



Textile Wearables – the Japanese Landscape -

Masahito KAWAMORI

Keio University



Textile Wearable Sensors

- Textile manufacturers are now introducing “smart textiles” into the market
- These smart textiles can be used as sensor devices to collect bio-data such as temperature, heart-rate, etc.
- Smart textiles enable textile wearable sensor devices and open many new applications and services
- Some of them are already in use in the market, especially for monitoring health level and workplace safety



CEATEC 2016

- CEATEC (Combined Exhibition of Advanced Technologies) is an annual trade show in Japan. It is regarded as the Japanese equivalent of Consumer Electronics Show (CES). It is Japan's largest IT and electronics exhibition and conference.
- It was held on 4-7 October this year
- CEATEC provides a platform for companies and organizations from all over the world to showcase their cutting-edge products, services and technologies.





Smart Textile at CEATEC 2016

- At the recent CEATEC 2016 (5 October) held near Tokyo, Japan, there was a session titled “Advanced Textile materials that contribute to Smart Society”, organized by the Japan Chemical Fibers Association.
- There were two companies (Toray and Toyobo) presenting their “smart textile” garments, using textile wearable sensors
 - Wearable Sensing Device <hitoe> that allows Bio-Monitoring by just wearing garments (Toray)
 - Smart Textile: Bio-info measurement using Smart Sensing Wear (Toyobo)
- This event demonstrates that the textile industry as a whole is promoting textile sensors as a promising area



<hitoe>

- Toray and NTT developed the textile wearable sensor called <hitoe> (pronounced “hee-toe-ay”) in 2014.
- World’s first textile wearable sensor
- Made up of nano-fiber, whose width is 1/7500 of a human hair
- Can have very close contact with the skin

[Video](#)



“Smart garment” using hitoe





Smart Garment for women

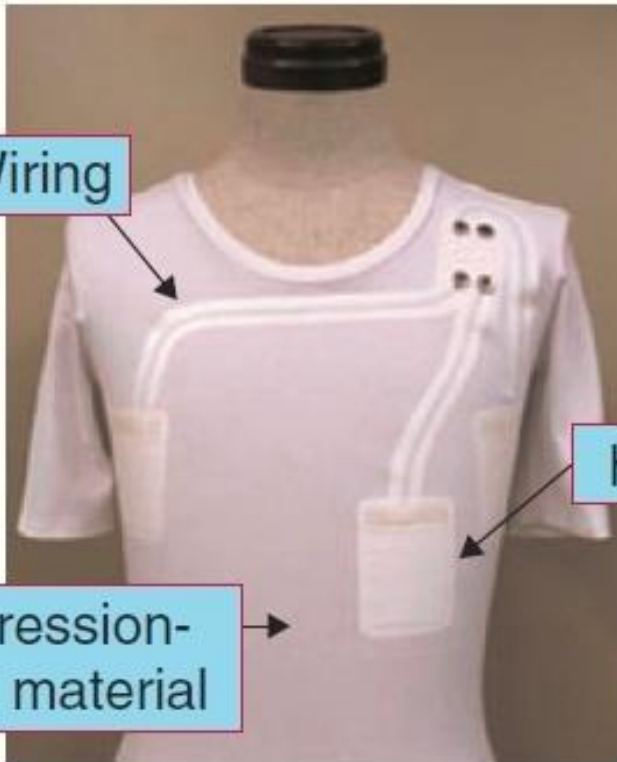


- GOLDWIN, Inc announced the launch of sports bras based on <hitoe> in on September 18, 2015



Original design of hitoe garment

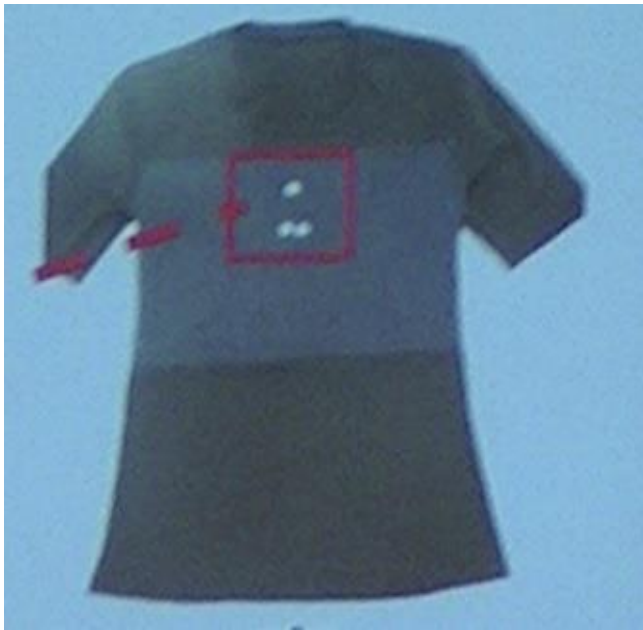
- Sensors and transmitter was put in front of the shirt





Current design of <hitoe>

- The positions of wiring, sensor device, and the transmitter have been changed



Front of the shirt



Back of the shirt



nano-fiber based textile sensor





<hitoe> sensor

- Electrode made up from combining nano-fiber and conductive polymer called PEDOT:PSS (*=poly(3,4-ethylenedioxythiophene) polystyrene sulfonate*) has high electricity conductivity and durability -> suitable as a wearable sensor
- Can make accurate measurement of biodata
- High affinity with water and sweat, which provides comfort in wearing the textile



Durability issue

- Clothes and garments are worn for many hours and washed many times
- How can smart textile remain electrically conductive after worn and wash?
- Mixing the fabric with conductive polymers is usually not enough
- With textile made of normal polyester fibers, large “gaps” between fibers -> the conductive polymers get easily taken out after the fabric is worn or washed.



Durability of <hitoe>

- In <hitoe>, electricity conductive polymers enter and fix themselves in position within the gaps left between the nanofibers.
- Thus the conductive polymers don't get separated easily but stay on the fabric even after it has been worn for many hours or washed repeatedly in garment form.



Transmitter for <hitoe>





Data transmission

- A garment (e.g., a shirt) with <hitoe>, and the transmitter device, will enable the continuous collection of heart rate and EEG data, etc.
- The collected data can be sent to a smart phone
- Can collect bio-data such as ECG, EMG, almost subconsciously
- Collection and analysis of such data
- Visualization of changes in physical conditions as well as emotions



Comparison with other wearables

- Electrolytic fiber => insufficient contact with skin surface (= more noises)
- Conductive Paste => rash (implies difficulty in long-term use)
 - Textile has an advantage over watches and wrist band in long-term use?
- <hitoe> (or textile wearable) is suitable for long-term wearing (?)



Current usage

- Currently marketed for personal uses
- Combination with Bluetooth LE, and smartphone is common
- Heart rate, EEG, EMG data
- Cloud-based development is to be initiated in 2016

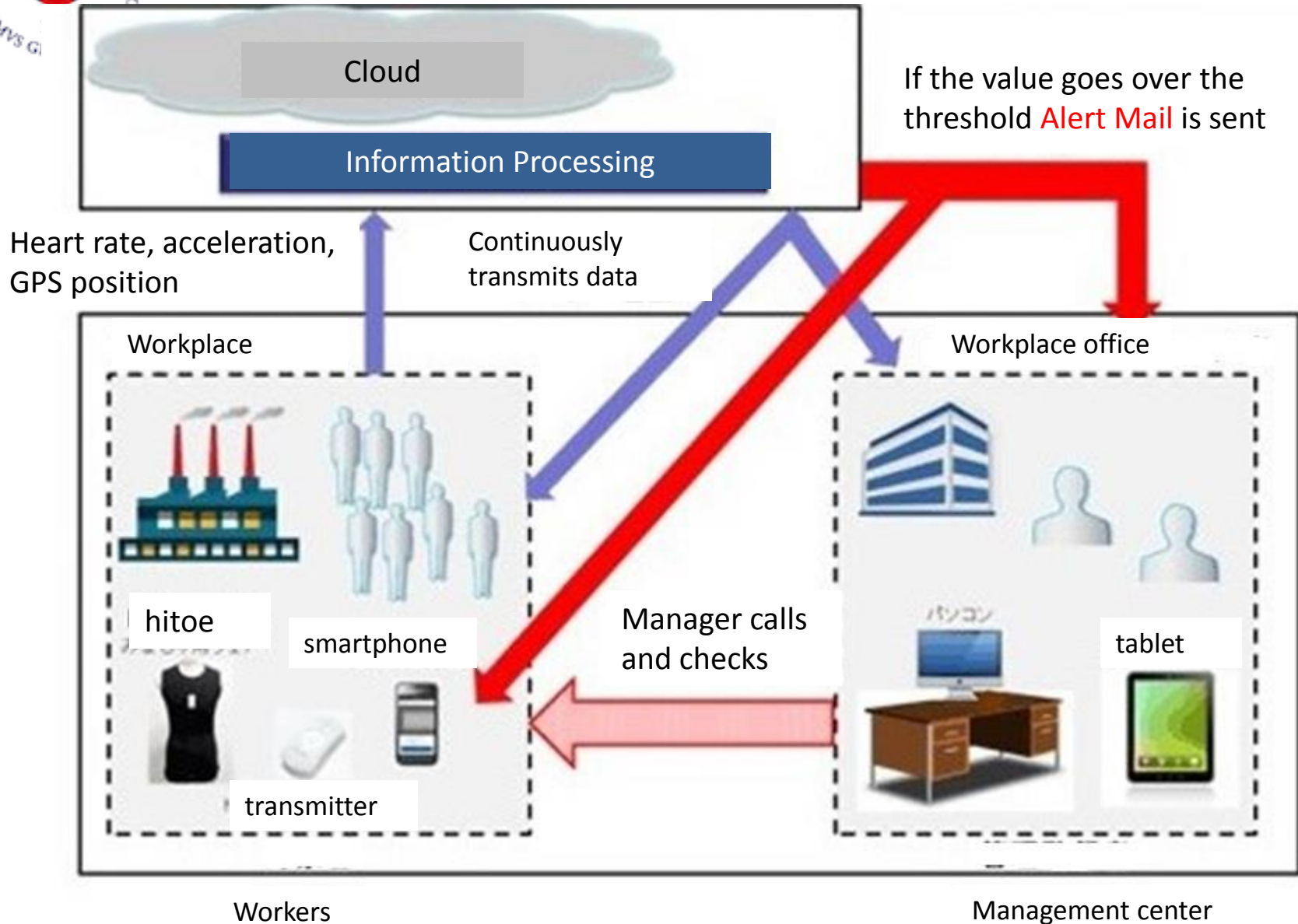


Monitoring at Work place

- <hitoe> is being used for
 - Monitoring of workers at a workplace (such as factories or construction)
 - Heart rate, body acceleration, GPS positions are continuous monitored and transmitted to Cloud
 - The Data is analyzed and reported back to a management center
 - If there is any outstanding issue, manager will call the workplace and check the workers



Monitoring at Work place (2)





Collected Data

- The workplace monitoring is done using the following collected data
 - *heart rate*
 - *Heat exposure level*: (measured according to the criteria set by the Ministry of Health, Labour and Welfare)
 - *Work intensity*: (by Karvonen method)
 - *Emotional stability*: (by inter-beat interval;
RRI=short -> stressed; long-> relaxed)
 - *Fall*: acceleration sensor
 - *Energy consumption*: (equation proposed by American College of Sports Medicine)
 - *Position*: GPS (of a smart phone)



Testbeds and Use cases

- A Major Airline company (Summer 2015)
- Construction company (Summer 2015)
- Toray factories (Okazaki, Ehime, Tsuchiura, Nagoya, Ishikawa, since Summer 2015)
- More expected in factories, mines, construction sites, municipality, etc.
- Drivers, and office workers



Further developments

- Monitor for Health hazard of a small group work force in a potentially danger-prone work place, esp. for heat exposure
- Offices: Management of workplace against excessive workload and mental health problems
- Hospitals: monitor the elderly -> lighten the workload of healthcare workers
- : Early detection of health hazards



Other approaches

- NTT Group co-developed <hitoe> with Toray
- They are using <hitoe> for different applications from those of Toray



Monitoring of athletes

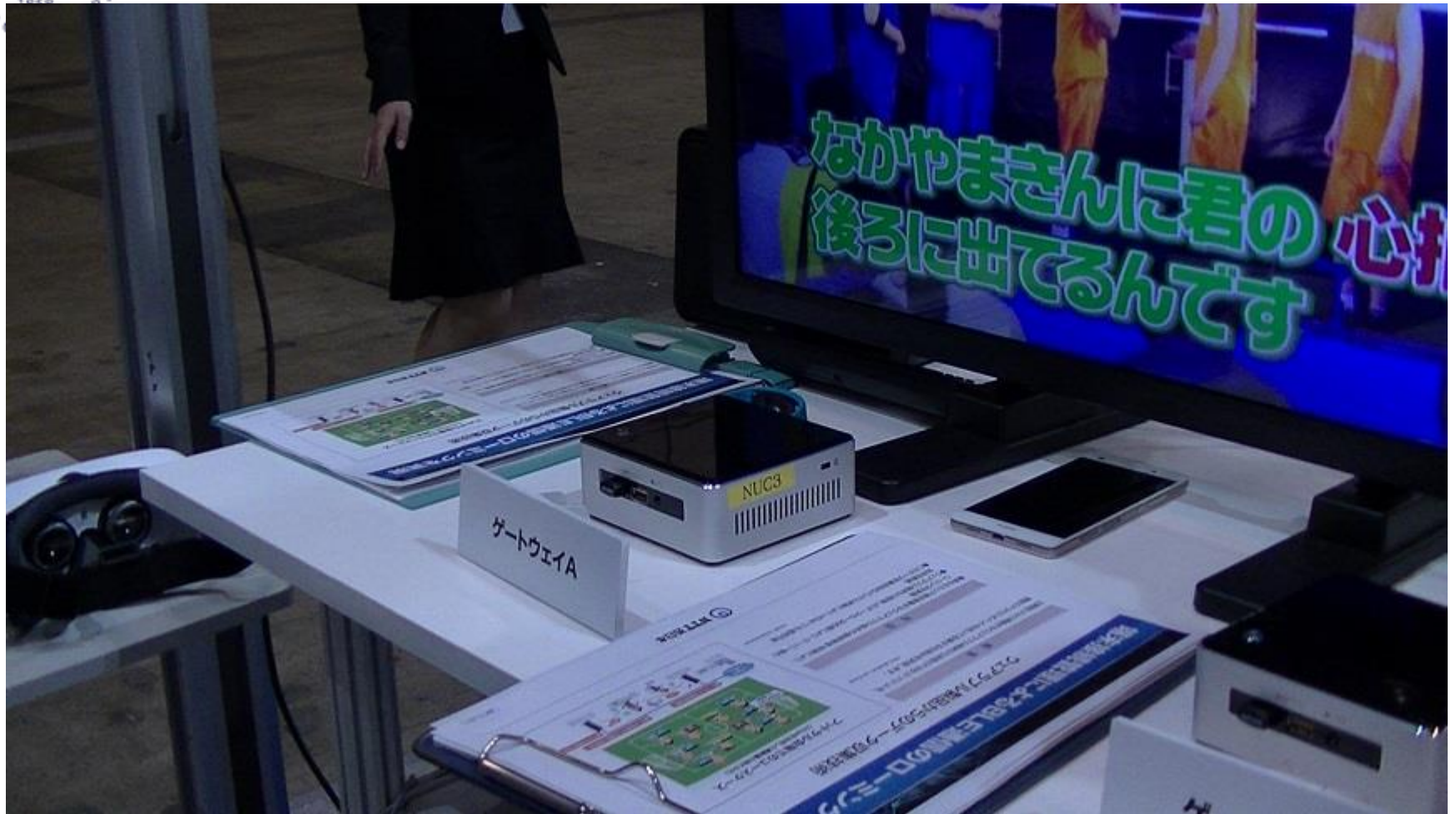
- NTT West is proposing to use <hitoe> system (with transmitters and gateways) for monitoring the physical conditions of athletes
- To visualize the subconscious use of body functions and coordination
- To be utilized in training
- Target for sports science and training for Tokyo Olympics 2020.





ゲートウェイB

C3fit IN-pulse
hitoeトランスミッター-01

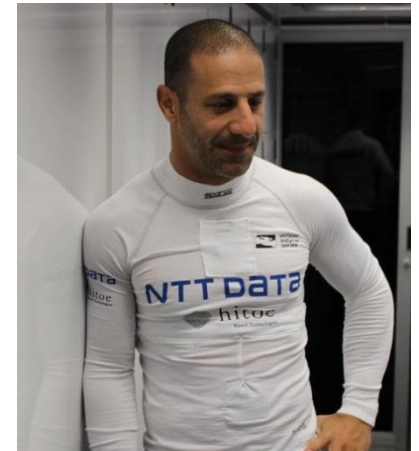




Indy Car Series

- Chip Ganassi Racing Team as well as Tony Kanaan worked with NTT Data during Indy Car Series (June-August 2015) to monitor the bio-data during driving.
- IndyCar drivers run at speeds of up to approx. 378 km/h, perspiring heavily and experiencing high G-forces and loud noises.
- Despite these challenges, the garment was able to successfully collect bio-data from Mr. Kanaan as he was driving.
- ECG and EMG data were filtered to eliminate vehicle vibration, myoelectric activity and certain types of noise.

[Video](#)





Toyobo

- Toyobo also developed its own Smart Sensing Wear, called “cocomi” (2015)
- a film-like functional material for cloths
- Used for electrodes as well as electric wires of sensors
- Characteristics.
 - Stretchable: can be stretched to roughly double length -> this leads to comfortable wear
 - Thin: about 0.3mm,
 - high conductivity.
 - easily attachable: thermo-compression bonding.

[Video](#)

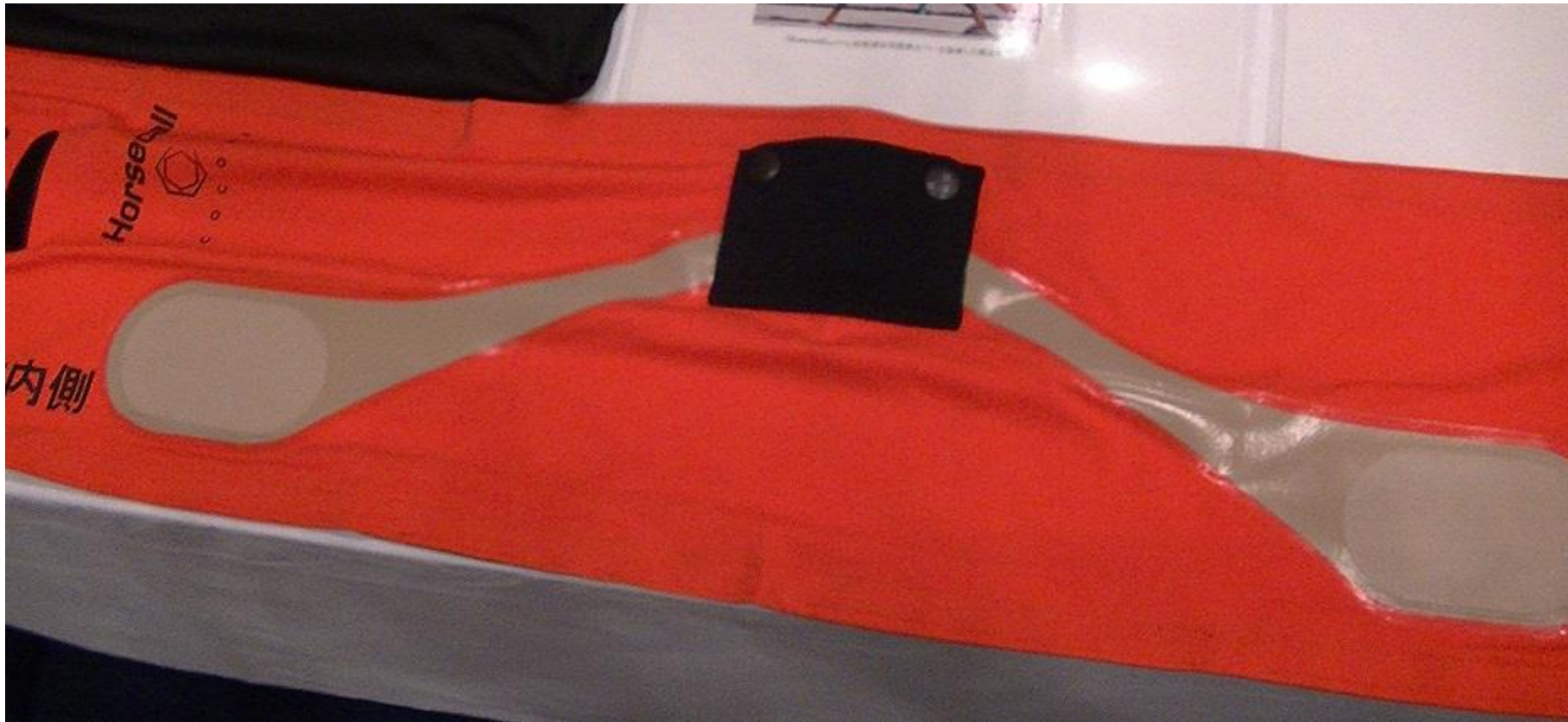


“Cocomi” Smart Wear





Cocomi sensor





Girth cover made of textile sensor



Girth cover

A race horse wearing Horsecall™ Girth cover for heart rate monitoring



Applications of Cocomi

Garment for race horse monitoring

- Hitherto training of race horses has relied on the trainers' experiences.
- The Scientific use of bio-data is expected to improve the effect of training
- Wearable bio-monitoring system will be necessary for that purpose
- Conventional wearable sensor device can monitor the horse when it is at ease or on a tread-mil.
- But could not monitor when the horse is running at full speed, due to the extremely robust movement of the horse
- The textile wearable sensor device “cocomi” was chosen for this purpose (July 2016)



Other expected applications

- Sleep monitoring
- Relaxation monitoring
- Toyobo has created a consortium called “Active For All”, which promotes active life through culturilization of sports
- Members include major hospitals, universities, and large corporations such as Hitachi and Panasonic.



Food for thought

- How can these measurement data can be shared and interoperate?
- Do we need standardized criteria for bio-data, e.g., “relaxed-ness” can be defined in several different ways?
- How can these data be combined with other bio-data from different devices?
- Even though they are not “medical devices”, if they are used along with medical devices, there may be needs for standards of quality, etc.



- Thank you.