system between doctors & patients who speech-imparing person**
- **KSL Interpretation System**







## Further Studies

- Consideration of Gestures with double hand-shaped posture
- Modification of FMNN Network
  - Considering on  $\theta$ ,  $\gamma$
- Direction classification by fuzzy rule using features
- Confirmation mode for correct recognition
  - using Inconsistent rule

