21CSE429T –
DATA SCIENCE FOR INTERNET OF THINGS

Unit V –
Case Studies in IoT Healthcare

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UNIT 5

- ***Unit-5 - Case Studies in IoT Healthcare 9 Hrs***
- *Big Data Analytics for Healthcare and Cognitive Learning* ***T2-Ch7***
- *Machine Learning for Big Data in Healthcare Applications* ***T2-Ch7***
- *Healthcare Problems and Machine Learning Tools* ***T2-Ch7.1***
- *IoT-based Healthcare Systems and Applications -* ***T2-Ch7.2***
- *Emotional Insights via Wearables –* ***T3-Ch 38***
- *Structural Health Monitoring -****T3-Ch 40***
- *Home Healthcare and Remote Patient Monitoring -* ***T3-Ch 41***

Healthcare Problems and Machine Learning Tools

- Outline
- The chapter deals with predictive analytics in healthcare and disease detection
- Review on IoT-supported healthcare systems
  - healthcare monitoring
  - Physical exercise promotion system
- Analytic solution systems using machine learning techniques supported by clouds, mobile devices and IoT resources are Presented later section

Healthcare and Chronic Disease Detection Problem

- Increasing Aged Population in 2050 -22% of population , in Japan 30%
- Shortage of medical facilities and outage
- One possible solution is incorporation of both wearable computing and IoT technology into health monitoring services. Compared to typical health care problems such as population ageing, the care for chronic disease becomes more and more important nowadays.
- The funds spent on treating the chronic disease becomes more
- 18% of UD GDP in this
- Mostly 80% saving of elderly is spent in treating the medical problems
- Life style changes, urbanization invites many chronic disease

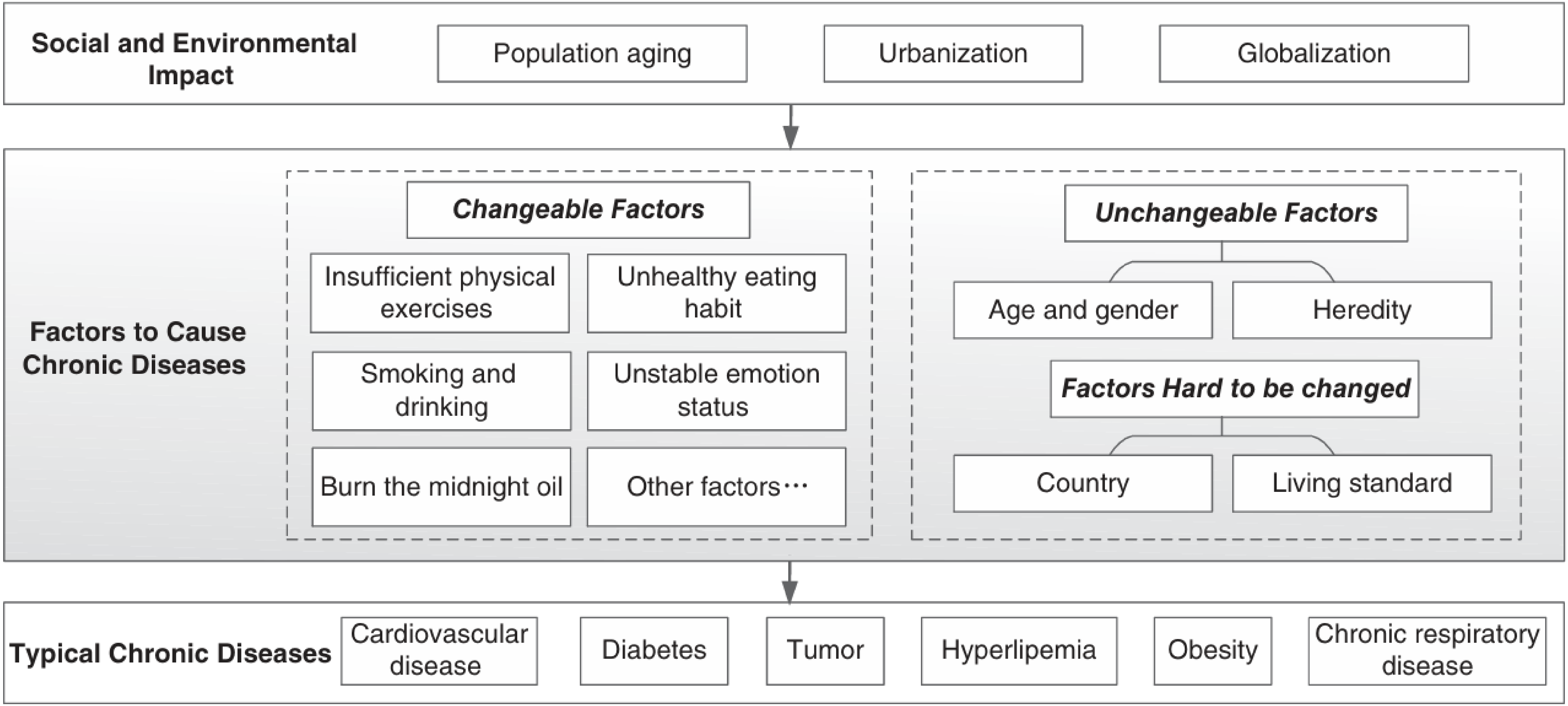


Figure 7.1 Factors that affect the detection accuracy in detecting chronic diseases.

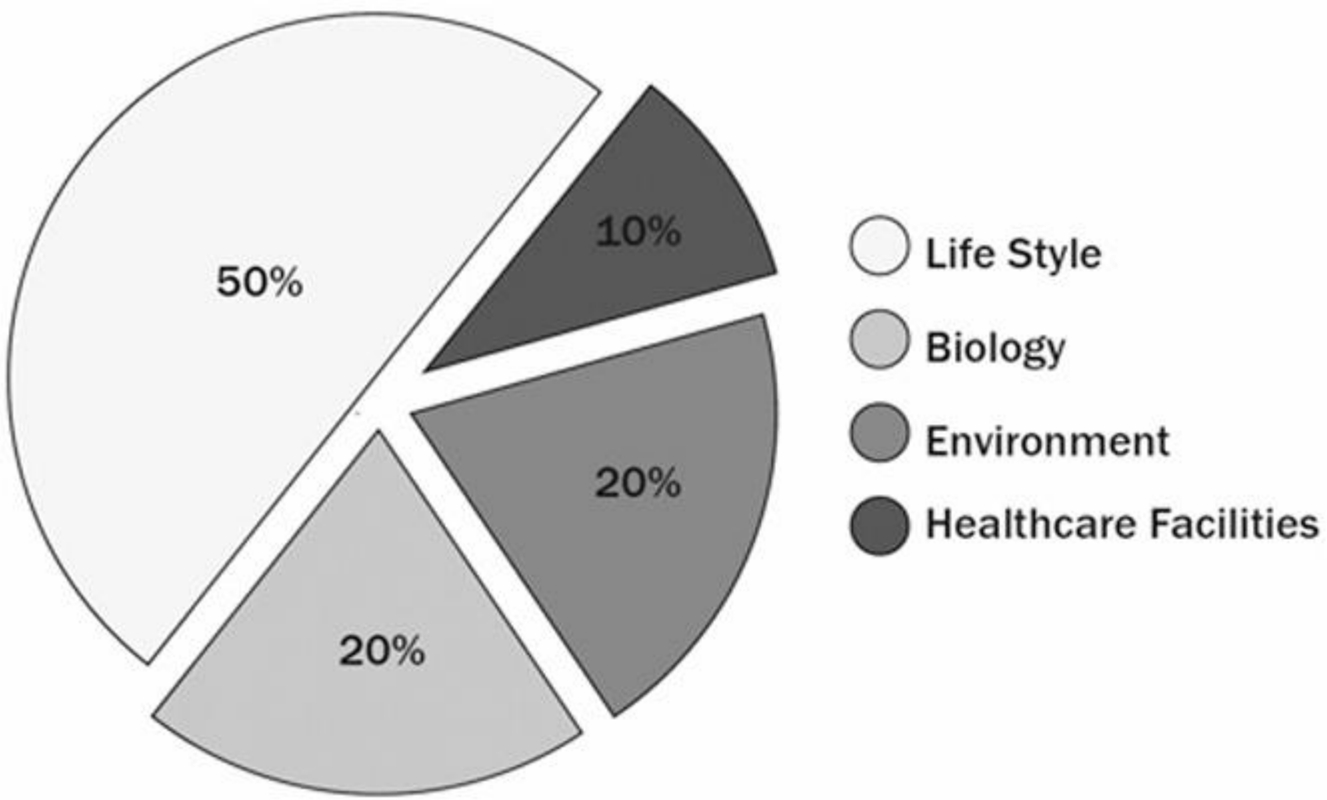


Figure 7.2 Determinants of health (statistics from centers for disease control in 2003).

- According to who report the determinants of health care

Software Libraries for Machine Learning Applications

Table 7.1 Commonly available machine learning toolkits.

Toolkit or Framework, Language, Website of Developer	Short Description of Functionality and Capability
Scikit-learn, Python, http://scikit-learn.org/stable/	Built with NumPy and Matplotlib, provides simple and efficient mathematical tools for data mining and big data analysis
Shogun, C++, http://www.shogun-toolbox.org/	SWIG interfaces enable communication between C++ and target languages Python, Octave, R, Java, C#, etc., focusing on SVM kernel functions
Accord, Aforge.net,.NET, http://accord.codeplex.com/ http://www.aforgenet.com/ framework	Applied for audio/image processing in face detection and image stitch-on SIFT, supporting real-time mobile computing with ANNs or decision trees
Mohout, Hadoop, https://mahout.apache.org/	Using MapReduce to run on a single or multiple nodes of a Hadoop cluster, greatly improving the data volume
MLlib, Spark http://spark.apache.org/mllib/	MLlib is designed to enable many ML algorithms to run fast on large clusters. It supports personalized ML code design
Cloudera, Hadoop, http://www.cloudera.com/	Provided by Cloudera Hadoop distribution, enabling machine learning models to run on real-time data flow, such as spam email filtering
GoLearn, Go, https://github.com/sjwhitworth/ golearn	Developed by Go with Google to support customized code design with simple tools to extend data structure and source code
Weka, Java, http://weka.wikispaces.com/	Weka is designed for data mining, preprocessing, classification, regression and clustering applications with visualization support
CUDA-Convnet, C++, https://code.google.com/p/cuda-convnet	CUDA is a speed-up toolkit of GPU, while CUDA-Convnet is a machine learning library for ANNs based on using fast GPU clusters
ConvNetJS, JavaScript, http://www-cs-faculty.stanford. edu/ people/karpathy/convnetjs/	An online training service for deep learning, which helps users understand the algorithms intuitively by showing some simple demos
FBLearner Flow, Python, https://code.facebook.com/posts/ 1072626246134461/	This platform reuses many algorithms in different products, by stretching into thousands of customized experiments of simulation. It also offers automatic generation of user interface experiences from Python codes

7.2 IoT-based Healthcare Systems and Applications

- The sensors used in this applications are Body sensor (These applications are Human centric)
- The Health-IOT is going to be a milestone in health care industry
- **IoT Sensing for Body Signals**
- The physiological information is collected from the person using a sensor play a vital role in assessing the physical situation and help doctors in their diagnose
- Because of the users’ demand for mobile medical treatment and health system this becomes necessary (includes challenges)
- Physiological information collecting devices in the applications of the Health-IoT are divided into two large categories,
  - one category collects the physiological information through sensing components integrated on universal mobile devices (GMD: General Mobile Device)
  - Dedicated medical health collecting device (MHS: Medical Health Sensor), which collects health information by designing and integrating one or multiple dedicated health sensors

- The universal mobile collecting devices possess the advantage of low cost as well as convenience in carrying and using. However, they also have disadvantages. For example, the precision of data collection is low and the collected physiological information types are limited.

- A complete Medical Healthcare System (MHS) is often equipped with the following devices or sensors, as shown Figure.

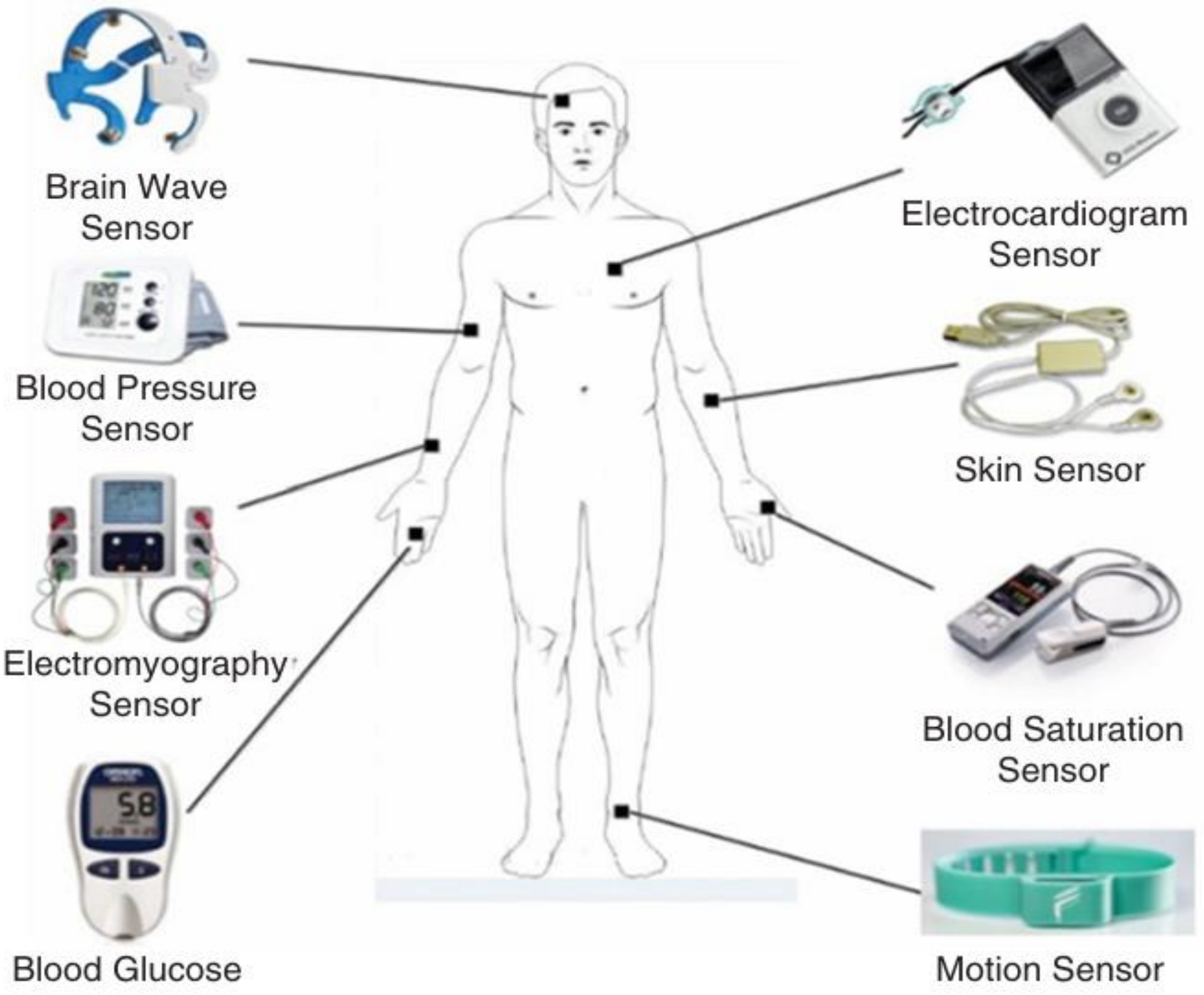


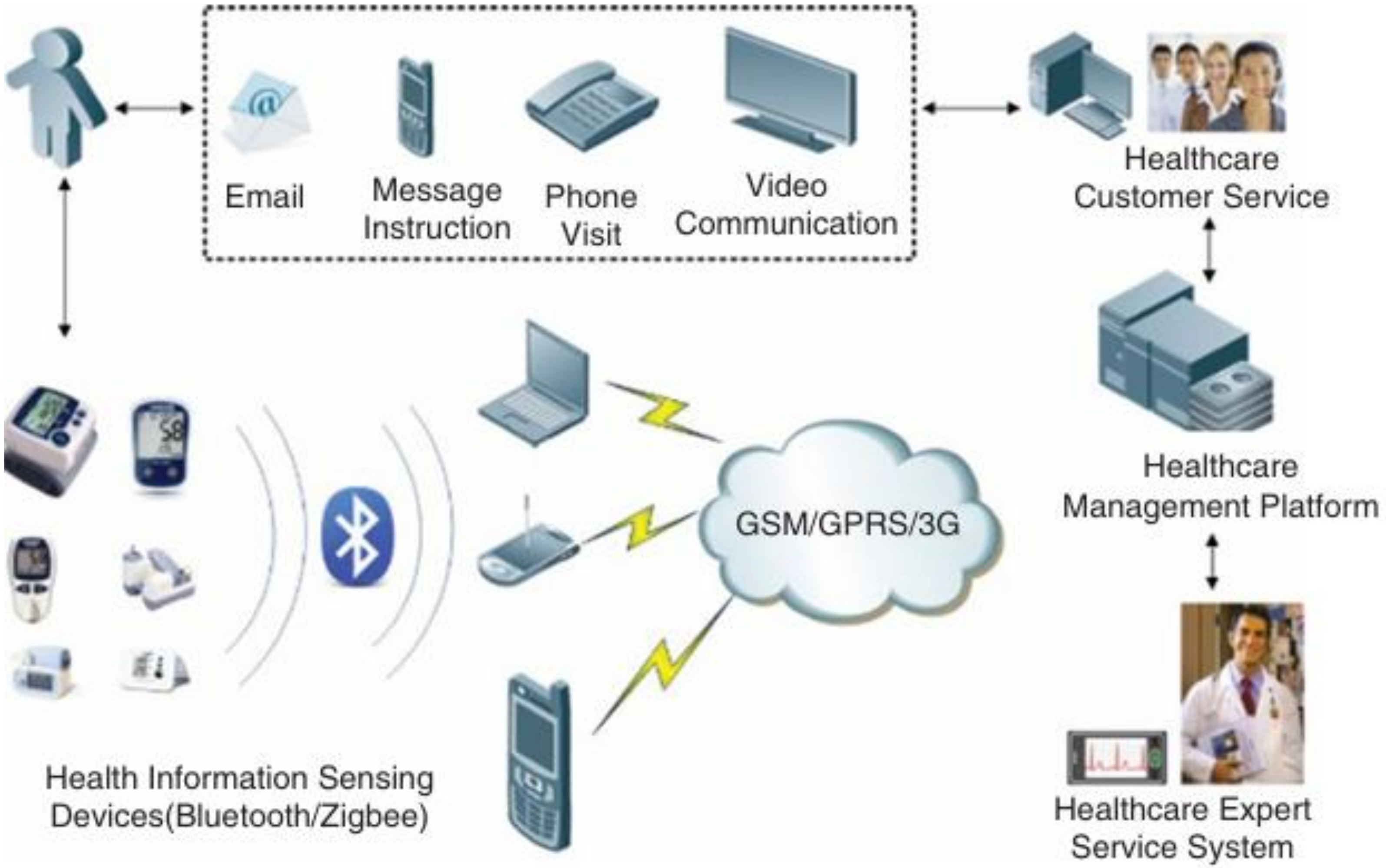
Figure 7.3 The layout of common human body sensors.

Based on MHS, there are following concerns for IoT sensing of body signals:

- Embedded Sensors – High cost and accuracy, insufficient portability and usability
- Wearability: almost all existing medical health collecting devices take wearability as the basic requirement
- Long working time: Crafted to collect data over a longer period so, high power supply capability of MHS
- Stability: MHS still can collect data normally when users are taking strenuous exercise or in extreme environment.
- Low participation degree of users: do not need the intervention of users during the data collecting procedure, and users only need to start up the power source, and the MHS will then start collecting
- Possessing data interim storage mechanism: The size will be relatively small to assist wearability, so data transmission module may not be supported- so a small interim storage with and tiny data transfer module is important

Healthcare Monitoring System

- health sensor, wireless communication and cloud computing became a Eco system for Healthcare monitoring system.



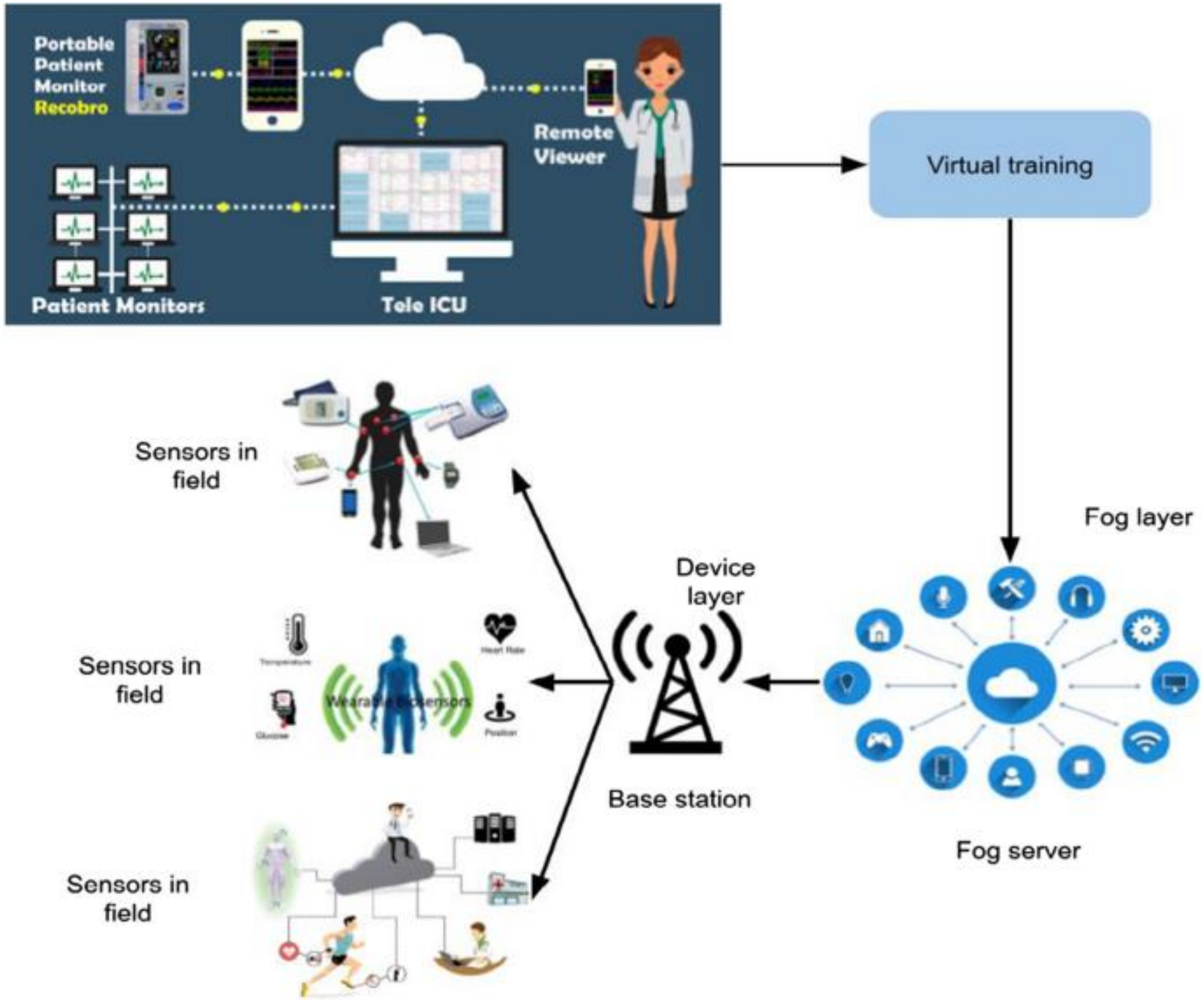
- The data collected by sensors are sent to mobile using Bluetooth
- Data then transmitted to the health management service platform in the clouds.
- The data used by anyone of the Health care monitoring service provided (Ref Table)

Common services provided by health monitoring system

No.	Service Contents	Service method
1	Providing 24 h remote ECG/blood pressure/blood glucose/blood oxygen/pulse/respiration/sleeping	Real-time monitoring service
2	Providing real-time warning of monitoring abnormality	Short message
3	Providing the service of notifying relatives of monitoring information	Short message
4	Providing the service of booking expert consultancy	Video or short message
5	Providing the emergency calling and aid service	Automatic telephone calling
6	Providing the family positioning service	Positioning
7	Regular health assessment report service	Short message or email
8	Regular health promotion care service	Short message or email
9	Regular follow-up service	Telephone
10	Life-long health record management service	Website inquiry
11	User data self-help inquiry service	Website inquiry
12	Providing 24 h consulting hotline service	Telephone

- Health Monitoring Systems into the following categories (6):
- **Health Cyber-Physical System**:
  - Health-oriented mobile Cyber-Physical System (CPS) plays a vital role in existing medical monitoring applications, such as diagnosis, disease treatment and emergency rescue, etc
  - **End-to-end delay is major concern in this model**
  - a framework that combines computer and network monitoring, physical processes, and data analysis to create feedback systems for healthcar**e**
- **Mobile Health Monitoring:**
  - Smartphones are used to collect physiological signals from the human body from a variety of health monitoring devices using a dedicated software
  - Further those signals are transferred to healthcare professional for review. An alert may be given to caretakers if necessary

- **Acute Care for Elders (ACE) Unit**



Typical Health Cyber-Physical System

- Wearable Computing for Health Monitoring:
  - The wearable devices are key in this area, some common functions are

Table 7.3 Several common health monitoring devices.

Name of Device	Monitoring content	Additional functions
Blood pressure monitor	Blood pressure	Recording the historical blood pressure data
e-health Cloud Blood pressure monitor	Blood pressure	Integrating the cloud platform, historical data curves and transmitting distress information
Sunstudy GPS LBS	Tracking the elderly	Mobile phone communication, SOS distress help-seeking alarm and successively dialing three numbers; uploading the tracking position regularly and low-power alarm
Smart blood pressure device	Blood pressure and heart rate	The blood pressure and heart rate monitoring may avoid atrial fibrillation by contacting doctors to obtain the right treatment and know the situations of other patients
jWatch wristwatch	Blood pressure and heart rate	Data analysis and manual calling center
Remote infant monitoring	Monitoring infants	Monitoring infants from a distance and add other guardians

- **Health Internet of Things:**
  - Health IoT is another way to provide a health monitoring service.
  - The mobile sensing, localization and network analysis based on IoT technologies can be used for healthcare.
- **Ambient Assisted Living:**
  - Ambient Assisted Living (AAL) aims at improving the life quality of patients, and it can notify relevant relatives, caregivers and healthcare experts.
  - Monitors the regular signals and warns if it exceeds the threshold value
- **Body Area Network based Health Monitoring:**
  - The main focus here is about the wearable devices
  - Energy consumption and connection to the network are notable areas

7.2.3 Physical Exercise Promotion and Smart Clothing

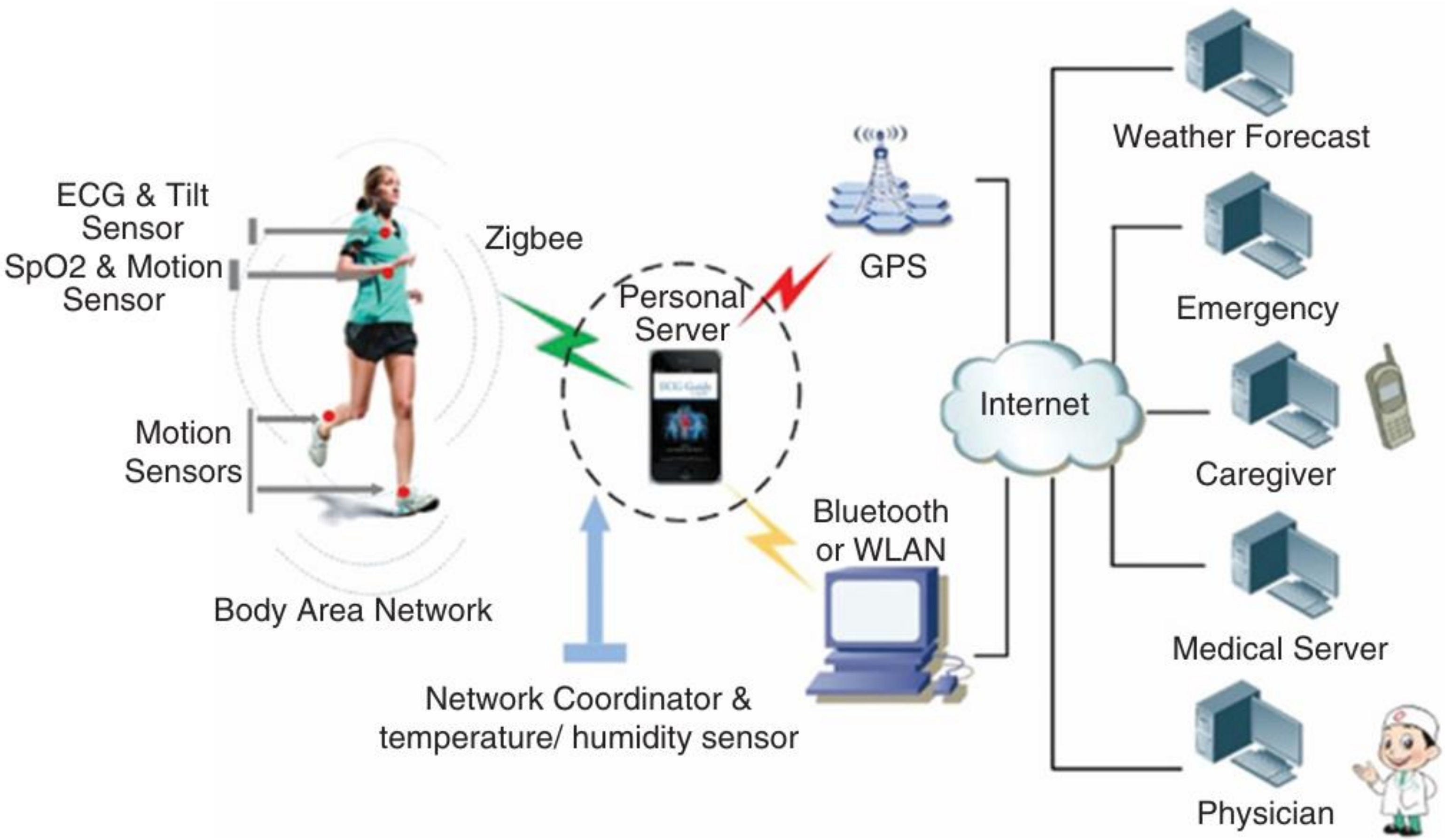


Figure 7.5 Communication architecture of exercise promotion devices.

- The wearable devices can record the amount of exercise, food consumption and sleeping status of users each day, thus effectively supervising and urging them to increase the amount of exercise to keep the body healthy.
- The professional application may sense the performance in the ground and offer the tips and directions
- Coach can keep track players routine

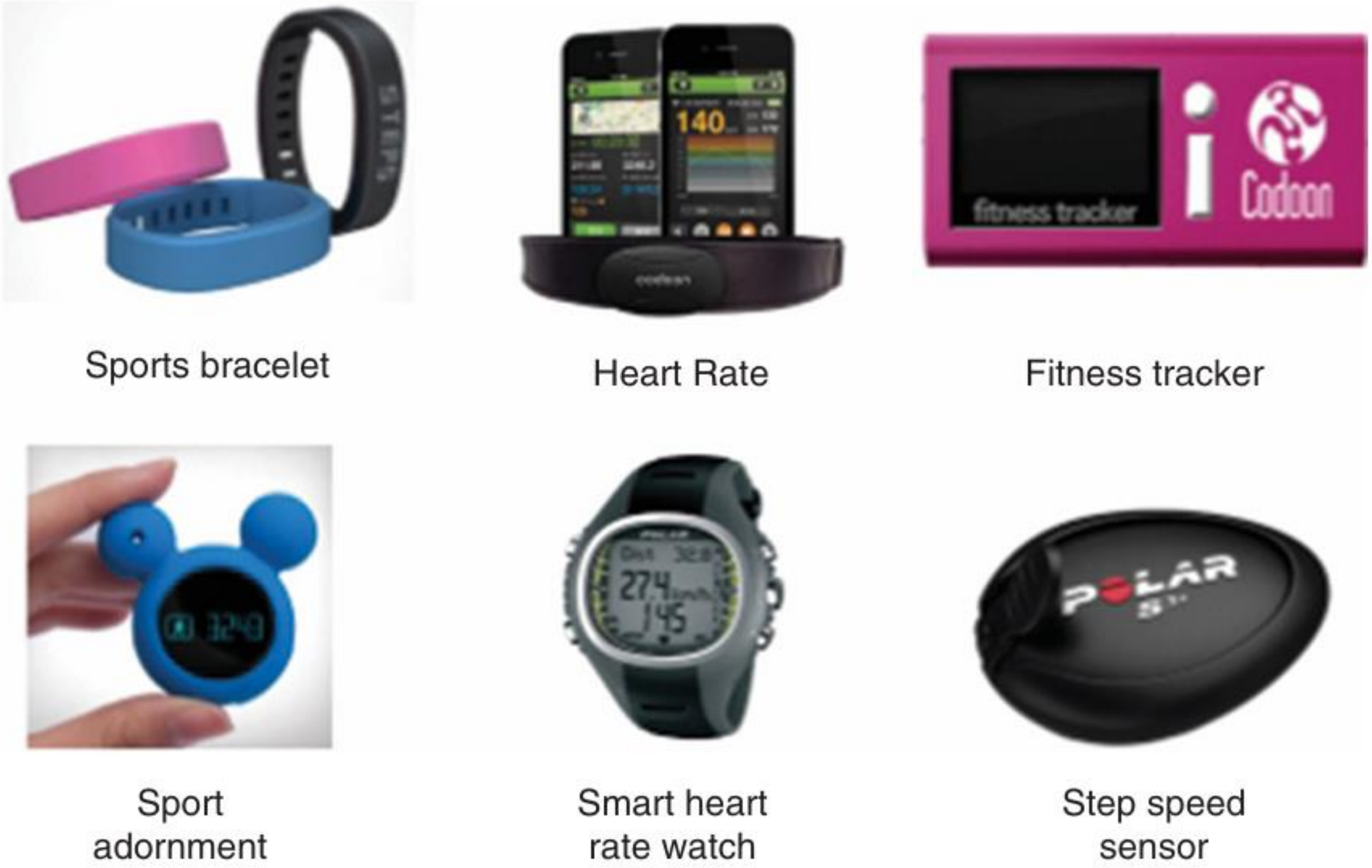
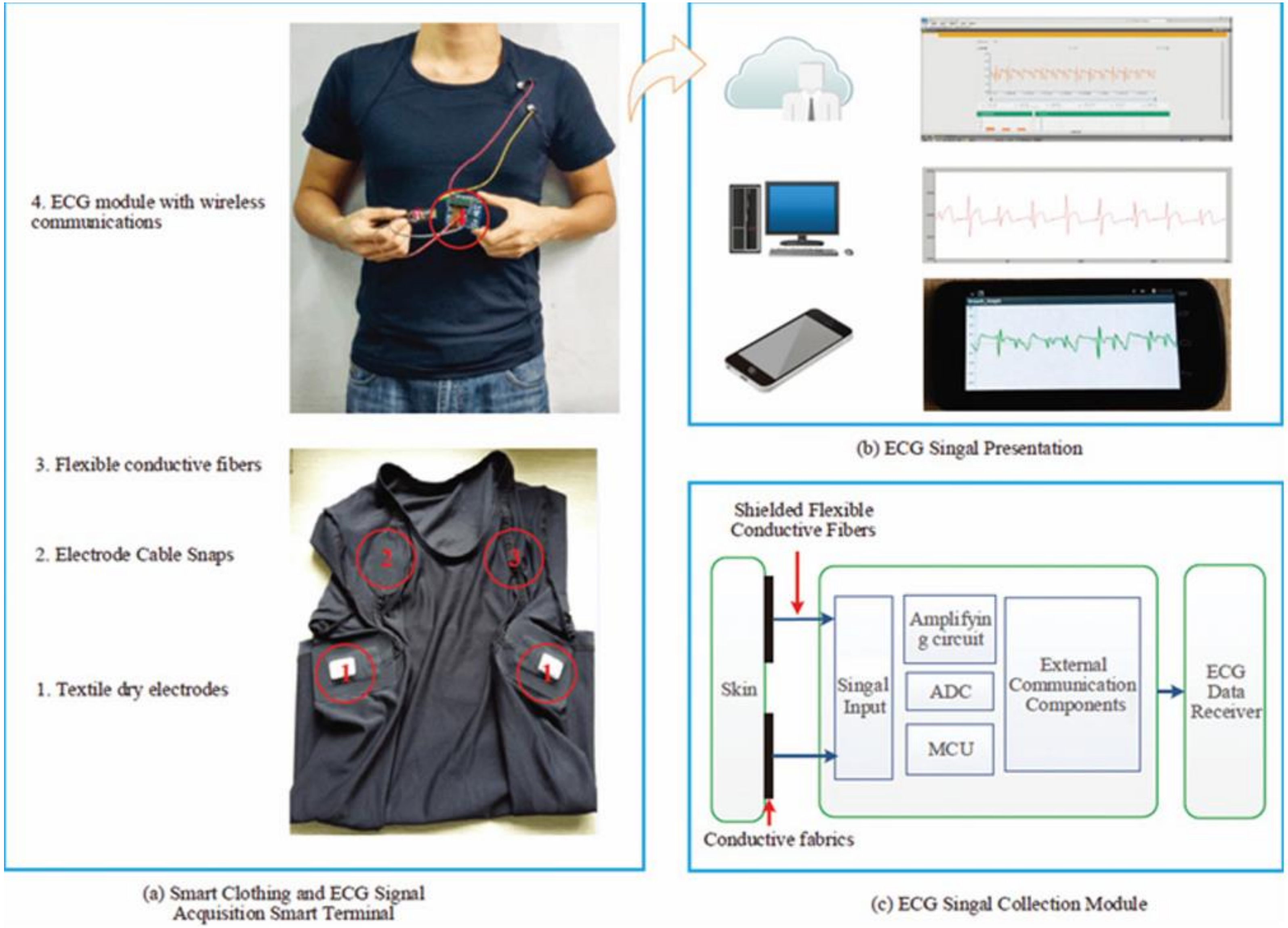


Figure 7.6 Exercise promotion products available in 2016

Smart Clothing Application Software and Testbed Setting

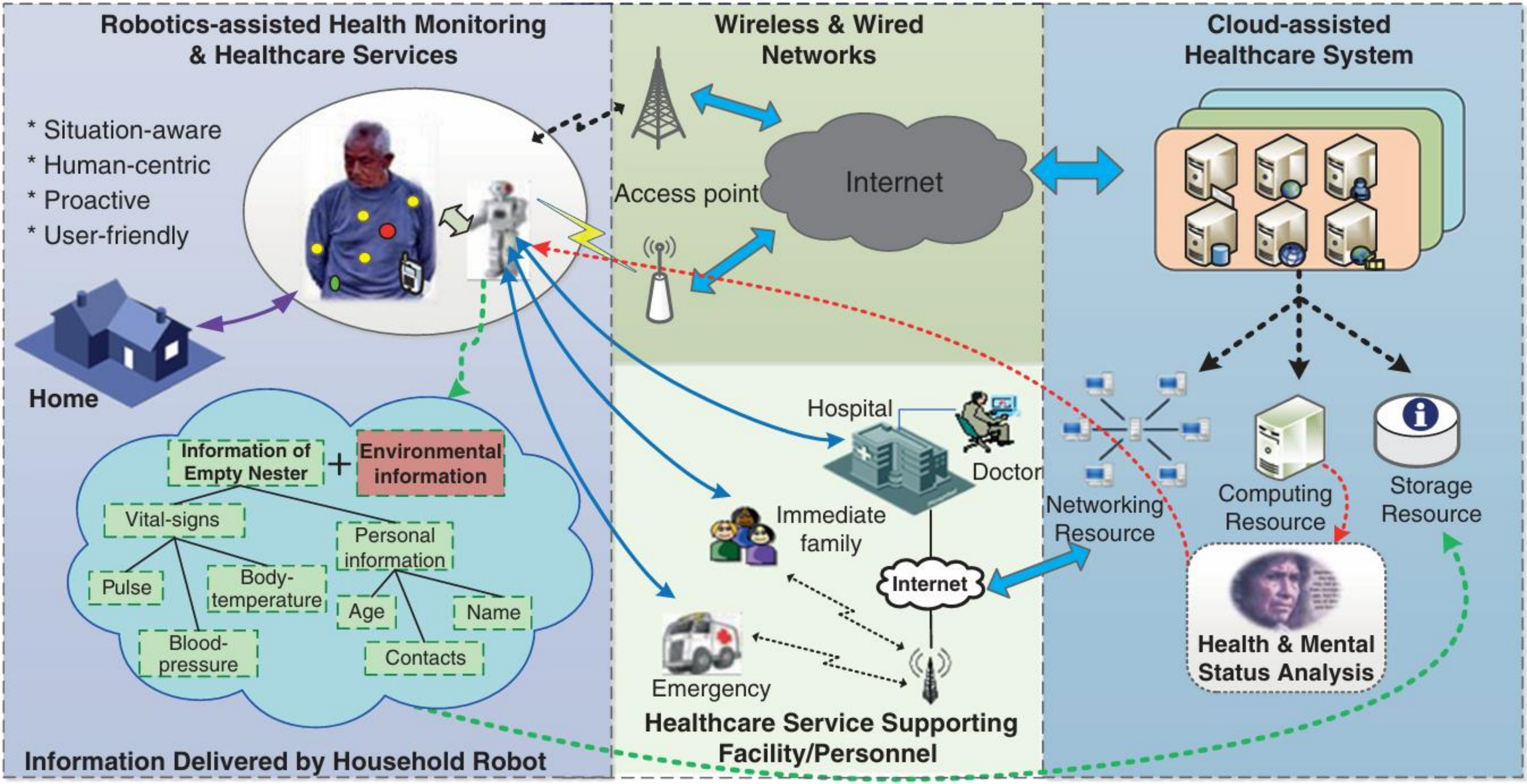
convenient, comfortable, washable, highly reliable and durable.



(b) The testbed settings

7.2.4 Healthcare Robotics and Mobile Health Cloud

- Cloud computing with robot technology
  - **Patient Care**: Robots help in patient monitoring, medication delivery, and even companionship, improving overall patient experience.
  - **Rehabilitation**: Robotic devices aid in physical therapy and rehabilitation, helping patients regain mobility and strength.
  - **Diagnostics**: Robots can speed up diagnosis processes by collecting and analyzing patient data efficiently.


Robotics-assisted Health Monitoring & Healthcare Services
* Situation-aware
* Human-centric
* Proactive
* User-friendly
Home
Information of Empty Nester
+
Environmental information
Vital-signs
Personal information
Pulse
Body-temperature
Blood-pressure
Age
Name
Contacts
Information Delivered by Household Robot
Wireless & Wired Networks
Access point
Internet
Hospital
Doctor
Immediate family
Internet
Emergency
Healthcare Service Supporting Facility/Personnel
Cloud-assisted Healthcare System
Networking Resource
Computing Resource
Storage Resource
Health & Mental Status Analysis

Emotional Insights via Wearables

- **MEASURING EMOTIONS**
- largely two schools of thought to emotions (according to Psychologists and with morals and self awareness)
- one is that your body generates the physiological change and that we then feel it,
- the other is that we judge the emotion, and then the physiology changes accordingly.
- Some statistics would have us believe that up to 95% of decisions are made instinctively and emotionally before we even know it.
- So study of both conscious and nonconscious processes to gain a holistic view of emotional response is necessary.

- MEASURING EMOTIONS: HOW DOES IT WORK?
- It is being measured in 3 ways
- 1. Externally through our face, body, and voice –
  - through muscle movements in our face, the tones of our voice, and the way we sit toward or away from someone
  - Paul Ekman's Facial Action Coding System (FACS) – Allow us to capture the emotions via any camera and analyze
  - Since camera and microphones are available in mobile phone it is easy to record and analyse
  - Additionally mild emotions and mixed emotions, beyond the basic emotions, can be difficult to assess.

- 2. Internally with physiological changes in “arousal,” which can be measured via changes in heart rate, skin conductance, skin temperature, breathing among others:
    - These emotions operate at the nonconscious level and cannot be controlled by a person
    - These signals are great for identifying when a stimulus has occurred, but with out the secondary data how/when the it is being stimulated.
    - emotional stimulus or driven by an alternative physical response – exercise
    - Some expertise is still required to be able to interpret what the signals mean

- 3 Consciously expressing how we think we feel
  - self-reporting how we feel – Surveys
  - wide number of tools exist for asking questions to express how we feel
  - problem with conscious measurement of emotions is that they can be biased based on what people think you want to hear,
  - or people can find it difficult to provide the precise emotion.

LEADERS IN EMOTIONAL UNDERSTANDING

- This chapter concentrate on research work done by **Paul Ekman, Dr. Daniel Kahneman, and Robert Plutchik.**
- Paul Ekman Is a important researcher in this domain
- His research concentrate of understanding and analyzing the facial emotions through facial coding analysis (pan-culturally)
- His research aims to create a FACS, and generating a taxonomy for every human facial expression.

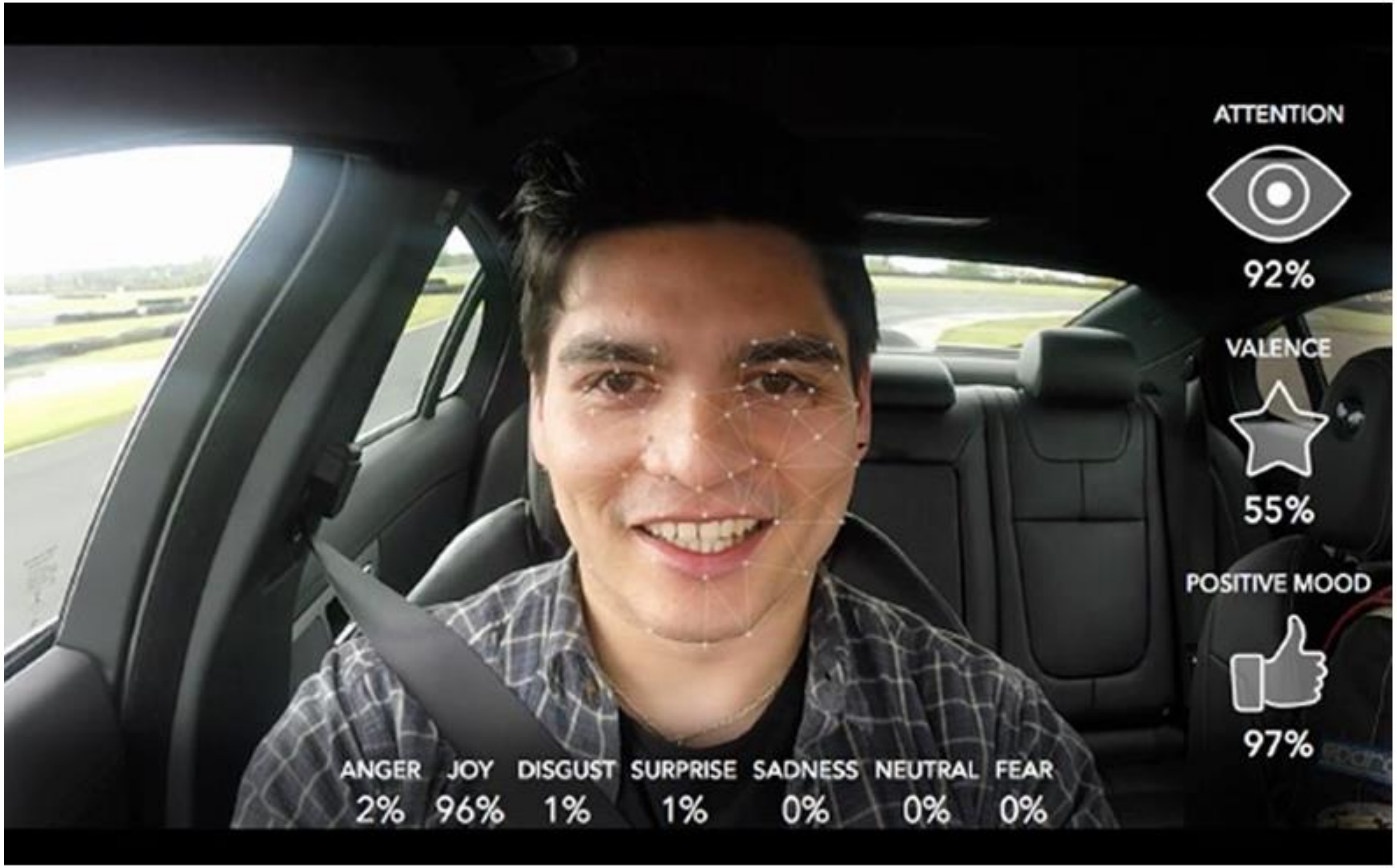


FIGURE 38.1 Use of FACS within a PR campaign. Courtesy of Sensum.

In 2011 Economics Nobel winner Dr. Daniel Kahneman released a book, Thinking, Fast and Slow, where he coined these terms for our two modes of thought (Figure 38.2):

"System 1" is fast, instinctive, and emotional:

- The nonconscious. The under-the-surface gut responses
- Biometric, Neurometric, Psychometric types of research

"System 2" is slower, more deliberative, and more logical:

- The conscious. The calculated processed response
- Surveys, Focus Groups, Ethnography research

- USE CASE 1 - “Unsound”: The World’s First Emotional Response Horror Film

FIGURE 38.3 Image from “Unsound” screened in SXSW 2011. Courtesy of Sensum.

Structural Health Monitoring

Bridge Monitoring Unit (BMU)

Operating Environment –

The BMU will be deployed directly on bridges. The system needs to be able to with stand direct exposure to all sorts of weather conditions.

Power Supply :

In some sites the grid power is available, in some cases they use solar power, But 5 day battery backup

Monitoring Only:

only used in monitoring, no supervisory control

- **Connectivity** – Physical connectivity,
- BMU is required to support both **wired and wireless connectivity**
- utilize local wireless service provider’s 3G/4G/5G service for uplink to server
- during an intense typhoon or earthquake that damages a local cell tower - Failure of network is expected.
- During that time 20 days of data backup is ensured –
- In the event of major structural failure, such data could be extremely valuable for forensic analysis

- **Data Acquisition-**
- BMU is required to monitor both dynamic and static parameters
- **Dynamic parameters** include acceleration in three axes and inclination in two axes.
- **Static parameters** include water level, water velocity, and structure temperature
- As specific choice of sensors may change over time, it would be ideal if the BMU could accommodate different sensor interfaces.
- The data samples should be grouped into a file every 30 seconds and timestamped.
- Notably, all sampled data needs to be transmitted to server for analysis and long term archive

- **Robustness** – Data transmission should be reliable
- in case of unreliable connectivity, data transmission to server should resume when connectivity is restored

- **Power Supply** :
- Both Grid and Solar are deployed,
- But to manage the power outages Battery backup is planned
- lithium iron phosphate ($LiFePO_4$) – Makes the battery bigger in size – But ok in this project
- **Connectivity**
- Wi-Fi mesh , Edge router
- Compress and uplink the data

- **Protocol choice :**
- Ssh over VPN
- TCP/IP
- Simple webserver deployed in each BMU
- Support to RESTful API
- **Architecture**

- Linux **single-board computer (SBC)** is the choice since it supports all the above
- ARM-based SBCs are known to have low power consumption
- Since this SBC has not supported ADC, external ADC is used.
- UART is used for

- ARM Cortex-M3 microcontrollers (MCUs) are 32-bit processors designed for real-time processing in cost-sensitive applications
- 2. GPS module
- 3. Terminal blocks to connect: a. Temperature sensor b. 3D accelerometer c. Two inclinometers d. Power supply e. SDI-12 bus for water velocity and water level sensors
- 4. Headers to mount the **BeagleBone SBC**
- 5. Many extra signal pins for future expansion