3D Animation System for Japanese Sign Language

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Abstract

In this paper, we discuss the design and the implementation of a learning system which animates human motion of Japanese Sign language. In this system, we realize the placement of sign words, which is considered one of the most important features of motion in Sign language. The translation is based on case structure of input sentence. From the relation between verb and modifying noun phrases, the motion is properly placed and oriented. In the animation we use OpenGL library, Wavefront OBJ format and BVH motion format which are considered as defact standard in computer graphics/animation. We also designed API functions in order to provide adequate interfaces for human animation.

Keywords Sign Language, animation, case structure, 3D model

構文に基づく手話アニメーション

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概要

本論文では日本語手話をアニメーション表示するシステムの設計と構築について述べる。通常、手話においては助詞を省略することが多いが、その場合、表出位置を適当に配置しないと誤解が生じる可能性がある。このため文の格構造を利用して、主格と対象格の明示や動作の方向性を正しく反映させた表出位置を決定し、アニメーション表示する方法を提案した。さらに三次元表示するためのアニメーションインタフェースを設計した。

キーワード 手話, アニメーション, 格構造, 三次元モデル

1 Introduction

Hearing impaired people communicate by means of writing, lip reading or sign language in their daily lives. Especially sign language is as important for them as spoken language for hearing people. Hearing impaired people often communicate each other by sign language, because they can communicate naturally without difficulty and delay. In recent years, people who want to study Japanese Sign Language (JSL) are increasing in number year by year, as the number of people who are interested in welfare for handicapped increases.

The conventional ways to study sign language are taking a course in sign language, to study using printed matter and video or TV [6].

When hearing people or become deafs, whose mother tongue is Japanese, study JSL, they often want to know signs or sentences corresponding to a certain Japanese word or sentence, or Japanese word or sentence corresponding to a certain sign movement vice versa.

It is, however, difficult to have time or chance enough to ask their questions as they need. To overcome the problem, it is strongly requested to realize Japanese-Sign language translation systems. To date, a few systems have been proposed. Kurokawa et al investigated the supposed case particles of Japanese in Sign motion, and constructed a translation system using structural analysis [4]

Kamata et al realized a system which translated from Japanese to Signed Japanese [5].

In these studies, they treated Sign language as the sequence of signs. However, we should consider not only the sequence of signs which correspond to words in Japanese sentences but also 3D placement of sign motion, in order to clarify the meanings of the motion of signs.

In this paper, we propose a system for learning Japanese Sign Language incorporating the placement and the orientation of sign motions.

In the present methods to learn Sign Language, we can study it at tutorial courses or using published text books and video tapes by ourselves.

When learning people or become deafs who have acquired Japanese begin to study Sign language, they often come to chances to want to know corresponding words or sentences between Japanese and Sign language. However each of the present method has some problems against above requests.

From the view point of education, it is desirable to study repetitively and interactively to learn language. Therefore it is obvious that the students require a computer supported system.

2 Description of JSL

2.1 Characteristics of Sign Language

In this paper, Japanese-Sign language translation system is discussed considering the following characteristics of Sign language and the motion.

In the following, we express sign words with braces (for example, {man}).

Locus and Orientation of Sign Words

When we express the sentence '彼が彼女に本をあげた' ("He gave her a book." in English) in sign language, first we place {man} at right side, second we place {woman} at left side, third we place {book} at the same locus at which {man} was placed, and then we express {give} from the locus of {man} to the locus of {woman} (see Figure 1).

Figure 1: An example of placement of sign motion.

Thus, we should place sign words at different place to distinguish agent, object, source, goal etc. of a verb, and to clarify the direction of sign motion.

Where, if the word subjects to the first person, it is placed just in front of one's chest, if that does to the second person, it is placed at listeners position (a bit far in front of one's chest), and if the third person, placed at other position than these two loci. Furthermore the present position is interpreted as the locus where is just in front of the first person's position, and the locus of the third person is placed according to the distance between the present position and objectives.

Simultaneous Combination of Sign Morphemes

For example, "while ten years" is expressed in the sign word shown at right side illustration in Figure 2. Right hand of this sign means "ten", left hand means "year", and the hand motion means "while" Thus, although the hand shape or the movement in Sign language are independent morphemes, we often see a sign motion composed of two or more words simultaneously.

Besides the above characteristics, there are some characteristics, ex. facial expression and pausing. However these are also seen in oral language conversation. In this paper we do not pay attention to these characteristics and exclude them from the system functions.

2.2 Description Model of JSL

First of all, we have to decide description model of signs, when we construct a translation and animation system from Japanese to Sign language. The model should be able to treat the features of Sign language, 1: Placement and orientation of sign word and 2: simultaneous combination of sign morphemes.

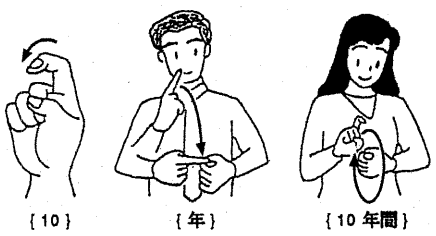

Figure 2: An example of simultaneous expression of signs.

Sign motion consists of hand shape, hand position and hand motion [1, 3]. In most cases, hand shape and hand motion have independent meanings. And a sign word is made up of them as shown in Figure 2. Furthermore, the meaning of a sentence varies according to the locus of sign words or start and end points of motion. Nagashima et al analyzed the morphemic structure of Sign language to explain these characteristics of Sign language [3]. The model to describe sign motion is determined as follows. In the model, sign motion is expressed in local configuration form and moving form. The former mainly consists of hand shape, and the latter possesses motion of hand position. Again, moving form have slots of locus or start and end points. Adopting this model, we should modify it in order to take above two features into consideration.

2.2.1 Local Configuration Form

Local configuration form mainly consists of hand (and finger) configuration and palm orientation. This form basically express local motion and shaping of hands which are preserved while the locus is changed or in global motion. If local configuration form includes both hands, it also contains spatial relation between both hands.

Table 1: Hand configuration code by Nagashima et al.

Basic Form (H)
Contacting Transconfiguration (C)
Bending Transconfiguration (B)
Pinching Transconfiguration (P)
Angling Transconfiguration (A)
Thumb Pressing Transconfiguration (T)
Covering Transconfiguration (V)
Frexing Transconfiguration (F)

Notice: Each fingers are numbered as follows, 1:fore finger, 2:middle finger, 3:ring finger, 4:pinky finger, 5:thumb.

Hand orientation of {男}("man" in English) or {家}("house") is independent of locus of sign word or direction of sign motion. But, palm orientation of the pointing sign aims to the object, and palm orientation of {言う (opponent(s)→ (s)self)}("say") aims from the start point to the end point of its motion. If palm orientation is influenced by locus or start and end points, we mark it as local "directional", and the information on relative palm orientation to the motion direction in the form.

Table 2: Adjustment code for more precise expression

Chink Adjustment (c)	narrows chink more
Bending Adjustment (b)	bends more
Angling Adjustment (a)	angles fingers more
Covered Thumb (-)	thumb covered by fingers

Sign motion {歩く}("walk") changes its hand configuration during its motion. {本}("book") changes its spatial relation between both hands. If there happens any change in local palm orientation or spatial relation, these are also included in the local form.

We use the hand configuration code proposed by Nagashima [3] (see Table 1) and add our original code to express more precise hand configuration (see Table 2). Figure 3 shows some examples of the hand configurations and their codes used in this system.

Examples of local configuration form, "Hc1.b" used in {行く} ("go") and "Habc12345" used in {本} ("book") are shown in Figure 3

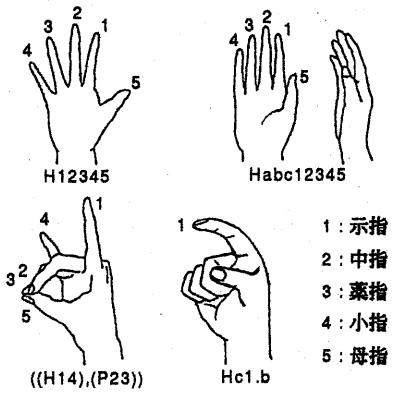

Figure 3: Examples of Hand Configuration Codes which are added our original code.

2.2.2 Moving Form

Moving form mainly consists of global motion of hand and change of hand orientation.

When we can change a locus of a sign motion, ex. pointing sign, {男} ("man") or {家} ("house"), its moving form should have a locus slot. And when we can set start and end points of a sign motion such as {行く} ("go") or {言われる (opponent(s)→ (s)self)} ("say"), its moving form has a position slot. The global

motion of hand is expressed in the following coordinates according to whether the expression has no slot, the position slot or the locus slot.

- If the moving form does not have position slot, the motion of hand is expressed in the coordinate system fixed on a body stem.
- If the moving form has a locus slot, the motion of hand is expressed in the coordinate system whose origin is set at the locus, and three axes (x, y, z) of it are parallel to those in the body coordinate system.
- If the moving form has a position slot (i.e. start and end points), the motion of hand is expressed in the coordinate system which is defined from the body coordinate by following processes.
  1. Set the origin of the coordinate system at the start point of the motion.
  2. Rotate it around y-axis and x-axis so as to coincide z-axis with the motion axis.
  3. Scale the distance between the start and end points to fit to 1 (unit).

2.2.3 Expression of sign motion

Each of sign word has both the local configuration form and the moving form, and stored in the dictionary.

For example the word { 行く } ("go") is expressed as "Hc1.b" in the local configuration form, and "concave arc" in the moving form. Further the word has the position slot with start and end points, in which appropriate values are set according to loci of subjective, objective, etc.

The default values of position are also given at the position slot in the moving form. For example, the word { 行く } ("go") has its default position, which is , however, replaced by values determined by the modifiers of the predicate. We store the information in sign word dictionary in "if-then" rule according to antecedent condition if necessary.

Another example: { ～年間 }("during ～ years") has a structure in the local configuration form which can contain another form.

3 Translation into JSL

3.1 Placement of Sign word

In Sign language, we can distinguish agent, object, location etc. by using exposition loci and start/end points of sign words. Exposition loci and start/end points of sign words play a role of case particles in Japanese. In Sign language there seem to be rules on placement and orientation of sign motion as follows.

- Some of exposition loci of sign words which are presenting person, object or place (ex. { 男 }, { 家 }, { 東京 }) can be replaced according to a meaning of sentence.
- If the sign words represent person or object or place but its exposition locus can not be changed (ex. { 佐藤 }, { 会社 }), we express its locus by adding a positioning pronoun after its motion.
- Some of exposition loci or start/end points of sign words representing predicate (ex. { 行く }, { 言われる (opponent(s)→self)}, { ある }) can be replaced with those of sign words which denote agent, object or location etc., and vice versa.
- If a modifier implies possessioner or location, an exposition locus of modified sign word is unified to that of the modifier.

In Sign language, each sign word representing person, object or place should have a locus slot and to be set the value in the slot. Therefore We can express semantic structure of sentence by connecting the located word with a motion or a locus of modifier or predicate. Conversely, we can give placement and orientation of sign motion, if we can get semantic relation between words in Japanese sentence.

A locus of a sign word described above is represented by using following descriptors (see Figure 4).

1. classification of noun in terms of placement (default / per1 / per2 / per3 / here)
2. the position along right→left axis if this locus is on the position of the third person (R1 / R2 / L1 / L2)
3. distance from "speaker" (sign motion player) if the word subjects to the third person (near / mid / far)

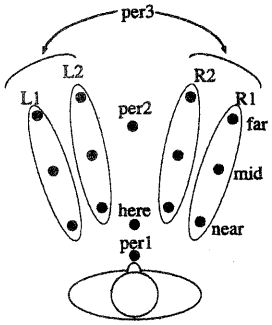

Figure 4: A point set for word position

3.2 Analysis of Case Structure

For analysis of a structure of a written sentence, the method to treat case structure written in [7, 8] by C.J.Fillmore has been widely used. This analysis tells us the relationship between predicate and noun. The

case gives classification of phrases which modify a predicate based on the semantic relationship between predicates and modifiers. We adopt the type of classification of case as shown in Table 3.

The outline of the analysis of case structure is as follows: the case frame as shown in Table 4 is assigned to each word; each modifier is classified into one case considering both the meaning category of the noun and the case particle assigned to it.

The result of the analysis is expressed in the following form:

$$(\text{PRED:}t,\ \text{MOD:}(K_{01} : t_{01}, \cdots, K_{0m} : t_{0m}),\ K_1 : t_1, \cdots, K_n : t_n)$$

where each symbol denotes as follows,

t	:	predicate
MOD:($K_{01} : t_{01}, \cdots$)	:	modality :
(TENSE:		past, present, future),
(ASPECT:		perfect, imperfect),
(FORM:		simple, emphatic, progressive),
(MOD:		declarative, interrogative, imperative),
(VOICE:		active, passive),
(ESSENCE:		affirmative, negative),
(MODAL:		may, can, must), etc.
$K_1 : t_1, \cdots, K_n : t_n$	:	case modifying t

Example : '私は昨日、公園で彼を見た.'
("I saw him in the park yesterday.")
= (PRED:see, MOD:(TENSE:past), OBJ:he, LOC:park, TIME:yesterday)

This form is called internal expression of the sentence. For a noun phrase, the modified noun is put at the head of parenthesis.

Example : '彼が書いた手紙'
(means "the letter which he wrote")
= letter(PRED:write, MOD:(TENSE:past), AG:he, OBJ: *)

Note that we do not account for analysis for Japanese sentences, and we assume Japanese sentences have been already divided into morphemes and stored as its internal expression with the case structure.

Table 3: Case system.

case type	explanation
AGent	one who does action
EXPERiencer	one who has experience
INSTRument	thing with which one act
OBJect	object of action
SOurce	thing from which one act
GOal	thing to which one act
LOCation	place where one act
TIME	time when one act
CAUSE	reason why one act
PURPOSE	purpose for which one act
POSSessor	one who own thing

Table 4: Examples of case frame.

word	case	semantic class	case particle
iku (go)	AG	⟨human⟩	"ga"
	SO	⟨place⟩	"ga"
	GO	⟨place⟩	"he"
	INSTR	⟨thing⟩	"de"
	TIME	⟨time⟩	"ni"
namae (name)	POSS	⟨human⟩, ⟨thing⟩	"no"
	LOC	⟨place⟩	"no"

3.3 Translation procedure

We can translate from input Japanese sentence and its case structure into corresponding sign motion by using following procedures.

- **assign value to locus attribute of word**
  First of all, words in an input sentence are scanned to be checked whether they have locus attribute consulting the dictionary. Words with locus attribute are assigned value to their locus attribute. For example, the word '私' ("I" in English), has a fixed locus: [self position], so the value is assigned to the locus attribute slot.

- **word-wise translation**
  A sentence is scanned again for word-wise translation consulting the Japanese – Sign language dictionary. As we assume that the sequential order of words in sign sentence is the same as that in Japanese sentence, word translation can be done one by one.

- **connect predicate and modifiers**
  Many of predicates which denote action(s) set loci of other words which concerns with them as their parameters specifying locus or position. If a reffering locus of concerned word has the value "unknown", the value "specified" is assigned to the locus of the predicate.

  When there exist conditions on spatial relation in the dictionary for a word, these are inherited to corresponding sign word description.

- **unification of loci of sign**
  The phrase '私の家' ("my house" in English) or '東京の銀行' ("bank in Tokyo" in English), implies a kind of locus, and loci of noun in the phrase are unified to that of their possesioner or location case.

  The locus attribute of the predicate 'ある' in the sentence '東京に家がある' ("I own my house in Tokyo" in English) is unified to a location case of it.

  The above unification depends on the order of words appeared in the sentence. If the object case word appears prior to the location case word, the unification does not occur.

  銀行 は あそこ に あり ます よ
  default per3 per3

If there happens conflict between cases of possessioner and location, then possessioner wins.

東京 に 私 の 家 が ある
per3 per1 per1 per1

- **insert pointing motion (if necessary)**
For example the word '会社' ("corporation" in English) has fixed exposition locus of its sign motion. If the locus of such words are assigned to belong to the 2nd or 3rd person, it is impossible to change their loci. In such a case the spatial assignment is performed by *pointing motion* just after the sign instead of changing the exposition locus of the sign.

- **fixing exposition loci of sign motion**
After the above all procedures, all of the loci of sign motion are fixed completely. The present state of locus of each word has one of the following value,

1. *NULL* : not specified (default)
2. *specified* mark
3. fixed person ($\in$ {per1, per2, per3}).

In the second case, the third person (per3) is assigned.

Loci of words with the third person are spatially assigned in terms of far-near direction and left-right direction.

As for left-to-right assignment the order of it is fixed as follows according to the word order appeared in an input sentence.

R1, L1, R2, L2 (see Figure 4)

As for far-near assignment it is fixed according to the semantic distance from the speaker (sign motion player). We define the distant order from the speaker to loci as follows,

here < per1 < near < mid < per2 < far

where, a word with the third person (per3) can be assigned at anywhere. The assignment is done as follows,

Step1. From head to tail of sentence, find the start and end points of action predicate. If there is a word with locus attribute whose locus has not been fixed, then jump to **Step2**. If all the words have been checked, then jump to **Step4**.

Step2. Sort the loci of words with respect to the distance from speaker, and put them into a list from nearest one in order. If the relation between words in sentences, for example "....go from A to B, then go B to C.....", hold the following conditions,

- NOT determined which start or end point is nearer
- end point is the same as start point of next action
- successive actions seem to have the same direction

then put one by one from farthest into the list, checking the relation holds the conditions.

Jump to **Step3**.

Step3. Assign each locus for elements in the list as follows,

Farthest element in the list is placed at *FAR* position.

Nearest element in the list is placed at *NEAR* position.

Others elements are placed at *MID* position.

Jump back to **Step1**.

Step4. If there is still unfixed locus, it is placed at *MID* position.

We can get all positions fixed for exposing sign motion by computing through these procedures.

4 Animation system

We exploit Wavefront OBJ format data for 3D surface model, and utilize OpenGL library to draw surfaces of human body. For the animation we use BVH motion capture file format data which consists of a skelton geometric structure of a human body and time sequence data for each of rotation angles of all joints in a human body.

As mentioned above some of the motion data are stored and expressed in position, length or direction in 3D Cartesian coordinates, so all joint angles have to be caliculated through inverse kinematics.

This enables the animation system independent between motion data and a geometric model of body. That's why we can change geometric models without arangements.

5 Results and Discussion

5.1 System performance and results

In this study the Japanese - Sign language translation system is implemented considering placements of sign motion. The system is able to realize the following three types of spatial relations.

- express the spatial relation between noun phrases in terms of predicate:
The system can express case structure of a sentence as a spatial relation by placing person, object and location, and by connecting them with predicate.

'彼が彼女に本をあげた' ("He gave her a book") =

{男}	{女}	{本}	{あげる}
3.R1	3.L1	3.R1	3.R1 → 3.L1

'彼に彼女が本をあげた' ("She gave him a book") =

{ 男 }	{ 女 }	{ 本 }	{ あげる }
3.R1	3.L1	3.L1	3.L1 → 3.R1

where, for words which have to be exposed at fixed position, ex. { 会社 }, pointing motion is inserted after the exposition to ensure its placement.

- far-near distance expression:
  If a word is subject to the 3rd person, the locus of its exposition is determined predicate according to the predicate. Especially when the verb is { 行く } ("go") or { 来る } ("come"), the start point is placed closer to the speaker (or the presenter) than the end point in case of { 行く } ("go").

'彼は京都から北海道へ行った' ("He went from Kyoto to Hokkaido") =

{ 男 }	{ 京都 }	{ 北海道 }	{ 行く }
	3.R1.near	3.L1.far	3.R1.near → 3.L1.far

- possession and place unification:
  By placing noun phrases at the same position possession or place unification is realized.

'私の家' ("My house") = { 私 } { 家 }
per1 per1

'あの本' ("That book") = { あの } { 本 }
per3.far per3.far

If the modifier is at a closer position than the modified phrase, they are not unified at the same position. Furthermore, when there are two modifiers; POSS(possessor case) and LOC(location case), LOC is took precedence over POSS.

In this system four segments (L1=left-out, L2=left-in, R1=right-out and R2=right-in) of location are prepared for the 3rd person's position (see Figure 4).

Therefore if the number of the position is five or more, they can be located in the same segment. However such a case is quite rare, and there is no example in the textbook used in TV program by NHK.

An example of translated motion is shown in Figure 5. The motion implies the sentence 'Tokyo no Honsha kara Koko ni Kuru'. (".. come here from the headquarter in Tokyo.")

5.2 Discussion

In this section, we discuss the difference between our implementation and sign motions in NHK textbook[13] in terms of spatial placement.

Insertion of subject for abbreviated sentence.

Though this is not the problem on spatial placement, there is other type of pointing motion except for that implemented in our system. In our system pointing motion is inserted in sign motion for words which have to be exposed at a fixed position. However there is a case to insert the motion which represents an agent of a behavior in order to specify it.

'Tannin no Sensei ni Soudan Shitai Koto mo Aru node' = ("As I also have something to talk over with my teacher...")
{tantou} {sensei} PT1 {soudan} {suki} {aru} PT1

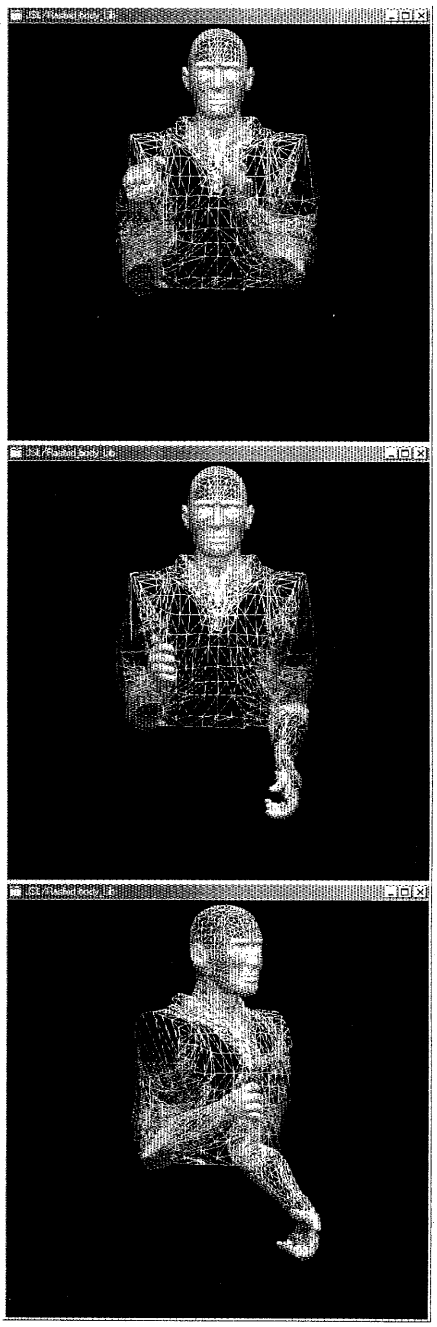

Figure 5: An example of animation images of sign motion.

The motion specifying subject is not always inserted, and this depends on situation, speaker, etc.

As this insertion is not always necessary, it is not implemented in our system. There is, however a case in which the sign motion would be misunderstood as shown in second example above.

Case a sign motion is not relocated

In this system the objective of the predicate { 行く } ("go") is placed at the end point of the motion. The following is an example in NHK textbook,

'今度の土曜日の文化講演会に行きますか？' =
{ 今度 } { 土曜日 } { 文化 } { 講演 } { 会 } { 行く }

where the objective { 文化講演会 } ("seminar")is not placed at the end point of the motion for the predicate { 行く } ("go"). Thus, when a sentence is simple enough to understand it, an objective is not sometimes located at an end point of the motion for the predicate { 行く } ("go"). Of course, doing so has no problem at all.

Placement using situation in real world

In this system motion is placed using a case structure of a sentence. So it is impossible to place sign motion according to the situation in the real world which is not specified in the input sentence.

'5番か6番の窓口におまわりください' =
("Please go to the desk #5 or #6.")

{5}	{6}	{ 窓 }	{ 口 }	{ 行く }
per3.R2	per3.R1			per2 → per3.R

In above example, the sign motion is composed assuming both the desks no.5 and no.6 are at right side of the speaker.

In the other example the sign motion needs to be composed using the situation that an officer requests one to seal next to a signature on a certain form of a document. However this requires knowledge on the arrangement of the document form. Such a specified motion cannot be generated in this system.

6 Conclusion

In this paper we discussed the design and the implementation of the translation system from Japanese to Sign language. In this system, we realized the placement and the orientation of sign motion, which is considered one of the most important features of motion in Sign language. The translation is based on case structure of input sentence. From the relation between verb and modifying noun phrases, the motion is properly placed and oriented. So we can provide the basis for environment to study Sign language interactively using this system. However there are still open problems, ex. implementation of facial expression and body motion, contextual analysis of input Japanese sentences and so on, so further investigation in this field is required for realization of a versatile translation system.

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