CHARACTERIZATION OF JAPANESE SIGNS AND COMPUTERIZED LEXICON

Kazuo Kamata[1], Yoshiko Fujino[2] and Yukie Usui[3]
[1]Professor, [2]Graduate Student, [3]Technical Official
Department of Information Science
Utsunomiya University
2753 Ishii-machi, Utsunomiya 321, Japan

1. INTRODUCTION.

Sign language which is used as a means of communication for the deaf is a visual-manual(visual-gestural) language. Elements of sign language might include head, eyes, eyebrows, mouth and hands, and elements of activity, then, include, for example, noding or shaking of the head, widening or narrowing of eyes, opening or closing of the mouth, and various movements for the hands. Many linguistic studies on sign languages have been done since 1960s, and many researchers have been studying several aspects of sign languages[For example, Battison(1978), Friedman (1977), Klima and Bellugi(1979), Kyle and Woll(1985), Liddell(1980)]. In phonological study of sign languages, hand configuration, place of articulation(location), movement, and orientation are well-known formational parameters and are given equal status.

The main aim of our study is building a machine dictionary for computer processing(understanding and generation) of Japanese sign language. Sign language processing by a computer as well as spoken language one requires certain types of stored data and several levels of analysis: Phonetic and phonological analyses, mophological analysis, lexical analysis, syntactic analysis, and so on. In spoken language processing by a computer, the first phase is sound wave processing for extracting sound features to proceed further analysis. In the sign language processing by computer, the first phase is motion image processing to extract formational parameters of sings.

The object of our current study is characterizing each sign with the use of formational parameters all of which will be extractable from given sign motion images with a computer processing. In the computer image processing, the identification of handshapes is most difficult among the extractions of sign formational parameters

How precisely can the movement parameters including location specify signs? This question, then, is basic when we study the computer understanding of sign languages. We use, in the characterization study, slightly different parameters from usual formational parameters used in linguistics. We also adopt a multi-stage classification approach in which each feature is applied in serial manner to subdivided groups to get smaller groups. We first use types of signs, or handedness of sign and parameters based on characteristics of movement in signing. We second apply other parameters to subdivided groups, which reflect particular characteristics of signs in each group. Note that we restrict our focus on manual elements of sings and exclude other nonmanual elements such as facial expressions[Baker-Shenk(1985), Liddell(1980), Vogt-Svendsen (1981)]. Since sings have two structural aspects, simultaneous and sequential structures [Liddell(1984), Sandler(1989), Stokoe *et al.*(1965)], our characterizing study based on movement parameters will also be relevant to linguistic study of sign languages.

Our study of characterizing Japanese signs has still been continuing. We show, in this paper, some results of classification of 1699 Japanese signs in DSJSL (Dictionary of Simultaneous Japanese Sign Language [Tochigi,1978]). Certain characterization results show one formational property of signs: Symmetrical Constraint[Battison(1978)]. We also show the implementation of computerized dictionary on a personal computer that stores 199 Japanese signs; Certain subset of 1669 signs classified. We can search sings that satisfy feature values specified. In linguistics, computerized lexicon for ASL(American Sign Language) has been presented[Teuber *et al.* (1980)]

2. MOTIVATION AND OBJECTIVES.

Computer processing of spoken or written languages has been studied extensively since the advent of a computer. These studies include translation of one written language into another one(Machine Translation), recognition and understanding of speech, production of speech from written text(Text-to-Speech Translation), and so on.

Less study, on the contrary, has been done in the computer processing of sign languages, although the technique is essential to promote social activity of the disabled. The final goal of our study is building machine dictionaries that should be used in the sign language processing(understanding and generation) by a computer. There are various dictionaries that will be used in several levels of processing. The machine understanding of spoken languages requires the computer to draw several types of stored data and to perform several levels of analysis. These are phonetic and phonological analyses(The analysis outputs phonemes to the next analysis), morphological analysis (morphemes), lexical analysis (words), syntactic analysis (syntactic structures), semantic analysis, pragmatic analysis, and reasoning [Winograd (1984)].

The object of our current study is building a notation system for signs which we can use at the first phase: phonetic and phonological analyses of signs. In the first analysis, a computer performs motion image processi-ngs and extracts formational features of signs. The notation system, therefore, should adopt descriptive para-meters all that are extractable by a computer image processing technique. This is not the case for notational systems in linguistic study. We then adopt a slightly different approach and also use different formational parameters from those in linguistics. This is the main reason why we first characterize signs with the use of types of signs, i.e., handedness, and certain features based on movement and without handshape parameters.

3. CLASSIFICATION OF JAPANESE SIGNS.

In this chapter we will show how to classify Japanese signs in DSJSL and show, furthermore, classification results. The classification, or characterization, adopts a multi-stage approach, i.e., we apply characterizing features in series and subdivide successively each group of sings into smaller ones. The main features used are types of signs, and some other movement parameters. Note that signs used are in the citation form.

3.1 ROUGH CLASSIFICATION.

Figure 1 shows a characterizing feature tree which we use in rough classification of signs. Note that we assume signers are right-handed.

[A] Feature A, the first feature of the classification, is HANDEDNESS, or the number of hands used to produce signs: ONE-HANDED means a sign is produced with one hand only, while TWO-HANDED means either (i)both hands are active or (ii)one hand is active(dominant) and the other is passive (nondominant) serving as the location of the sign.

[B] Feature B for ONE-HANDED signs, is which hand signers use in signing: RIGHT HAND means the right hand and LEFT HAND the left hand.

[C] Feature C is MOVEMENT. WITHOUT MOVEMENT means signs do not involve any movement in the citation form. Sings of WITH MOVEMENT involve certain movement.

[D] Feature D is INTERACTION BETWEEN HANDS. This feature takes 8 values: (i)LEFT HAND FIXED: The left hand is passive and the right hand active. (ii)RIGHT HAND FIXED: The right hand is passive and the left hand active. (iii)SYMMETRICAL:Both hands move and perform symmetrical action. (iv)PARALLEL: Both hands move and perform parallel action. (v)SYMMETRICAL AND PARALLEL: Both hands move and perform symmetrical and parallel action. (vi)ALTERNATIVE: Both hands move and perform alternative action. (vii)CONTINUOUS CONTACT: Both hands keep contacting throughout signing. (viii)INDEPENDENT: Signs which both hands move and do not fall into any one of categories above.

<u>3.2 DETAILED CLASSIFICATION.</u> *In* this section we will show how we make further characterization, or detailed classification. Features used for the detailed classification are decided for each group of signs so that features can reflect characteristics of the group of signs.
[E] <u>Feature of CONTACT.</u> (E-a)We apply the feature to the group with WITH MOVEMENT and with either TWO-HANDED or ONE-HANDED. This takes five values. (i)NON-contact: Hand(s) does not contact with any part of the signer's body. (ii)END-contact: The hand(s) makes contact at the end of the sign with some part of the body. (iii) BEGINNING-contact: The sign begins with the contact with some part of the body. (iv)TEMPORAL-contact: The hand(s) makes contact at neither beginning nor ending point with some part of the body. (v)REPETITIVE-contact: The hand(s)

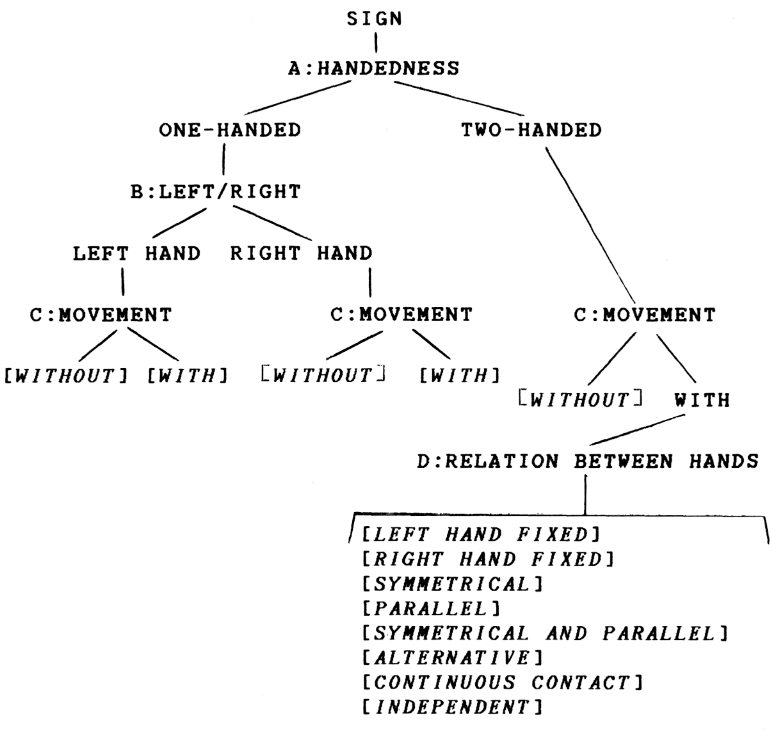

Fig.1 Features for rough classification of signs.
[*X*] indicates the leaf of the tree.

makes contact with some parts of the body more than once including beginning and end points.
(E-b)We apply the feature to the groups of signs with WITHOUT MOVEMENT. This feature takes values: (i)WITH-contact, (ii)NON-contact.
[F] Feature of CHANGE-OF-HANDSHAPE. This feature is applied to the groups of signs with MOVEMENT. If a sign takes value WITH, then the sign involves hand-internal movement(IM).
[G] Feature of the PARTS-OF-MOVEMENT. We apply this feature to the groups of signs with MOVEMENT. The feature takes four values. (i)ARM: The sign entails the movement of the arm(s), that is, hand(s) moves from one location to another one. (ii)ARM/WRIST: The arm(s) moves together with certain movement of the wrist(s). (iii)WRIST: The sign involves only certain action of wrist(s). (iv)FINGER: The sign involves only certain action of finger(s). Note that the first two features indicate path movement(PM) and the last two hand-internal movement(IM).
[H] Feature of LOCUS-OF-MOVEMENT. The shape of locus is divided into some categories. (i)STRAIGHT-LINE takes three values: ONE-direction, MULTI-direction and REPETITIVE (ii)CURVE takes two values: CIRCULAR/ARC, and OTHERS. (iii)NON-movement: This means the sign does not involve PM.

Table 1. Result of Rough Classification.

TYPE OF SIGN	MOVEMENT	RELATION	NUMBER
TWO-HANDED	WITH	LEFT/FIXED	360
		RIGHT/FIXED	8
		SYMMETRICAL	203
		PARALLEL	28
		SYM/PARALLEL	69
		ALTERNATIVE	55
		CONT/CONTACT	196
		INDEPENDENT	79
	WITHOUT		93
ONE-HANDED/RIGHT	WITH		523
	WITHOUT		54
ONE-HANDED/LEFT	WITH		1

3.3 CHARACTERIZATION RESULTS. In this section, we show some of the characterization results for 1669 signs in DSJSL. Certain signs are excluded from the classification that are compound ones or consist only of one or more manual alphabets.

Table 1 shows the result of the rough classification. Table 2 shows the detailed classification for the group of signs with two-handed and with symmetrical movement. Table 3 shows the result of detailed one for the group of signs with two-handed and with the left hand is fixed, that is, the right hand is active and the left hand is passive. Table 4 shows the result of detailed one for the group of signs with one-handed, with the right hand and with movement.

Table 2. Some Results of Detailed Classification for the Group of Signs with Symmetrical Movement.

CONTACT	PARTS OF MOVEMENT	LOCUS LINEAR	CURVE
NON	ARM	49	15
	ARM/WRIST	6	13
	WRIST	12(NON*)	
	FINGER	13(NON*)	
END	ARM	13	4
	ARM/WRIST	3	3
BEGINNING	ARM	18	4
	ARM/WRIST	5	16
	WRIST	10(NON*)	
TEMPORAL	ARM	1	0
REPETITIVE	ARM	5	3
	ARM/WRIST	0	5
	WRIST	1(NON*)	

(*)Signs do not involve path movement(PM).

Table 3. Some Results of Detailed Classification for the Group of signs with the Left-Hand is Fixed.

CONTACT	PARTS OF MOVEMENT	LOCUS LINEAR	LOCUS CURVE
NON	ARM	42	26
	ARM/WRIST	7	14
	WRIST	27(NON*)	
	FINGER	6(NON*)	
END	ARM	55	18
	ARM/WRIST	1	12
	WRIST	2(NON*)	
BEGINNING	ARM	39	16
	ARM/WRIST	3	6
	WRIST	7(NON*)	
TEMPORAL	ARM	4	3
	ARM/WRIST	2	23
	WRIST	1(NON*)	
REPETITIVE	ARM	18	15
	ARM/WRIST	1	4
	WRIST	8(NON*)	

(*)Signs do not involve path movement(PM).

3.4 FORMATIONAL PROPERTIES OF SIGNS. It is well-known that certain constraint appears on signs. Among them, 'Symmetry Constraint' and 'Dominance Constraint' have been proposed as universal restrictions on sign form[Battison(1978)]. The symmetry constraint states: If both hands of a sign move independently during signing, then both hands must be specified for the same location, the same handshape, the same movement(either simultaneous or alternating) and the specification for orientation must be symmetrical or identical. The dominance constraint states: If one hand is passive and the other active in a two-handed sign, the specification for passive handshape is restricted to one of a set of unmarked handshapes.

Since, in our study, we do not use handshape parameters as characterization features, we can not state definitely whether or not those two constraints apply to Japanese signs used. But we can state the first constraint, Symmetrical Constraint, will apply, because most signs(355 out of 434) satisfy certain specifications of the constraint.

Table 4. Some Results of Detailed Classification of One-Handed Signs.

CHANGE OF HANDSHAPE	PARTS OF MOVEMENT	LOCUS LINEAR	LOCUS CURVE
WITH	ARM	52	14
	ARM/WRIST	5	6
	WRIST	4(NON*)	
	FINGER	42(NON*)	
WITHOUT	ARM	180	108
	ARM/WRIST	19	37
	WRIST	59(NON*)	

(*) Signs do not involve path movement(PM).

4. COMPUTERIZED LEXICON.

In this chapter we show the computerized lexicon (computerized dictionary) using the characterization results in the previous chapter. The present system which has implemented on a personal computer(NEC PC98), stores a certain subset of Japanese signs that have been characterized.

4.1 OVERVIEW OF THE SYSTEM.

The system offers two search methods, that is, the system has two main search programs: One searches certain sign and outputs feature values for a particular sign when entry word(A Japanese word that is the translation of a sign) is inputed. We call this search Sign Feature Search(SFS-Operation). The other searches and outputs a certain sign(Japanese word) or a set of certain signs(A set of entry words) that satisfy parameters(feature values) specified as an input. We call this Sign Search(SS-Operation).

A subset of Japanese sign used in this system consists of 199 signs those which have the feature values: (1)TWO-HANDED, (2)WITH MOVEMENT, and (3)SUMMETRICAL MOVEMENT. Information about each sign is stored with the structure shown in Figure 2:

(0) Entry Word	(1) Sign Number	(2) Sign Type	(3) Movement

(4) Relation between Hands	(5) Parts of Movement	(6) Contact

(7) Change of Handshape	(8) Locus of Movement

Fig.2 Data structure for an item of a sign.

(0)An entry word represents the Japanese word that corresponds to a sign(Japanese translation). Although a sign may correspond to more than one spoken word, these information is not stored with the item.
(1)Different positive integer number is attached to each sign(Sign number).
(2)Sign Type comprises: 1.Two-Handed and 2.One-Handed.
(3)Movement comprises: 1.Sign involves movement and 2.Without movement.
(4)Relation between Hands comprises:
1.The left hand is fixed and the right hand moves.
5.The right hand is fixed and the left hand moves.
Movement is: 2.Symmetrical, 3.Parallel,
4.Symmetrical and Parallel, 6.Altrenative,
7.Continuous Contact, and 8.Independent.
(5)Parts of Movement comprises: 1.Arm(s),
2.Arm(s) and wrist(s), 3.Wrist(s) and 4.Finger(s).
(6)Contact comprises: 1.Noncontact, 2.Beginning contact,
3.Endcontact, 4.Temporal contact and
5.Repetitive contact.
(7)Change of Handshape comprises: 1.With change and
2.Without change.
(8)Locus of Movement comprises: 1.Linear and 2.Curve.

4.1.1 SIGN FEATURE SEARCH. The system searches the sign that has an input word as an entry word, and then outputs a set of feature values of the sign. We will show one example of SFS-Operation in 4.2.

4.1.2 SIGN SEARCH. In this search operation, we should specify each feature value in the following manner:
(a) Within each feature category we can specify more than one value. The system combine these values with logical OR operation. We also can choose special value: The wildcard specification that is denoted by symbol "? ".
(b) The system combines every feature categories with

logical AND operation.

4.2 SOME EXAMPLES. In this section we show some examples for sign feature search(SFS-Operation) and sign search(SS-Operation).

(a) Figure 3 shows one example of SFS-Operation. 「大きい(Large)」 is inputed to the search system.

検索する単語を入力して下さい。
{Plese input word}
――――――→ 大きい

(a)

手話番号 : 255
{Sign Number}

手話の型 : 両手 {Two-handed}
{Sign Type}

動き : 動く {With Movement}
{Movement}

両手関係 : 対称 {Symmetrical}
{Relation between Hands}

動く部分 : 腕 {Arms}
{Parts of Movement}

両手の接触 : 無 {Noncontact}
{Contact between Hands}

手の形 : 変化しない {Without}
{Change of Handshape}

動きの形 : 直線的 {Linear}
{Locus of Movement}

(b)

Fig.3 Example of SFS-Operation for 大きい.
(a)Input and (b)Output of the system.

(b) Figure 4 shows an example of SS-Operation. In this case, each feature value is definitely specified. The system, in this case, searches and outputs a set of 6 signs all that satisfy the feature values specified.

どのような手話か選んで下さい。わからない時は？を入力して下さい。

☆手話の型は何ですか？　　１．両手　２．片手
{Type}　　----->1

☆動き　　１．動く　２．動かない
{Movement}　　----->1

☆右手と左手の動き方は？
{Relation of Each Hand}　　----->2

１．右手だけ動く　２．対称　３．並行　４．対称・並行
５．左手だけ動く　６．交互　７．継続的接触　８．独立

☆右手と左手は接触しますか？
{Contact}　　----->1

１．無　２．有→無　３．無→有　４．一時的　５．繰返し

☆身体のどの部分が動きますか？
{Parts of Movement}　　----->1

１．腕　２．腕・手首　３．手首　４．指

☆手の形は変化しますか？　　１．する　２．しない
{Change of Handshape(IM)}　　----->1

☆動きの形？　　１．直線的　２．曲線的
{Locus of Movement}　　----->1

(a)

該当する単語は、6語です。{Number of signs are...}

251: 横断歩道 {pedestrian crossing}　463: 看護婦 {nurse}　481: 消える {disapear}

967: 情報 {infomation}　997: 神経質 {nervousness}　1434: 突然 {suddenness}

(b)

Fig.4 SS-Operation in which all the feature values are definitely specified (a)Input, and (b)Output of the system.

(c) In this example more than one values in one feature category are specified as shown in Fig.5. These values are combined with logical OR operation.

どのような手話か選んで下さい。わからない時は？を入力して下さい。

☆手話の型は何ですか？　1．両手　2．片手
{Type of Sign}　-----> 1

☆動き　1．動く　2．動かない
{Movement}　-----> 1

☆右手と左手の動き方は？
{Relation between Hands}　-----> 2

1．右手だけ動く　2．対称　3．並行　4．対称・並行
5．左手だけ動く　6．交互　7．継続的接触　8．独立

☆右手と左手は接触しますか？
{Contact}　-----> 23

1．無　2．有→無　3．無→有　4．一時的　5．繰返し

☆身体のどの部分が動きますか？
{Parts of Movement}　-----> 123

1．腕　2．腕・手首　3．手首　4．指

☆手の形は変化しますか？　1．する　2．しない
{Change of Handshape(IM)}　-----> 1

☆動きの形？　1．直線的　2．曲線的
{Locus of Movement}　-----> 1

(a)

該当する単語は、12 語です。{Number of signs are...}

137: 糸 {thred}　259: 岡山 {Okayama}　1023: ずいぶん {fairy}　1310: つなぐ {connect}

1391: 統一 {unification}　1597: 爆発 {explosion}　1746: ふくれる {expand}

1763: 太い {big}　1863: ぼんやり {vague}　1995: もち {rice cake}

2096:ラグビー {rugby}　2163: 綿 {cotton}

(b)

Fig.5 SS-Operation in which some of features are specified by more than one value. (a)Input, and (b)Output of the system.

(d)In this example, Figure 6, some features are specified by the wildcard. The system takes all the values for each feature and combine these with logical OR operaton.

どのような手話か選んで下さい。わからない時は？を入力して下さい。

☆手話の型は何ですか？　　1．両手　2．片手
{Type of Sign}　　　　----->1

☆動き　　1．動く　2．動かない
{Movement}　　　　----->1

☆右手と左手の動き方は？
{Relation between Hands}　　　　----->2

1．右手だけ動く　2．対称　3．並行　4．対称・並行
5．左手だけ動く　6．交互　7．継続的接触　8．独立

☆右手と左手は接触しますか？
{Contact}　　　　----->5

1．無　2．有→無　3．無→有　4．一時的　5．繰返し

☆身体のどの部分が動きますか？
{Parts of Movement}　　　　----->?

1．腕　2．腕・手首　3．手首　4．指

☆手の形は変化しますか？　　1．する　2．しない
{Change of Handshape(IM)}　　　　----->?

☆動きの形？　　1．直線的　2．曲線的
{Locus of Movement}　　　　----->?

(a)

該当する単語は、14語です。{Number of signs are...}

242: 円満 {harmony}	329: カード {card}	473: 関東 {Kantoh}	631: 結論 {conclusion}
738: 細かい {fine}	821: 算数 {mathematics}	841: 四角形 {rectangle}	
903: 社会 {society}	1127: 全部 {all}	1193: タオル {towel}	
1237: 団体 {group}	1450: トラブル {trouble}	1786: ふろしき {wrapping cloth}	
1854: ほめる {admire}			

(b)

Fig.6 SS-Operation in which some of features are specified by the wildcard. (a)Input, and (b)Output of the system.

5. CONCLUDING REMARKS.

We have introduced an approach to characterizing Japanese sings in DSJSL. The final goal of our study is building machine dictionary for the computer processing of Japanese Sign Language(JSL). Then the formational features of signs used in a notation system should be extractable by motion image processing techniques. The features which have been used in the classification were handedness and certain motion parameters, excluding handshape parameters. These were slightly different from usual ones proposed in linguistics: Handshape, location, movement and direction, and those are given equal status.

We have also showed some results of the classification of 1699 Japanese signs and the implementation of computerized lexicon with 199 Japanese signs: Certain subset of signs classified. Furthermore, characterization results have shown certain properties of the form of signs. Symmetry and dominance constraints have been proposed as universal restrictions on sign form [Battison(1978)]. Although our study has not used handshape parameters as characterizing features, a certain constraint has appeared on the sign form. We might state symmetry constraint could be applied to Japanese signs used in our study.

The linguistic model of signs has reflected two aspects: simultaneous and sequential structures [Liddell (1984), Sandler (1989),Stokoe *et al.*(1965)]. Although our study was highly motivated by the computer processing of sign language and based on certain features of movement, the characterization study would be relevant to linguistics; specifically phonetic, phonological and morphological analyses of signs. Our classification study has been continuing with certain refinement.

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REFERENCES

Baker-Shenk, C.(1985) The Facial Behavior of Deaf Signers: Evidence of a Complex Language. **American Annals of the Deaf**,130,4,297-304.

Battison, R.M.(1978) **Lexical Borrowing in American Sign Language**, Linstok Press.

Friedman L.A. ed.(1977) **On The Other Hand - New Perspectives on American Sign Language -.** Academic Press.

Kyle, J.G. and Woll, B.(1985) **Sign Language.** Cambridge University Press.

Klima, E. and Bellugi, U. eds.(1979) **The Signs of Language.** Harvard University Press.

Liddell, S.K.(1980) **American Sign Language Syntax.** Mouton.

(1984) THINK and BELIEVE: Sequentiality in American Sign Language,**Language**,60,2,372-399.

Sandler, W.(1989) **Phonological Representation of The Sign - Linearity and Nonlinearity in American Sign Language -**, Foris Publications.

Stokoe, W.C., Casterline, D. and Groneberg, C.(1965) **A Dictionary of American Sign Language on Linguistic Principles**, Gallaudet College Press.

Teuber, H., Battison, R., Lane, H., Heck, J., and Stungis, J.(1980) A Computerized Lexicon of American Sign Language: The DASL 1965 In FORTRAN, **Sign Language Studies**,29,349-369.

Tochigi Prefectural School for The Deaf, and Tochigi Prefectural Association for The Deaf, ed.(1978) **手指法辞典 [Dictionary of Signs].**

Vogt-Svendsen, M.(1981) Mouth Position and Mouth Movement in Norwegian Sign Language. **Sign Language Studies**,33,363-376.

Winograd, T.(1984) Computer Software for Working with Language, **Scientific American**,251,3,91-101.