# A NEW DESCRIPTIVE SYSTEM FOR HAND SHAPES USED IN SIGNING BASED ON BIOMECHANICAL MODELING OF FINGER ACTIONS

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ABSTRACT

Based on the biomechanical modeling of finger actions, a new descriptive system for hand shapes used in signing is proposed. Hand shapes are classified systematically on a chart consisting of combinations of finger actions for changing the shapes and mutual relationships for each of the combinations of the active fingers. This chart serves as a language-independent framework for describing the hand shapes in manual communication.

## PURPOSE

As part of the investigation of the coordination of descriptive systems proposed for different sign languages with biomechanical modeling of the hand and arm movements [1], classification of hand shapes is discussed based on the anatomical structure and control mechanism.

## MODEL OF FINGER ACTIONS

Hand shapes are described based on the combination of finger actions for changing the shapes and mutual relationships, for each of the combinations of the active fingers.

The extension and flexion of the index, middle, ring and little fingers are modeled by the rotation of three kinds of joints (distal/proximal interphalangeal and metacarpophalangeal joints) caused by the contractions of seven kinds of muscles (flexor digiti minimi brevis, extensor digitorum/indicis/digiti minimi, flexor digitorum superficialis/profundus, and lumbrical muscles). While those of the thumb are modeled independently from the other fingers by the rotation of three kinds of joints (inter/metacarpophalangeal and carpometacarpal joints) caused by the contractions of four kinds of muscles (flexor/extensor pollicis longus/brevis muscles).

Abduction and adduction of the index, middle, ring and little fingers are modeled by the rotation of the metacarpophalangeal joint caused by the contraction of three kinds of muscles (dorsal interosseous, abductor digiti minimi and palmar interosseous muscles). Palmar abduction/adduction and radial abduction/ulnar adduction of the thumb are modeled by the rotation of the carpometacarpal joint caused by five kinds of muscles (abductor pollicis longus /brevis, opponens/adductor pollicis and flexor pollicis brevis muscles).

## SYMBOL SYSTEM

By combining the above finger actions, hand shapes in signing can be described using the new system proposed here.

The descriptive system consists of symbols for the five fingers, marks denoting actions, and several marking conventions. The marks denote the actions of extended or flexed fingers for changing their shapes: extended, clenched, half-clenched, hooked angled, and half-angled, and those of extended fingers for changing their mutual relationship; and abducted, radial-abducted for the thumb, palmar-abducted and palmar-adducted also for the thumb, crossed and touched.

## HAND SHAPE CHART

Theoretically possible hand shapes are classified in the form of a matrix consisting of the marks denoting finger actions for changing the shapes in columns, and for changing mutual relationships in rows, for each of the combinations of the active fingers. The hand shapes without and with the actions of the thumb are classified in chart A and B, respectively (Table1 and 2).

For simplicity of display, only the hand shape with the action indicated by the mark on the left-side of "/" is shown for the element in each column and row in these charts. The number of hand shapes involved in chart A and B is 215 and 572, respectively, and 789 in total.

## DIFFICULTY IN ACTIONS

The number of hand shapes decreases to about 713 kinds, if some of the combinations are eliminated on account of being highly difficult to manipulate. (They are indicated by "−" in the charts.) The degree of the difficulty is estimated by analyzing the nature of control in the neuromuscular mechanisms of the hands, with regard to their original function of exerting forces to outside objects.

There are 76 kinds of shapes, which correspond to about 10% of total, in the criterion used here; and most of them are related to the actions of the middle finger, ring finger, index plus ring fingers and middle plus little fingers.

## SHAPES USED IN SIGNING

These 713 kinds of hand shapes encompass most of the hand shapes found in the previously devised descriptive symbol systems for the manual alphabet and both traditional and simultaneous sign languages in America, 19 kinds of symbols proposed by Stokoe [2], 41 kinds of symbols by Friedman [3], 22 kinds of symbols by Liddel [4], 40 kinds of symbols by Sutton [5], 40 kinds of symbols in the SignFont [6]; in Sweden, 33 kinds of symbols by Bergman [7]; and in Japan, 54 kinds of symbols by Kanda [8] and 32 kinds of symbols by Yonekawa [9]. (They are indicated by "+" in the charts.)

The result is 78 different kinds of hand shapes, or about 10% of the total, but the remaining 80% of the hand shapes can be also utilized for finding a more effective system of the hand shapes in manual communication in general, as well as for describing the hand shapes in other sign languages.

## APPLICATIONS

The descriptive symbol system of hand shapes proposed here is currently being applied in the computer simulation of signing gestures by combining it with models of arm and hand movements. It is also planned to apply it to the retrieval strings in electronic sign language dictionaries by modifying the system with regard to the degree of difficulty of recognition.

## REFERENCES

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*Table 1. Hand shape chart A consisting of combinations of actions of the index, middle, ring and little fingers (215 shapes)*

MARKS DENOTING ACTIONS FOR CHANGING SHAPES
(EXTENDED FINGERS) C: CLENCHED c: HALF-CLENCHED H: HOOKED A: ANGLED a: HALF-ANGLED
(FLEXED FINGERS) C': CLENCHED c': HALF-CLENCHED H': HOOKED A': ANGLED a': HALF-ANGLED

FOR CHANGING MUTUAL RELATIONSHIPS
(EXTENDED FINGERS) V: FINGER 2-5 ABDUCTED
FINGER 1 RADIAL-ABDUCTED
B: FINGER 1 PALMAR-ABDUCTED
d: FINGER 1 PALMAR-ADDUCTED
X: CROSS T: TOUCHED

SYMBOLS OF FINGERS
FINGER 2: INDEX, 3: MIDDLE, 4: RING, 5: LITTLE, 1: THUMB

MARKING CONVENTIONS
1. MARKS ATTACHED TO THE RIGHT OF SYMBOLS OF FINGERS
2. EXTENDED NOT MARKED
3. ( OR ): THE SAME ACTIONS FOR ALL FINGERS ENCIRCLED WITH A MARK
4. c' NOT MARKED FOR FINGER 1

+: USED IN THE SYMBOL SYSTEMS PROPOSED IN DIFFERENT SIGN LANGUAGES (78 SHAPES, ABOUT 10% OF THE TOTAL)
−: HIGHLY DIFFICULT TO MANIPULATE (76 SHAPES, ABOUT 10% OF THE TOTAL)

(FOR SIMPLICITY OF DISPLAY, ONLY THE HAND SHAPE WITH THE ACTION INDICATED BY THE MARK ON THE LEFT-SIDE OF / IS SHOWN FOR THE ELEMENT IN EACH COLUMN AND ROW.)

(ACTIVE FINGERS EXTENDED) MUTUAL RELATIONSHIP

| | FINGER 2 | V | X |
|---|---|---|---|
| FINGER 2 | +2 | | |
| | c/H ++(2c | | |
| | c'/H' 2(345c | 2V(3V4V5H | |
| | A/a +2A | | |
| SHAPE | A'/a' 2(345A | | |

| | FINGER 0 | V | X |
|---|---|---|---|
| FINGER 0 | +(12345C | | |
| | c/H | | |
| | c'/H' +(2345c* | (2V3V4V5H*** | |
| | A/a | | |
| SHAPE | A'/a' (2345A** | (2V3V4V5a**** | |

| | FINGER 3 | V | X |
|---|---|---|---|
| FINGER 3 | +23 | +2V3 +2X3 | +−3 |
| | c/H +(23c | +(2V3H | (3c |
| | c'/H' 23(45c | 2V3V(4V5H 2X3(45c | 2c3(45c |
| | A/a ++(23A | (2V3a | 3A |
| SHAPE | A'/a' 23(45A | 2V3(45A 2X3(45A | −2A3(45A |

| | FINGER 4 | V | X |
|---|---|---|---|
| FINGER 4 | −24 | −2V4 | −34 |
| | c/H (24c | −(2V4H | (34c |
| | c'/H' −23c45c | −2V3HV4V5H | 2c345c |
| | A/a (24A | (2V4a | (34A |
| SHAPE | A'/a' −23A45A | | −2A345A |

| | FINGER 4 | V | X |
|---|---|---|---|
| FINGER 4 | −3V4 | +−4 | |
| | c/H (3V4H | 4c | |
| | c'/H' 2HV3V4V5H | (23c45c | (2V3HV4V5H |
| | A/a (3V4a | 4A | |
| SHAPE | A'/a' −2A3V45A | −(23A45A | |

| | FINGER 5 | V | X |
|---|---|---|---|
| FINGER 5 | +25 | +2V5 | −35 |
| | c/H (25c | (2V5H | −(35c |
| | c'/H' 2(34c5 | 2V(3V4HV5 | −2c34c5 |
| | A/a (25A | (2V5a | (35A |
| SHAPE | A'/a' 2(34A5 | | −2A34A5 |

| | FINGER 5 | V | X |
|---|---|---|---|
| FINGER 5 | +5 | | |
| | c/H (5c | | |
| | c'/H' (23c45 | (2V3V4HV5 | |
| | A/a (45A | (4V5a | |
| SHAPE | A'/a' (23A45 | (23A4V5 | |

| | FINGER 5 | V | X |
|---|---|---|---|
| FINGER 5 | +2345 | +2V3V4V5 | 2X345 |
| | c/H (2345c* | +(2V3V4V5H*** | |
| | c'/H' | | |
| | A/a (2345A** | (2V3V4V5a**** | |
| SHAPE | A'/a' | | |

(ACTIVE FINGERS FLEXED) MUTUAL RELATIONSHIP

| | FINGER 2 | V | X |
|---|---|---|---|
| | 345 | 3V4V5 | |
| | c/H (345c | (3V4V5H | |
| | c'/H' 2c345 | 2HV3V4V5 | |
| | A/a (345A | (3V4V5a | |
| SHAPE | A'/a' 2A345 | 2A3V4V5 | |

| | FINGER 3 | V | X |
|---|---|---|---|
| | 245 | −2V4V5 | |
| | (245c | (2V4V5H | |
| | 23c45 | 2V3H4V5 | |
| | (245A | (2V4V5a | |
| | −23A45 | −23A4V5 | |

| | FINGER 4 | V | X |
|---|---|---|---|
| | 235 | −2V3V5 | −2X35 |
| | (235c | (2V3V5H | |
| | 234c5 | 2V3V4HV5 | 2X34c5 |
| | (235A | (2V4V5a | |
| | −234A5 | −2V34A5 | −2X34A5 |

| | FINGER 5 | V | X |
|---|---|---|---|
| | +234 | +2V3V4 | 2X34 |
| | (234c | +(2V3V4H | |
| | 2345c | 2V3V4V5H | 2X345c |
| | (234A | (2V3V4a | |
| | 2345A | 2V3V45A | 2X345A |



*Table 2. Hand shape chart B consisting of actions of the thumb combined with chart A (572 shapes, 789 shapes in total of A and B)*

(ACTIVE FINGERS EXTENDED) MUTUAL RELATIONSHIP

| | FINGER 2 | 1V/B(d) | V | X |
|---|---|---|---|---|
| FINGER 2 | 12 | +++1V(d)2 | | +1X2) |
| | c/H +(12c | | | |
| | c'/H' 12(345c | 1V2(345c | 1V2(3V4V5H | |
| | A/a 12A | ++1V2A | | |
| | A'/a' 12(345A | +1V2(345A | | |
| | Tc/A 1T2)c | | | |
| SHAPE | Tc'/A' +1T345)c2 | | | |

| | FINGER 1 | 1V/B(d) | V | X |
|---|---|---|---|---|
| FINGER 1 | +1 | +1V | | |
| | c/H ++(1c | | | |
| | c'/H' 1(2345c | 1V(2345c | 1V(2V3V4V5H | |
| | A/a | | | |
| | A'/a' ++1(2345A | 1V(2345A***** | +1B(2V3V4V5a****** | |
| | Tc/A | | | |
| SHAPE | Tc'/A' 1T2345)c******* | | | |

(ACTIVE FINGERS FLEXED) MUTUAL RELATIONSHIP

| | FINGER 0 | 1V/B(d) | V | X |
|---|---|---|---|---|
| FINGER 0 | +12345 | +1V(d)2345 | +1V(d)2V3V4V5 | 12X345 |
| | c/H +(12345c | | +(12V3V4V5H | |
| | c'/H' | | | |
| | A/a 1(2345A | +++1V(2345A***** | 1B(2V3V4V5a****** | |
| | A'/a' | | | |
| | Tc/A ++1T2345)c******* | | | |
| SHAPE | Tc'/A' | | | |

| | FINGER 3 | 1V/B(d) | V | X |
|---|---|---|---|---|
| FINGER 3 | 123 | 1V(d)23 | +1V(d)2V3 | 12X3, +1X23) |
| | c/H (123c | | +(12V3H | |
| | c'/H' 123(45c | 1V23(45c | 1V2V3V(4V5H | 1V2X3(45c |
| | A/a 1(23A | +1V(23A | 1B(2V3a | |
| | A'/a' 123(45A | 1V23(45A | 1V2V3(45A | 1V2X3(45A |
| | Tc/A ++1T23)c | | | |
| SHAPE | Tc'/A' 1T45)c23 | | 1T45)c2V3 | 1T45)c2X3 |

| | FINGER 3 | 1V/B(d) | V | X |
|---|---|---|---|---|
| FINGER 3 | −13 | −1V(d)3 | | |
| | (13c | | | |
| | 12c3(45 | 1V2c3(45 | 1V2H3(4V5 | |
| | 13A | 1V3A | | |
| | −12A3(45A | −1V2A3(45A | | |
| | 1T3)c | | | |
| | 1T245)c3 | | | |

| | FINGER 4 | 1V/B(d) | V | X |
|---|---|---|---|---|
| FINGER 4 | −124 | −1V(d)24 | −1V(d)2V4 | −134 |
| | c/H (124c | | −(12V4H | (134c |
| | c'/H' +123c45c | −1V23c45c | −1V2V3HV4V5H | 12c34c5 |
| | A/a 1(24A | 1V(24A | 1B(2V4a | 1(34A |
| | A'/a' −123A45A | −1V23A45A | | −12A34A5 |
| | Tc/A 1T24)c | | | 1T34)c |
| SHAPE | Tc'/A' −1T35)c24 | | 1T35)c2V4 | 1T25)c34 |

| | FINGER 4 | 1V/B(d) | V | X |
|---|---|---|---|---|
| | −1V(d)34 | −1V(d)3V4 | −14 | −1V(d)4 |
| | | (13V4H | (14c | |
| | 1V2c345c | 1V2HV3V4V5H | 1(23c45c | 1V(23c45c 1V(2V3H4V5H |
| | 1V(34A | 1B(3V4a | 14A | 1V4A |
| | −12A34A5 | −1V2A34A5 | −1V2A3V45A | −1(23A45A −1V(23A45A |
| | 1T34)c | | | 1T4)c |
| | 1T25)c34 | 1T25)c3V4 | | 1T235)c4 |

| | FINGER 5 | 1V/B(d) | V | X |
|---|---|---|---|---|
| FINGER 5 | 125 | +1V(d)25 | 1V(d)2V5 | −135 |
| | c/H (125c | | (12V5H | −(135c |
| | c'/H' 12(34c5 | 1V2(34c5 | 1V2V(3V4H5V | −12c34c5 |
| | A/a 1(25A | 1V(25A | 1B(2V5a | 1(35A |
| | A'/a' 12(34A5 | 1V2(34A5 | | −12A34A5 |
| | Tc/A 1T25)c | | | −1T35)c |
| SHAPE | Tc'/A' +1T34)c25 | | 1T34)c2V5 | −1T24)c35 |

| | FINGER 5 | 1V/B(d) | V | X |
|---|---|---|---|---|
| | −1V(d)35 | −1V(d)3V5 | 145 | 1V(d)45 1V(d)4V5 |
| | | −(13V5H | (145c | (14V5H |
| | −1V2c34c5 | −1V2HV3V4HV5 | 1(23c45 | 1V(23c45 1V(23H4V5 |
| | −1V(35A | 1B(3V5a | 1(45A | 1V(45A 1B(4V5a |
| | −1V2A34A5 | | 1(23A45 | 1V(23A45 1V(23A4V5 |
| | −1T35)c | | 1T4)c | |
| | 1T24)c35 | 1T24)c3V5 | +1T23)c45 | 1T23)c4V5 |

| | FINGER 5 | 1V/B(d) | V | X |
|---|---|---|---|---|
| | 15 | +1V(d)5 | | |
| | (15c | | | |
| | 1(23c45 | 1V(234c5 | 1V(2V3V4HV5 | |
| | 15A | 1V5A | | |
| | 1(23A45 | 1V(234A5 | | |
| | 1T5)c | | | |
| | +1T234)c5 | | | |

(ACTIVE FINGERS FLEXED) MUTUAL RELATIONSHIP

| | FINGER 2 | 1V/B(d) | V | X |
|---|---|---|---|---|
| | 1345 | 1V(d)345 | 1V(d)3V4V5 | |
| | c/H (1345c | (13V4V5H | | |
| | c'/H' 12c345 | 1V2c345 | 1V2HV3V4V5 | |
| | A/a +1(345A | 1V(345A | 1B(3V4V5a | |
| | A'/a' 12A345 | 1V2A345 | 1V2A3V4V5 | |
| | Tc/A 1T345)c | | | |
| SHAPE | Tc'/A' T1T2)c345 | | +1T2)c3V4V5 | |

| | FINGER 3 | 1V/B(d) | V | X |
|---|---|---|---|---|
| | 1245 | 1V(d)245 | −1V(d)24V5 | |
| | (1245c | | (12V4V5H | |
| | 123c45 | 1V23c45 | +1V2V3HV4V5 | |
| | 1(245A | 1V(245A | 1B(2V4V5a | |
| | −123A45 | −1V23A45 | −1V23A4V5 | |
| | 1T245)c | | | |
| | +1T3)c245 | | 1T3)c2V4V5 | |

| | FINGER 4 | 1V/B(d) | V | X |
|---|---|---|---|---|
| | 1235 | 1V(d)235+ | −1V(d)2V3V5 | −12X34 |
| | (1235c | | (12V3V5H | |
| | 1234c5 | 1V234c5 | +1V2V3V4HV5 | −1V2X34c5 |
| | 1(235A | 1V(235A | 1B(2V3V5a | |
| | −1234A5 | −1V234A5 | +−1V2V34A5 | 1V2X34A5 |
| | 1T235)c | | | |
| | +1T4)c235 | | 1T4)c2V3V5 | |

| | FINGER 5 | 1V/B(d) | V | X |
|---|---|---|---|---|
| | 1234 | 1V(d)234 | +1V(d)2V3V4 | 12X34, +1X234) |
| | (1234c | | (12V3V4H | |
| | 12345c | 1V2345c | 1V2V3V4V5H | 1V2X345c |
| | 1(234A | 1V(234A | 1B(2V3V5a | |
| | 12345A | 1V2345A | 1V2V3V4V5A | 1V2X345A |
| | 1r234) | | | |
| | +1T5)c234 | | 1T5)c2V3V4 | 1T5)c2X34 |