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Applying NISHIJIN Historical Textile Technique for e-Textile

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***Abstract*— The e-Textile is the key technology for continuous ambient health monitoring to increase quality of life of patients with chronic diseases. The authors introduce techniques of Japanese historical textile, NISHIJIN, which illustrate almost any pattern from one continuous yarn within the machine weaving process, which is suitable for mixed flow production. Thus, NISHIJIN is suitable for e-Textile production, which requires rapid prototyping and mass production of very complicated patterns. The authors prototyped and evaluated a few vests to take twelve-lead electrocardiogram. The result tells that the prototypes obtains electrocardiogram, which is good enough for diagnosis.**

I. Introduction

The rapid increase of health care cost is the universal problem for all advanced societies. The home medical care based on ambient health monitoring [1] is expected to be the silver bullet to overcome the problem. The ambient health monitoring requires bio-signal sensors embedded into fabric items for daily living, such as sofa, bed, and cloths.

The e-Textile [2] is the key technology for continuous ambient health monitoring. Although many researchers proposed e-Textile prototypes and applications, almost all of them have not been realized as commercial products. Just a few commercial e-Textile producers [3] are available.

In order to boost up academic or commercial prototyping of e-Textile bio-signal sensors, and commercialization (mass production) of the successful models among the prototypes, a commercial factory available for simultaneous production of prototypes and mass products, called mixed flow production, is indispensable.

At the same time, the production process should be available for complex designed textiles. Unlike conventional pictorial designs, circuit patterns of e-textile care number of contacts, patterns of hidden layers, and other additional conditions to change electric nature of the circuit.

This paper proposes to utilize NISHIJIN, a historical textile production process for e-Textile production, and prototyped e-Textiles for electrocardiogram (ECG) sensing.

II. Why NISHIJIN?

NISHIJIN [4] is the name of the northwestern district of Kyoto city, where the western military base (NISHI-western, JIN-military base) was placed during the ONIN civil war (1467-1477). The origin of NISHIJIN-ORI textile, however, dates back to origin of city of Kyoto, which is founded as the capital of Japan in 794 A.D. After the civil war, textile technicians gathered around NISHIJIN district and restarted production of high-quality silk textiles. The NISHIJIN brand was established in 1548, when the thirteen textile technicians were offered the official posts from ASHIKAGA- shogun regime as the monopoly on silk textile in Kyoto.

Disruptive innovation came in 1872 when NISHIJIN introduced Jacquard loom and the flying shuttle from Europe. Since then, NISHIJIN continuously using mechanical Jacquard loom combined with computational replacement of punch card named "direct Jacquard loom," and putting-out production system. Although both the loom and the system are rather old-fashioned, they provide mixed flow production of very complicated weave textiles capability for NISHIJIN.

The special weave techniques named TSUZURE (Fig. 1) and NUIWAKE make NISHIJIN suitable for e-Textile production. The techniques illustrate almost any pattern by sewing warps by multiple single colored woofs. The techniques enable NISHIJIN to illustrate a wire of electric circuit pattern on an e-Textile by a single conductive yarn. Thus, NISHIIN has potential to produce e-Textiles with good electric nature.

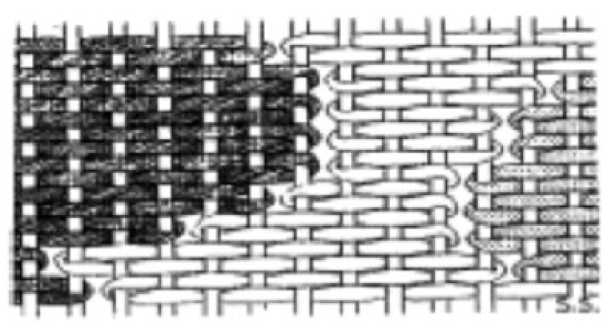

Figure 1. Weave of TSUZURE [5]

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III. Prototyping ECG underware

A. *The first prototype*

The authors first developed single lead ECG as shown in figure 2. The prototype was developed to know the technical potentials.

The authors used the standard polyvinyl chloride yarn as the non-conductive yarn. The conductive yarn is made of six stainless steel fibers of 40 micrometer through basket stitch yarn production process. The basket stitch produces flexible and stretchable yarn out of stainless steel fibers. Three concentric circles, one of the most challenging patterns to weave, was illustrated through TSUZURE, each circle consisted of a single conductive yarn.

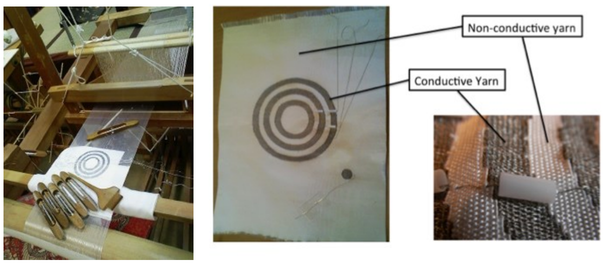

Figure 2. The first prototype

The authors developed a simple ECG amplifier circuit with a differential amplifier and a band pass filter. A subject attached the developed e-Textile to place the center of the concentric circles at V4 of twelve lead ECG as shown in the left of the figure 3. The obtained ECG signal, shown in the right of the figure 3, tells that the textile could collect ECG signal properly.

Snapshot of evaluation

Obtained ECG

Figure 3. Evaluation of the first prottotype

The first prototype reveals the potentials of NISHIIN for e-Textile development, as the prototype picks up ECG signal without any gels between the electrode and the skin. However, the stainless-steel conductive yarn makes the final textile uncomfortable to wear.

The first prototype was developed through full hand-made TSUZURE production process. The process is suitable for initial prototyping without rigid design. Although the process itself was not applicable for mass production, to transfer the developed design for automated loom production is not difficult.

B. *The second prototype*

To evaluate whole production process to produce commercial e-Textile, the authors designed and developed a twelve-lead ECG vest.

The authors used the standard polyester yarn as the non-conductive yarn. The conductive yarn was made of three silver-plated nylon fibers, which is developed for static electricity removal but widely used for antibacterial socks.

The prototype was developed through NUIWAKE technique, which create TSUZURE like textile on Jacquard loom. Thus, again, each electrodes and connecting wire from electrode to the connector was consists of a single conductive yarn. Figure 4 shows the developed electrode.

Figure 4. Electrodes of the prototype

Figure 5 shows the developed prototype vest. The prototype has four square-shaped electrodes for limb leads and six small electrodes for precordial leads. The vest is designed to be tightening up by Velcro tape around the neck and the waist of the user.

Figure 5. The twelve-lead ECG vest

All the conductive yarns are terminated at the bottom of the vest by snap buttons or connectors as shown in figure 6.

Figure 6. Connector part

The prototype was evaluated using commercial electrocardiograph. Subjects measured ECG using the prototype connected to Labtech EC-12R/S twelve channel resting ECG system [6] (figure 7). Obtained ECG is compared with ECG taken by the reusable electrodes provided by Labtech. The obtained signal was compared on Labtech Cardiospy Lite software. All the filters (Mains, Baseline, Smoothing) of the software were set.

Figure 7. Labtech EC-12R and its original electrods

Figure 8. A snapshot of evaluation

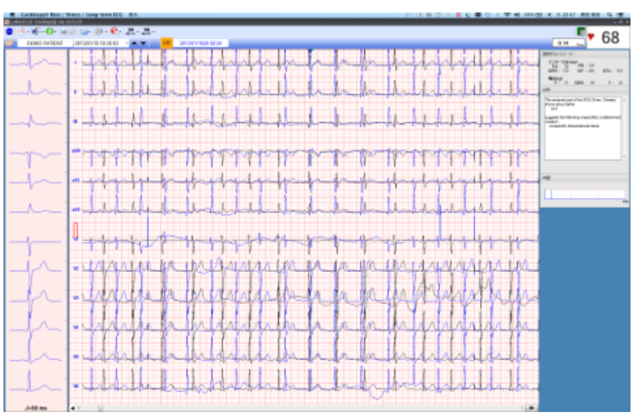

Figure 9. Resulting ECG

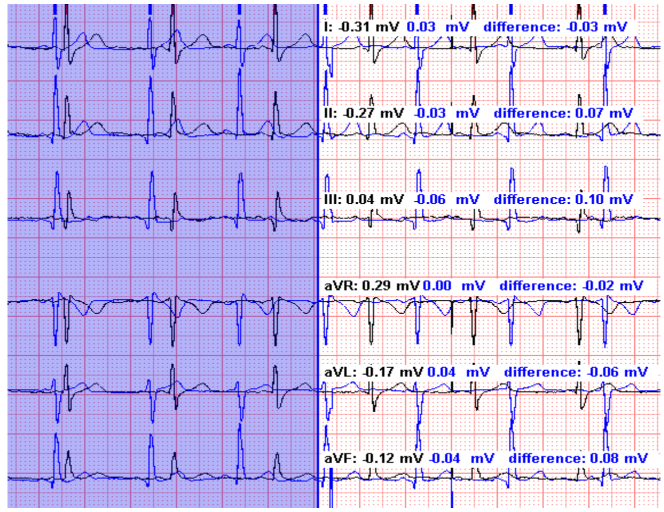

Figure 10. Zoom up resulting ECG (limb leads)

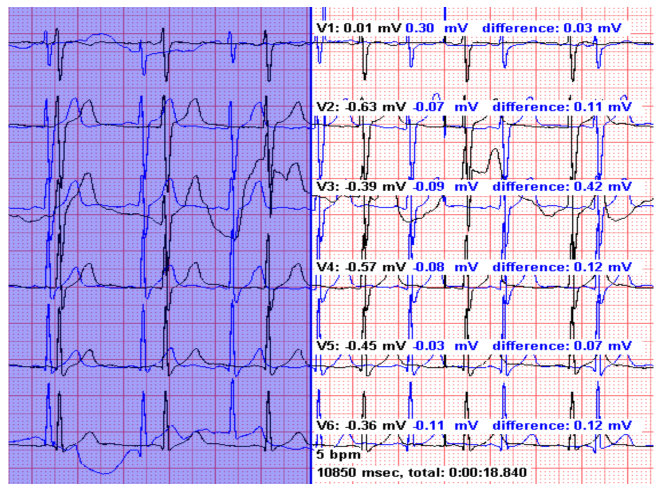

Figure 11. Zoomup of resulting ECG (precordeal leads)

Figure 9 shows a snapshot of ECG signal of a subject taken by the prototype and the original electrodes. Figure 10 and 11 shows the part of taken signal and evaluation of the difference of two obtained signals. The blue colored signal is the one taken by the prototype and the black colored signal is the one taken by the original electrodes.

The snapshot clearly shows that there are almost no differences between two obtained signals. The developed prototype obtains good-enough ECG for diagnosis.

The tests are performed rainy autumn days and dry winter days. The subjects putted the electrodes and the vest without using ultrasound gel. On the dry winter days the e-Textile vest could not collect the ECG signals initially. However, by simply giving small amount of tap water to wet the electrodes of the vest, the vest could collect the ECG signals. Once the vest start collecting the ECG, the vest collect signal for several minutes.

The authors evaluated several patterns of Velcro tape to tighten the vest. Especially precordial electrodes in the center of the chest, V1 and V2, or near the edge of the vest, V6, sometimes could not collet the signal from time to time in some patterns for some subjects.

IV. Discussions

The twelve lead ECG vest prototype will be supreme tool for cardiovascular disease care from preventive stage to chronic stage.

Although AHA/ACC guideline recommend to record twelve lead ECG for management of patient with ST-elevation myocardial infarction, ambulatory condition doesn't allows emergency medical technician to place ten electrodes for precise position to monitor ECG for initial diagnose. The twelve lead ECG vest coupled with wireless ECG sharing solution [7] will ease the technicians to take ECG, and, consequently, will increase the survival rate.

The vest enables patients to monitor their own twelve lead ECG under daily activity for longer period to capture pre-heart attack symptoms, which conventional 48-hours monitoring using Holter ECG. The vest also ease chronic patient to monitor their cardiac activities at home, and promote home healthcare and home cardiac rehabilitation [8]. Additionally the vest will promote cardiac rehabilitation in hospital too. Once the vest is coupled with sensor network to track the position of the patient [9][10], hospital information systems record ECG with activities of patient and assess the condition of the patient semi-automatically. Thus, the semi- autonomous cardiac rehabilitation as shown in figure 12 will be enabled

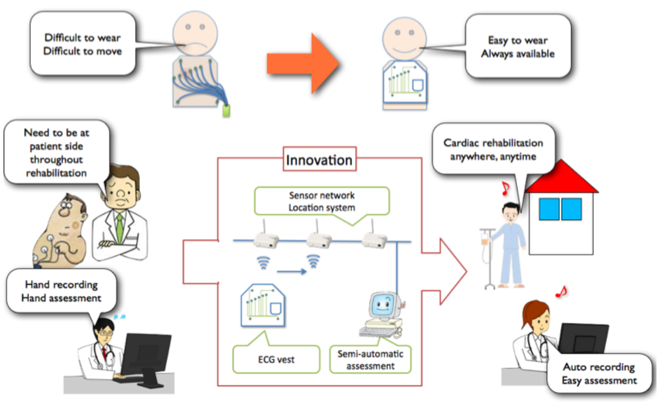

Figure 12. Road to semi-autonomous cardiac rehabilitation

The evaluation of the prototype indicates two important issues; the e-Textile developed through NISHIJIN has well enough electric nature for bio-signal sensors, and the properness of the design defines the performance of the e-Textile products. These findings clearly support the authors' initial hypothesis; the production process should be available for mixed production of complex weave textiles.

Whole process of the prototyping ECG vest, discussed in this paper, clears that NISHIJIN provides quite flexible platform for textile prototyping and production. Additionally, the special weave techniques of NISHIJIN provide good electric conductivity for e-textile development.

The flexibility and the quality of NISHIJIN enable us to produce wide variety of high-quality e-textiles. The wide variety of textile bio-signal sensors embedded into our daily living environment coupled with wireless ubiquitous sensor networking technique will provide us ambient health support environment for healthy lifestyle.

V. Conclusions

This paper proposed to apply NISHIJIN historical textile production process for e-textile production, and evaluated through prototyping process of twelve-lead ECG cloth.

NISHIJIN production process is suitable for e-textile prototyping and production, and its outstanding weave technologies provide high electric quality on its product.

The historical textile technology boosts up innovation of the new digital technology. NISHIJIN lets us create ambient health monitoring for coming aged society.

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