Consumer price data-glove for sign language recognition

T Kuroda[1], Y Tabata[2], A Goto[3], H Ikuta[4] and M Murakami

[1]Department of Medical Informatics, Kyoto University Hospital,
54, Kawahara-cho, Shogo-in, Sakyo-ku, Kyoto, 606-8507, JAPAN

[2]Kyoto College of Medical Technology,
1-3, Imakita, Koyama-higashi-machi, Sonobe-cho, Funai-gun, Kyoto, 62-0041, JAPAN

[3]AMITEQ Corp.,
5F, Hahshikan-LK-building, 1-6, Azuma-cho, Hachioji, Tokyo, 192-0082, JAPAN

[4]Teiken Limited,
1-6-7, Minami-honmachi, Chuo-ku, Osaka, 541-8587, JAPAN

[1]*Tomohiro.Kuroda@kuhp.kyoto-u.ac.jp*, [2]*yoshi-t@kyoto.medtech.ac.jp*,
[3]*amtq_goto@pop21.odn.ne.jp*, [4]*h.ikuta@teijin.co.jp*

[1]*www.kuhp.kyoto-u.ac.jp/~tkuroda*, [2]*www.kyoto.medtech.ac.jp*

ABSTRACT

A data-glove available for full degrees of freedom of a human hand is a key device to handle sign language on information systems. This paper presents an innovative intelligent data-glove named StrinGlove. StrinGlove obtains full degrees of freedom of human hand using 24 Inductcoders and 9 contact sensors, and encodes hand postures into posture codes on its own DSP. Additionally, the simple structure of the glove decreases the price. Several sign experts tried the prototype and the results show that the prototype has sufficient recognition rate as a sensor unit and sufficient comfortableness as a glove to wear.

1. INTRODUCTION

Sign linguistic engineering is a group of research to develop communication aid (called sign information system) for the Deaf and the Hearing Impaired, who have communication barrier in social lives, using information technology (Nagashima and Kanda 2001). Figure 1 shows the general view of sign information systems. Any sign information systems, such as virtual reality based sign language telephones, automatic translation system between sign languages and phonetic languages, and even sign language dictionary, share same basic structure. Most of sign information systems use three-dimensional computer graphic model of human beings called avatar to show signs. To obtain signs, though several systems using image recognition technologies, most of them are utilizing motion capture systems consists of data-globes and position and orientation sensors either magnetic-field-based, ultrasound-based, and image-based. The authors also developing sign language telephone named S-TEL (Kuroda et al, 1998) and consequent systems based on motion capture system consists of two data-gloves and three position and orientation sensors.

Thus, a data-glove available for full degrees of freedom of a human hand is a key device for sign information systems, and human computer interface for hearing impaired. However, data-gloves available on the current market are quite expensive, which cost as much as a luxurious car. Although several data-gloves are available in reasonable price, they can obtain only limited degrees of freedom. This poor variety of data-gloves prevents not only sign information systems but also other virtual reality based systems to spreading in the consumer market.

This paper presents an innovative data-glove named StrinGlove.

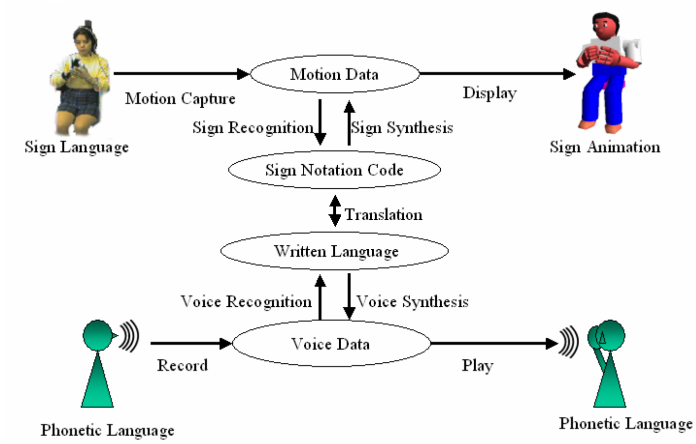

Figure 1. *General Overview of sign information systems*

2. FOREGOING DEVICES

In 1983, Jaron Lanier and Tom Jimmerman designed first glove type motion sensor to play music without touching any musical instruments, and 1984, they founded VPL Research to sell their sensor named DataGlove. DataGlove is a lightweight glove mounts ten fibre-optic cables along each finger. Each fibre-optic cable equips an LED at one end and phototransistor at the other end. When cable flexed, some of LED's light goes out from small scratches on surface of optic cable, so sensor obtains posture of a human hand. After invention of DataGlove, several types of data-gloves are presented (Zelter and Starman, 1994). Some gloves, such as Space Glove of Virtual Entertainment uses fibre-optic sensors as DataGlove, some Gloves, such as Nintendo's Powerglove and Altek's GLAD-IN-ART Glove utilizes piezoresistive sensors and some gloves, such as Exos' Dextrous Hand Master utilizes exoskeletal mechanical sensors. However, because of size and non-linearity of sensors, most of them have already gone away from market.

Most popular product on current market is CyberGlove of Immersion and 5DT Glove of 5th Dimension Technologies. These gloves utilize linear bend sensors mounted along each finger joints and present linear response. Although CyberGlove can obtain most of bending angles of human hand, it costs as much as a luxurious car. Nissho electronics' SuperGlove has same features as CyberGlove and cost much cheaper, it senses quite limited degrees of freedom and cannot applicable for motion capture on sign information systems.

3. DESIGN OVERVIEW OF STRINGLOVE

3.1 Sensing Bending Angles

When finger bends, wrinkles of back of finger joint stretches and distance along back of finger lengthen. Therefore, StrinGlove senses changes of distance between back of palm to each joint and fingertips as bends of each joint.

Figure 2 shows the basic structure of bending sensor of StrinGlove. The cable B consists of non-stretch fibre C and stretch fibre D connected by magnetizable material E. When joint A bends, the material E is pulled out from sensor tube. The motion of material E changes magnetic-flux density inside the sensor tube produced by active coil F, and the sensor obtains the change of magnetic-flux density as changes of inductance of coil F.

Figure 3 shows the detailed sensing mechanism of the sensor tube named Inductcoder® (Encoder Technology, 2001). Inductcoder induces magnetic field by giving single-phase alternating current $\sin(\omega t)$ on primary coil PW. Denoting displacement of material 15 as $0 \le \theta < 2\pi$, amplitudes of secondary coil S1~S4 become $\sin(\theta)$, $\cos(\theta)$, $-\sin(\theta)$, $-\cos(\theta)$ respectively. Therefore, S1 and S3, and S2 and S4 coupled as differential circuit as shown in Fig. 4, output alternating current A and B comes to $\sin(\theta)\cdot\sin(\omega t)$ and $\cos(\theta)\cdot\sin(\omega t)$ respectively. Thus, Inductcoder outputs two alternating currents as resolver. Therefore, Inductcoder can obtain absolute displacement of material 15 in high resolution using simple digital phase-shift detector.

As the Inductocoder gives linear output because of its simple mechanism, the glove just needs to obtain maximum and minimum sensing value to calibrate sensors. Therefore, StrinGlove obtains maximum and minimum value during certain period of time after its initialization and calibrate itself automatically. Therefore, users has no needs to perform any special calibration process before using the sensor instead of opening and closing one's hands for several times.

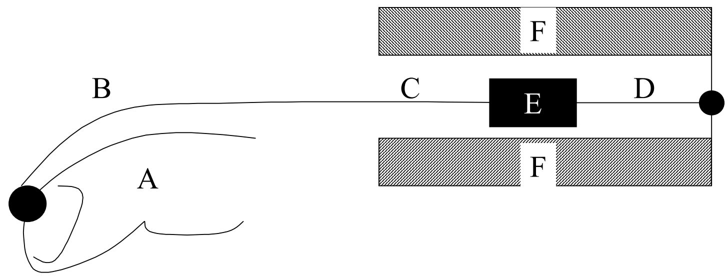

Figure 2. *Basic structure of bending sensor.*

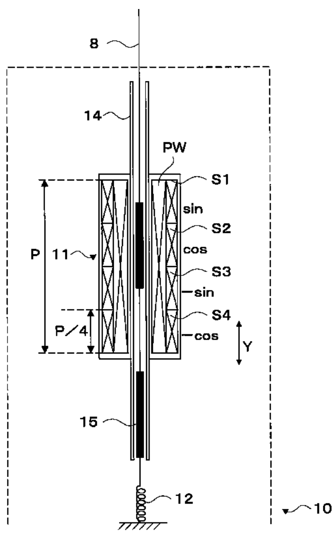

Figure 3. *Detailed design of Inductcoder.*

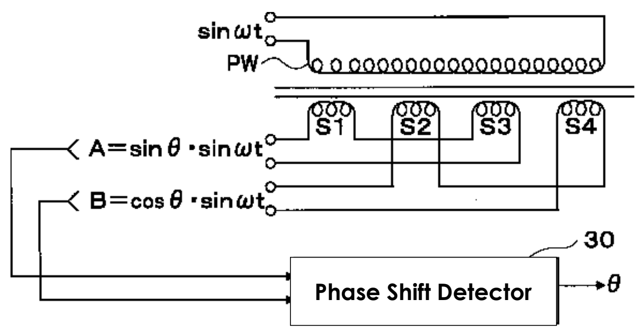

Figure 4. *Circuit diagram of Inductcoder.*

StrinGlove equips 24 Inductcoders to obtain 22 degrees of freedom of human hand as shown in Fig. 5. As wrist bends both inner and outer directions, four sensors are equipped to obtain two degrees of freedom of wrist. As the external diameter of sensor tube is only three mille-meters, most of sensors can be equipped on back of palm without disturbing any hand motion. Depends on maximum changes of distance between finger tip and perm, the standard length of sensor tube is 44.5 mille-meters although length of some sensor tubes to obtain bends of metacarpophalangeal joint (MPJ) are 30.5 mille-meters. The Inductcoder fasten its cable with small clasp as shown in Fig. 6 in both ends, users can adjust or replace sensor cable in case it cut.

3.2 Sensing contact between fingertips

To obtain contacts between fingertips using bending sensors are quite difficult as size of human hands varies widely. Therefore, the authors decided to put contact sensors on fingertips. PinchGlove of Fakespace or TouchGlove of Infusion Systems obtains pressures given by sensors or contacts of fingers. However, human beings not always really touch fingertips firmly even when one intends to do so. Therefore, StrinGlove utilizes approaching sensor using magnetic coils.

The authors examined hand postures in sign languages around the world and found that nine contact sensors as shown in Fig. 7 is sufficient to obtain any hand posture. To give different frequency on each active sensor coils on fingers, StrinGlove may distinguish to which finger the thumb touches from sensor value from reactive sensor coil mounted on tip of thumb. Additionally, frequency shift of each active sensor coils may obtain crossings of fingers such as posture shown in Fig.8, indicates Japanese character "ra".

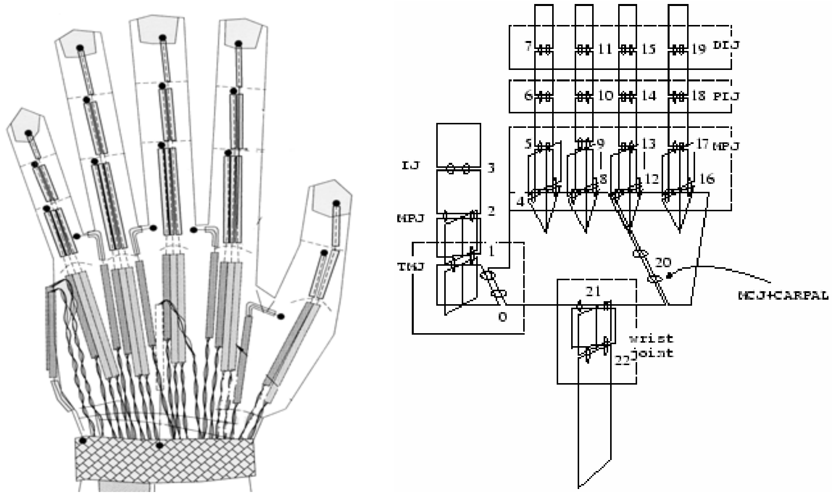

Figure 5. *Bend sensor arrangement and target hand model.*

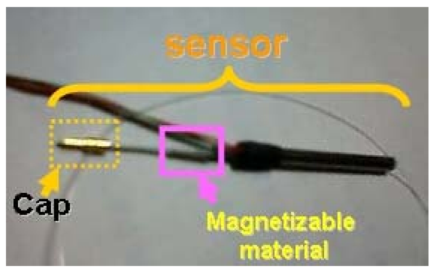

Figure 6. *Clasps to fasten sensor cable.*

3.3 Fabrics

Make glove type sensor sensitive enough, glove must fit perfectly on human hand. On the other hand, glove mustn't disturb free motion of human hand. Therefore, soft and stretchable fabric should be used for glove type sensor. The authors realized alpha version glove using soft fabrics. However, trial performed by sign experts reveals that too soft fabric make the glove difficult to wear on and off. Because the glove made of too soft fabric cannot hold its shape at any moment, and cannot hold sensors mounted on the glove. Moreover, sensor cables are cut out from sensor tube easily because the glove itself stretches too much when user wear off the glove.

To overcome these problems, the authors used two different fabrics; semi-stretching fabric, which stretches only for a single direction, and stretching fabric, which stretches in any directions. The glove uses stretching fabric for backside and semi-stretching fabric for palm side to avoid stretching along finger direction. Thus, although the glove has enough elasticity to fit user's hand and sense stretches of sensor cable, any sensor cables won't be cut.

Additionally, StrinGlove mounts sensor units by Velcro in order to enable to take all the sensors away and to wash the sensor glove. As no sensor gloves in market is washable, StrinGlove has high advantages for public use.

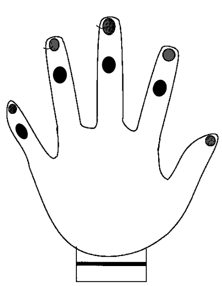

Figure 7. *Arrangement of contact sensors.*

Figure 8. *Japanese character "ra" (Yohei).*

3.4 Encoder

Sign language is a group of most sophisticated coding system of human motion. The authors reviewed existing notation system for sign languages, such as HamNoSys (Hanke 2004), sINDEX (Kanda 1997), and so on, and defined hand shape coding system, which covers most of intentional hand motion. Table 1 shows a part of developed coding system. As the coding system is rather simple, StrinGlove encode hand posture into notation code using DSP mounted on the glove itself using vector quantization.

This automatic encoding function decrease calculation load of central CPU, so it eases to develop sign information system and any virtual reality applications. StrinGlove, as matter of course, presents sensor data as it is in twelve bits depending on given order. Figure 9 shows the beta prototype.

Table 1. *Example codes of developed coding system.*

Code	Finger states	Code	Finger states
H	Full stretches of all fingers	**A**	Abduction between fingers
B	Full bending of all fingers	**G**	Abduction of first joint in thumb, and bending of second, third joints in thumb
b	Bending of all fingers	**I**	Adduction of first joint in thumb, and stretch of second, third joints in thumb
F	Bending of first and second joints	**T**	Touch between fingertips

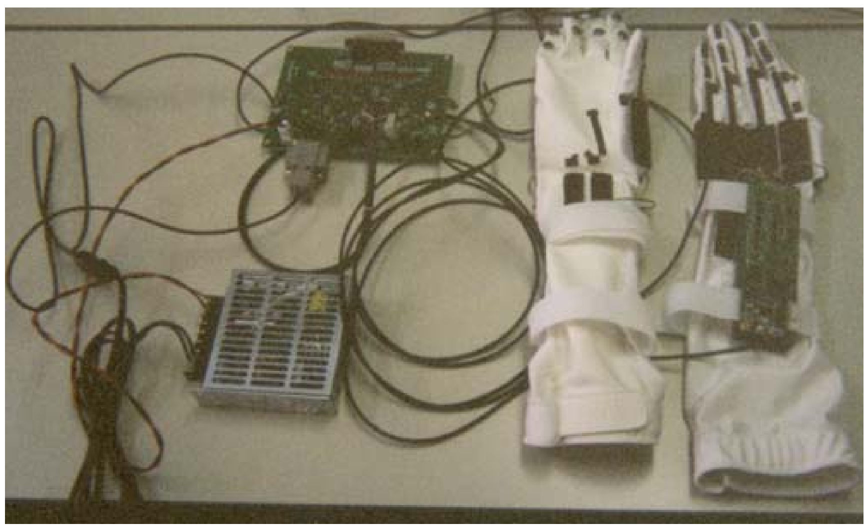

Figure 9. *Prototype of StrinGlove.*

4. EVALUATION

Ten sign experts including four deaf evaluated the beta prototype. All subjects were women. Figure 10 shows several snaps from the trial.

The subjects compared comfortableness of the prototype in comparison with CyberGlove. The subjects were asked to wear both gloves and to express several words. After the trial, the subjects were interviewed. All subjects claimed that they could play with the prototype without any physical fatigue although they cannot play with the CyberGlove for a long time, because the prototype allows subjects to bend their finger without hindrance. This claim ensures the comfortableness of the prototype.

The accuracy of coding function of the prototype is examined. The subjects are asked to express 48 finger characters with the prototype on, and the sensor outputs are compared with correct notation code of each finger characters. The accuracy of encoding was about 85%. Although two pairs of prototypes in different size are prepared, pinkies of several subjects didn't fit with the prototype. Thus, ill-fitting glove seems lower the recognition rate. Although ill-fitting glove lowered the accuracy, the result shows that the prototype encodes human hand posture in sufficient accuracy.

Additionally, the prototype obtains finger character “ra” (see Fig. 8), which conventional data-gloves cannot distinguish, without any error throughout the trial. This result clears that the prototype utilizing bend and contact sensors to obtain hand posture has clear advantage in comparison with conventional data-gloves.

Thus, the experimental results show that StrinGlove, which is comfortable to wear and has sufficient coding function, has clear advantage in comparison with conventional data-gloves.

Figure 10. *Snaps from evaluation of the prototype.*

5. CONCLUSION

This paper presents an innovative intelligent data-glove named StrinGlove. StrinGlove captures motion of human hand using 24 bending sensors and nine contact sensors and encode given postures by itself. Thus, StrinGlove eases to develop sign information system and any virtual reality system. Additionally, the simple structure of StrinGlove allows cutting the cost of the glove into reasonable price and makes itself washable. Therefore, the authors believe that StrinGlove accelerate development of commercial sign information systems and virtual reality systems.

Acknowledgements: The authors appreciate for warm support of Fujita Corp. (JP), Digital Research Inc. (JP), Data Processing and Research Inc. (VN), TMA Solutions (VN), Polygon Pictures (JP), Matsumura Corp. (JP), and NIF Ventures Co. Ltd. (JP). The authors also thank “FUREAI”, sign language learning club of Sakai city. This research is partly funded by Japan Science and Technology Agency. All patents about Inductcoder® and StrinGlove are pending.

6. REFERENCES

Encoder Technology (2001) A Discussion of Encoder Technology’s Converter and Impedance Detector, http://www.encoder-technology.com/products/amitech/inductcoderwhitepaper.pdf

D Zeltzer and D J Sturman (1994), A survey of glove-based input, *IEEE Computer Graphics and Applications*, **14**, *1*, pp.30-39

K Kanda, Y Nagashima, A Ichikawa, and M Terauchi (1997), A proposal of Standard Labelling System for JSL: Signdex V.1, *Proc. HCI 97*, p.15

T Hanke (2004) HamNoSys &hibar; representing sign language data in language resources and language processing contexts, *Proc. LREC 2004*, pp.1-6

T Kuroda, K Sato and K Chihara (1998), S-TEL an avatar based sign language telecommunication system, *Int, J. Virtual Reality*, **3**, *4*, pp. 21-27

Y Nagashima and K Kanda (2001), Present state and issue of sign linguistic engineering, *Proc. HCI International*, **3**, pp. 387-391

Yohei, Yubimoji –BIG GATE–, http://www2.incl.ne.jp/~yohei/