IoT Applications for Healthcare and Wellness Management

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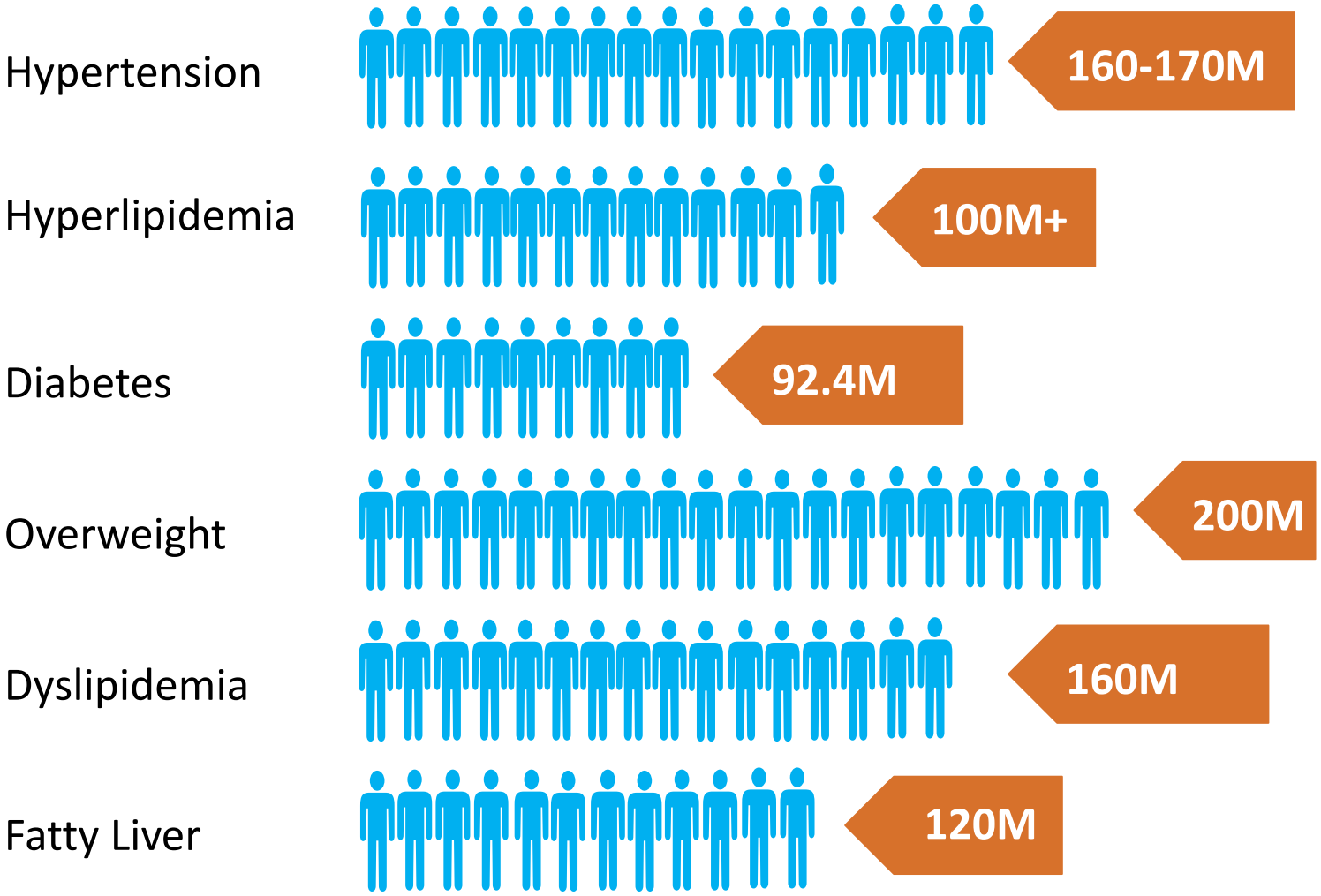
健康从新开始

CONTENTS

Health Related Big Data in China



Patients are Getting Younger

Middle-aged Chinese die of heart and brain disease

22%

70%

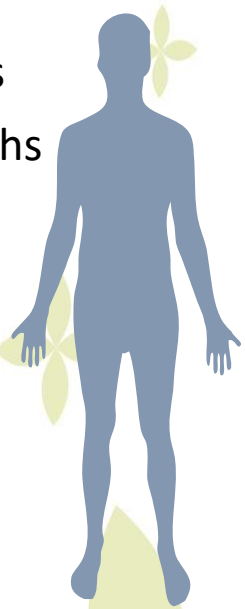
Intellectuals are on the verge of "being overworked"

White-collar workers suffer from sub-health

76%

- Young women are easy to get gynecology, cardiovascular and cerebrovascular diseases
- Young men face sudden death, fatigue and cancer
- The prevalence of chronic diseases
  - Accounted for 83% of all deaths

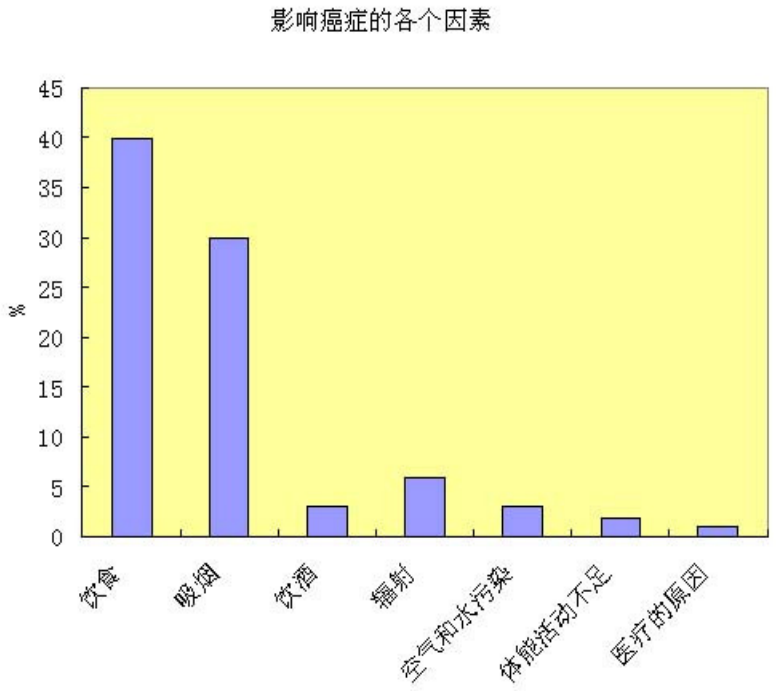
- 35-46 years old patients died of Cardiovascular disease: China 22% vs. USA 12% (2013 - 2014)
- China has spent 300 billion RMB per year on the treatment of cardiovascular and cerebrovascular diseases



From: Healthcare Forecast Report 2020
China Talent Development Report

The Importance of Healthy Lifestyle

- 75% of cancers are associated with lifestyle
- With proactive prevention and intervention, at least 40% of the tumors can be prevented
- In the cause of chronic diseases
  - Genetic factors 15%, social factors 10%, climatic 7%, medical conditions 8%, and personal life style 60%



Strong Push from National Strategy & Policy

- **"Healthy China" has officially risen to a national development strategy**
- Following the Internet industry, the health industry has become the new engine of China's economy growth
- China's health industry will have a market size of 16 trillion RMB by 2030

Great Challenge Ahead

Limited medical resources, scarce senior doctors, short of beds in hospitals, poor service quality, unbalanced usage

The beds in hospital have been occupied!

Patients prefer to visit senior doctors for flu.

Very few patients visit community hospital or healthcare center

My God, we have to wait for another two months!

Patient: I cannot get an appointment with any senior doctor even if we wait in line at 6 A.M.

Doctor: There is no need for patients to visit senior doctors if they only got common diseases

Call for Life-Cycle Healthcare Management

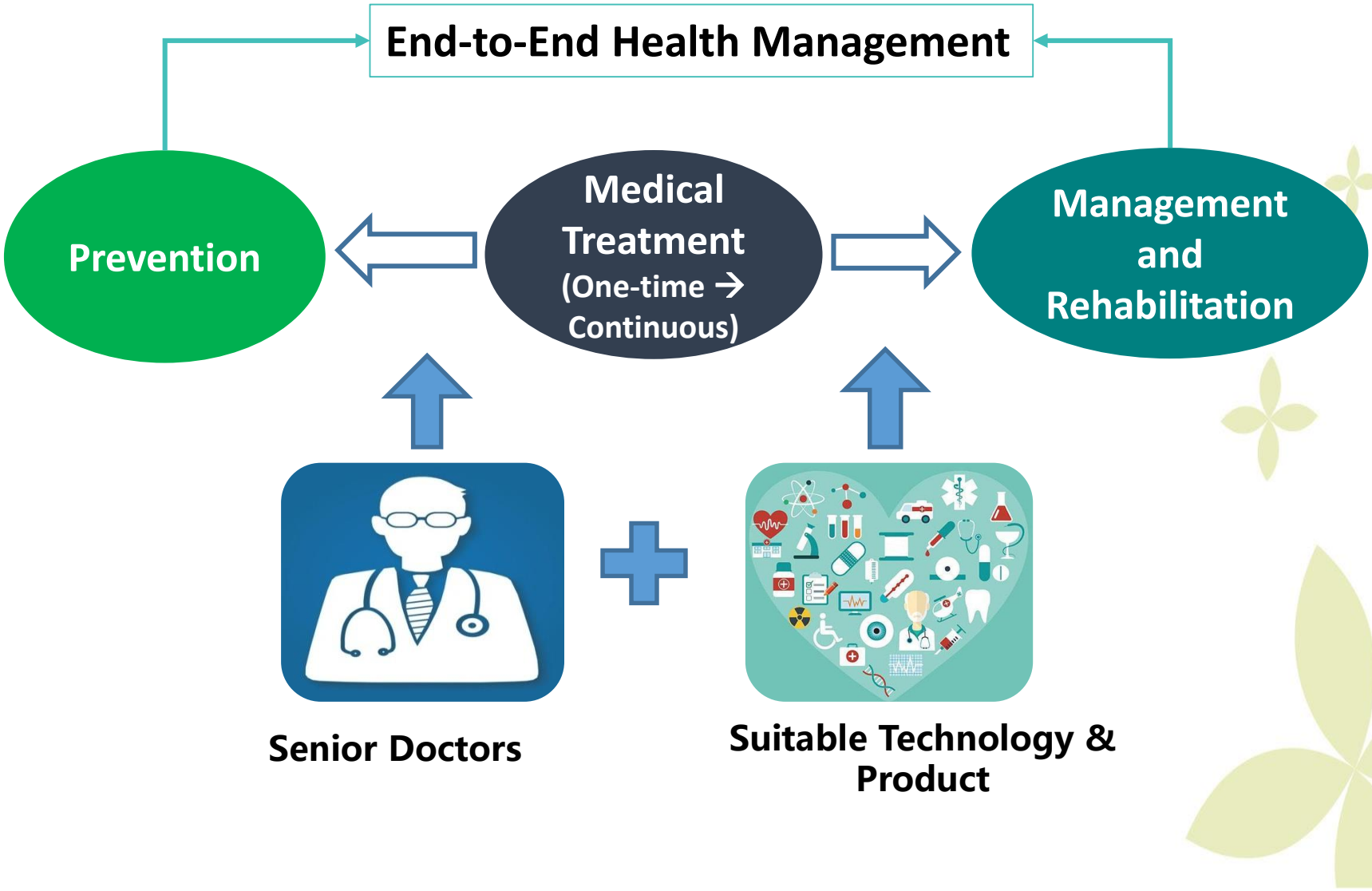
Treatment Centric → **'Prevention + Treatment + Rehabilitation' Life-Cycle End-to-End Healthcare Management**

One-Time Treatment → **Post-Evaluation, Continuous Treatment**

Intelligent technology, innovative medical equipment for personnel empowerment

- **Closed Collaboration btw Medical Specialist and Engineering Experts**
- The change of diagnosis/treatment mode leads to the change of healthcare service mode

To Tackle the Challenge



CONTENTS

2 IoT Technology Empower Healthcare Industry

- Sleep monitoring (住)
- Dietary monitoring (吃)
- Walking assessment (行)

Rise of Smart Devices

[source] Cisco, "Global Mobile Data Forecast Update, 2016-2021", VNI, 2017

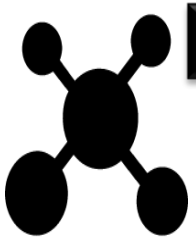
Mobile Device

8.0 billion in 2016, may reach **11.6 billion** in 2021

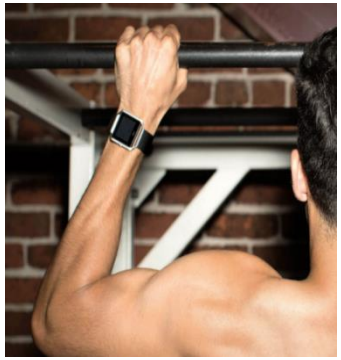
Wearables

101.9 million shipments in 2016, **29%** growth over 2015

IoT Device



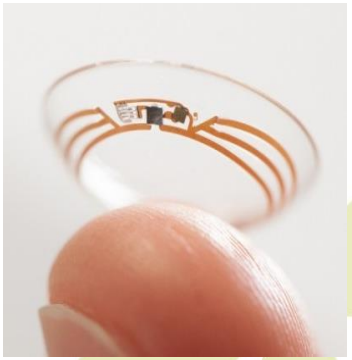
6.4 billion connected things worldwide in 2016, will reach **20.8 billion** by 2020



Working out

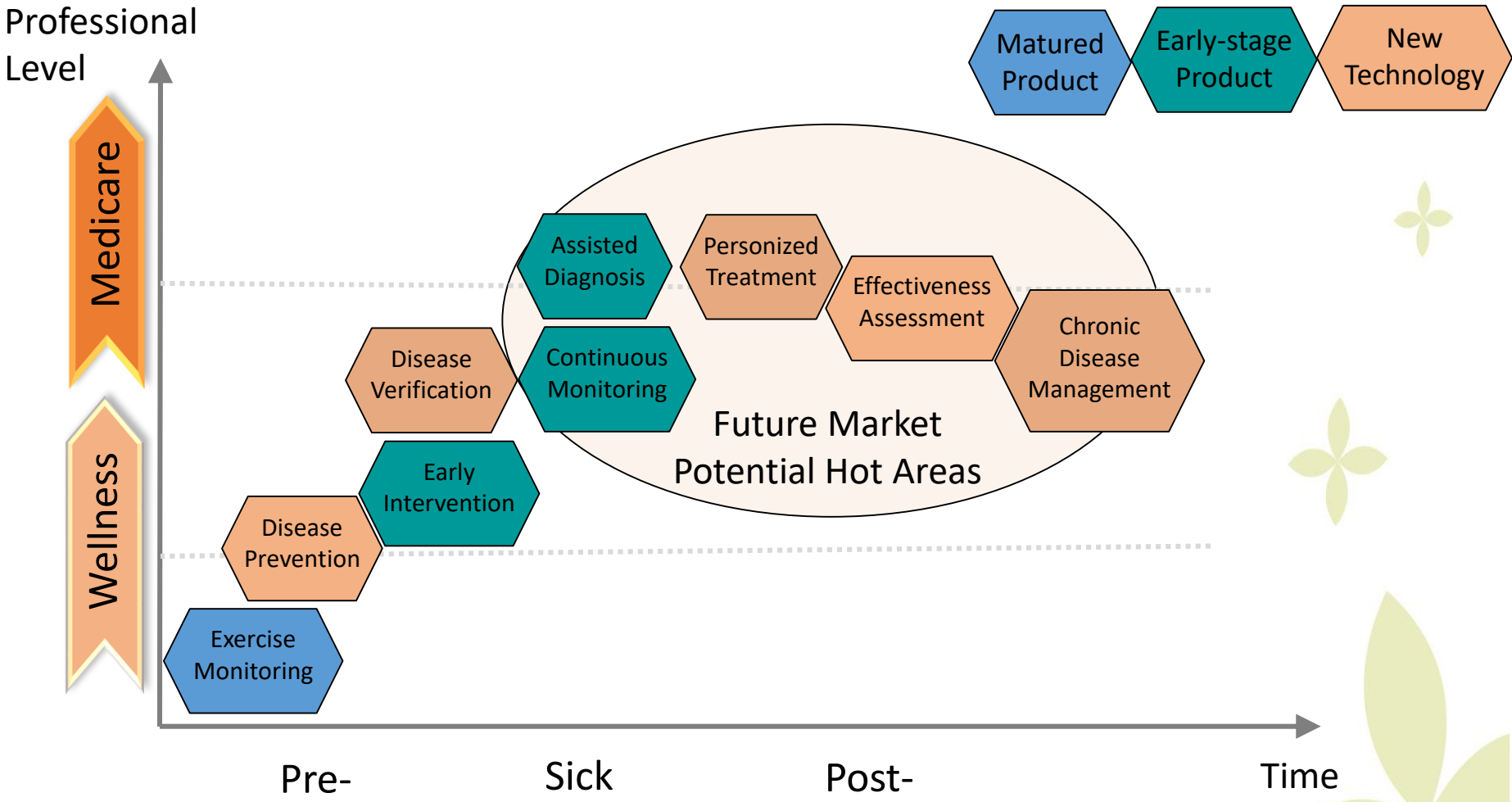
Daily activity

Mobile payment

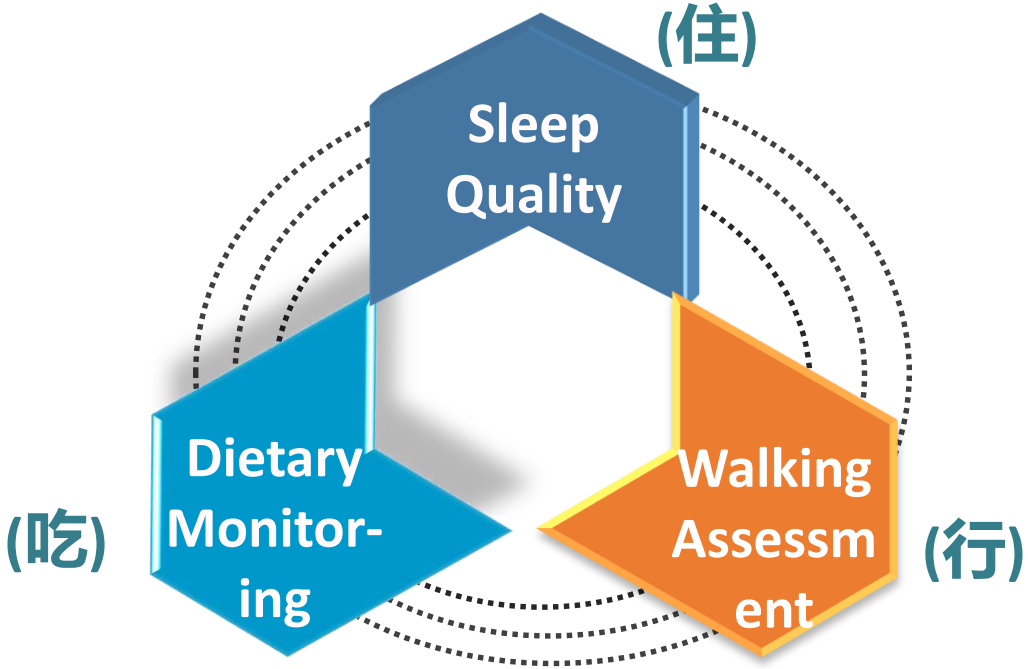


Healthcare

Application Scenario for Wearable in Healthcare



From: 动脉网


(住)
Sleep Quality
(吃)
Dietary Monitor-ing
Walking Assessm ent
(行)

1) Sleep Rhythm and Sleep Apnea Monitoring

- 27% of people have sleep problems, the prevalence of sleep disorders in China's residents as high as 42.7% (WHO data)
- More than 90 types of diseases are related to sleep disorder
- The diagnosis of sleep disorders require the analysis of circadian rhythms, ECG, EEG, blood oxygen, respiration and other data
- 93% of male patients and 82% of female patients suffering from OSAS miss the most suitable time for treatment due to lack of proper diagnosis

Collaborate with The Sleep Medicine Research Center of PLA General Hospital (301 Hospital)

Sleep Quality Analysis with IoT Device

- Different types of sleep disorders have different signs
- Effective vital signs monitoring
- Data analysis helps doctors develop personalized treatment plan

Collected Signal

- Activity
- PPG
- Pulse Rate
- Blood Oxygen

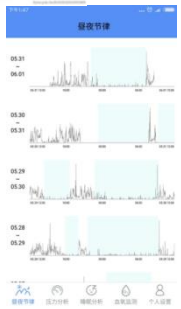
Analysis

- **Daily Activity**
  - Energy Consumption
- **Sleep Stage**
  - wake
  - REM
  - Light Sleep (S1/S2)
  - Deep Sleep (S3/S4)
- **Sleep Apnea**
  - AHI Index
  - Apnea Type

- Analysis of sleep stage
  - HRV
  - Detrended Fluctuation Analysis (DFA)
  - Activity analysis
- Sleep apnea detection
  - Blood oxygen analysis
  - Heart rate periodic analysis

J. Zhang, D. Chen, J. Zhao, M. He, Y. Wang, and Q. Zhang, "A Portable Real-time Automatic Sleep Scoring System", *IEEE RTSS 2012*.

Monitoring → Personalized Treatment



Sleep Quality Monitoring

- Sleep apnea detection
- Sleep quality/ sleep rhythm monitoring
  - Sleep, awake, stage

- Insomnia
- Sleep Apnea
- Rhythm Disorder
- Low Quality

Treatment Plan Adjustment

+

Sleep-assisted Device/Exercise

Adjustable Pillow System

The oximeter collects vital signals, and then sends them to the health mobile phone via Bluetooth

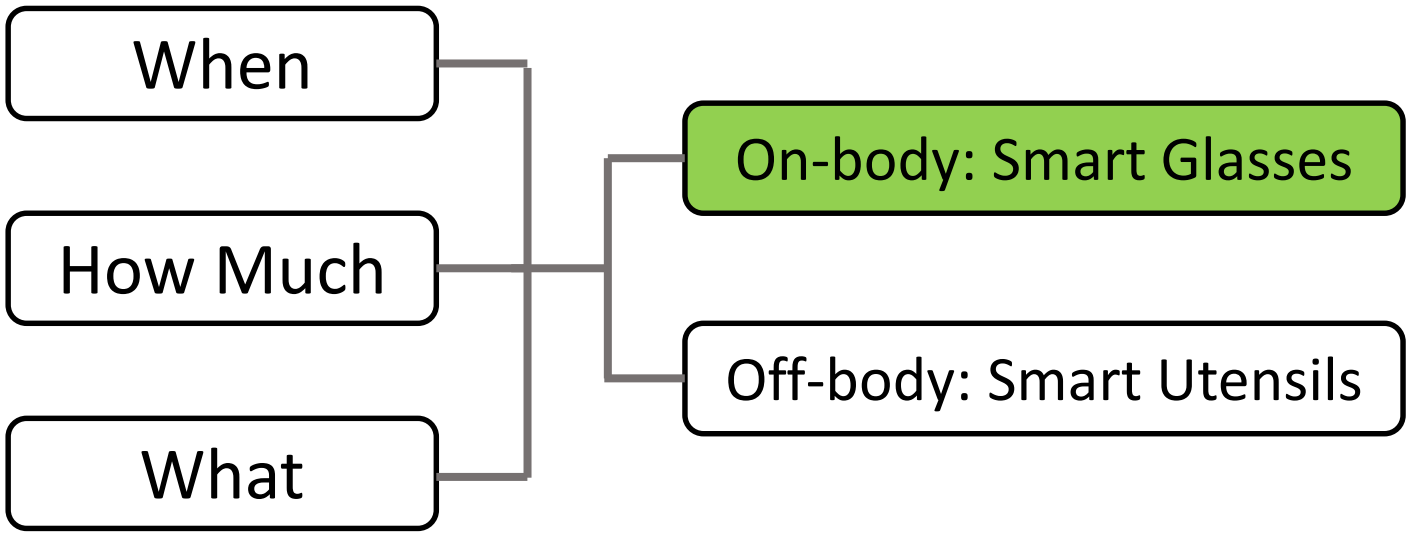
The health mobile phone monitors the apnea and adjusts the height and appearance of the pillow via Bluetooth

- Monitor the sleep apnea
- A patient is recommended to adjust the height and appearance of the pillow to keep the airway open. Real-time feedback can be achieved to relieve and cure the OSAS
- Auto-adjustment or remote and manual adjustment by doctors
- **Advantage**: advanced technology, comfort, safety and efficient

J. Zhang, Q. Zhang, Y. Wang, and C. Qiu, "A Real-time Auto-Adjustable Smart Pillow System for Sleep Apnea Detection and Treatment", in *IEEE IPSN 2013*.

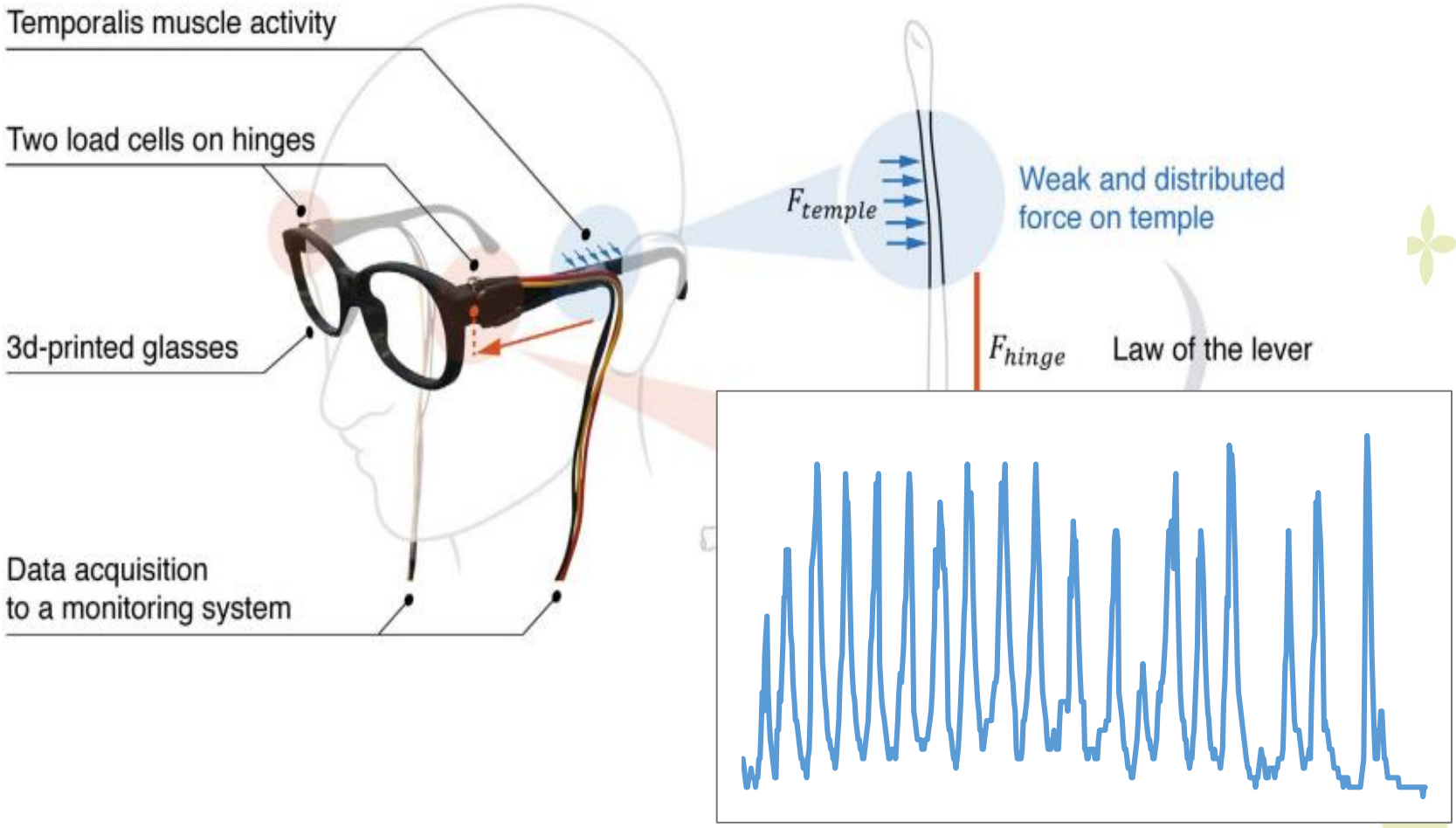
2) Dietary Monitoring

Heavily related to diabetes, overweight, cardio-cerebrovascular disease



Q. Huang, W. Wang, Qian Zhang, "Your Glasses Know Your Diet: Dietary Monitoring Using Electromyography Sensors", IEEE Internet of Things Journal 4(3): 705-712 (2017)

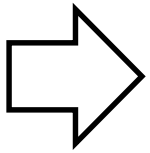
Observation



Chung, Jungman, et al. "A glasses-type wearable device for monitoring the patterns of food intake and facial activity." *Scientific Reports* 7 (2017): 41690.

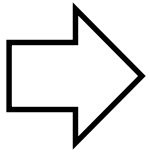
Challenges

Confounding activities, e.g., talk, head movement



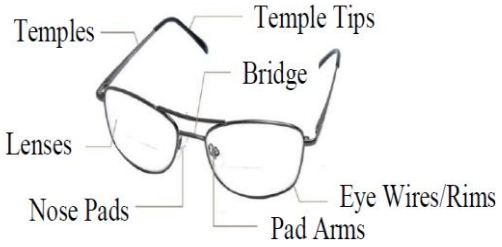
Chewing is a periodic activity

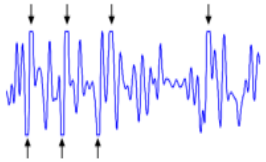
Unpredictable signal quality



Use adaptive thresholding

System Design





EMG Sampling

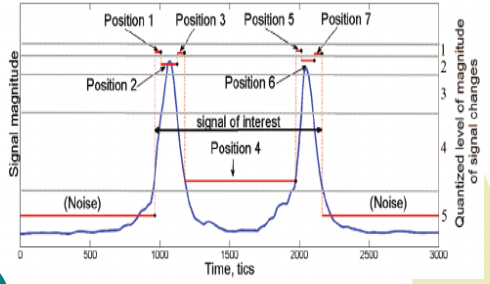
Adaptive Thresholding

Chewing Detection

Feature Extraction

Food categorization

Crispy or Soft, wet or dry



- **96%** accuracy for counting the number of chewing cycles
- **80%** accuracy for distinguish different food categories

2) Dietary Monitoring

Heavily related to diabetes, overweight, cardio-cerebrovascular disease

- When
- How Much
- What

→

- On-body: Smart Glasses
- Off-body: Smart Utensils

Q. Huang, Z. Yang, Q. Zhang, "Smart-U: Smart Utensils Know What You Eat", in IEEE INFOCOM 2018.

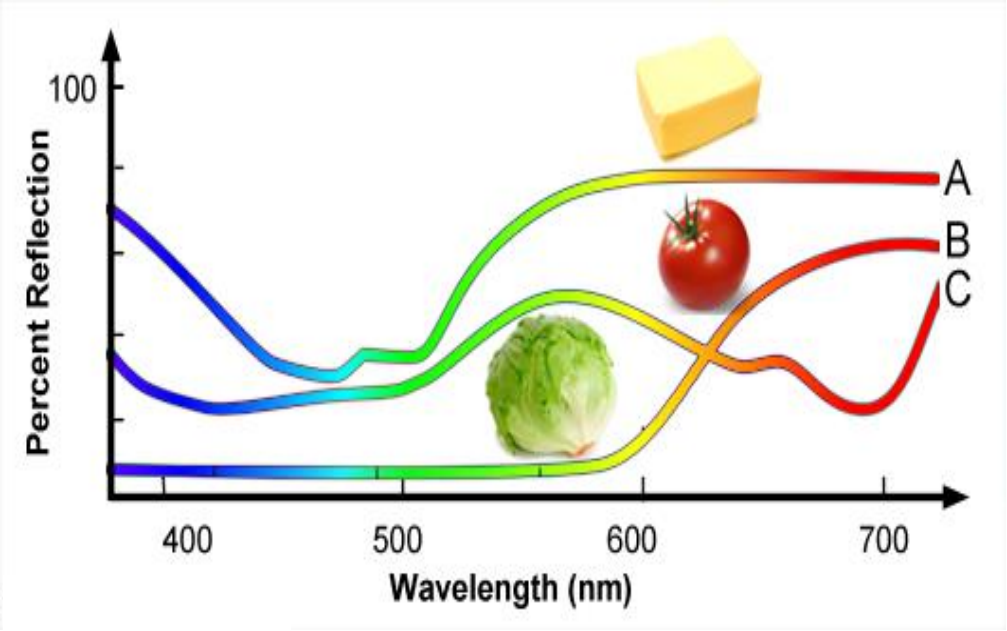
Food Recognition

Drawback: Cannot handle occlusion

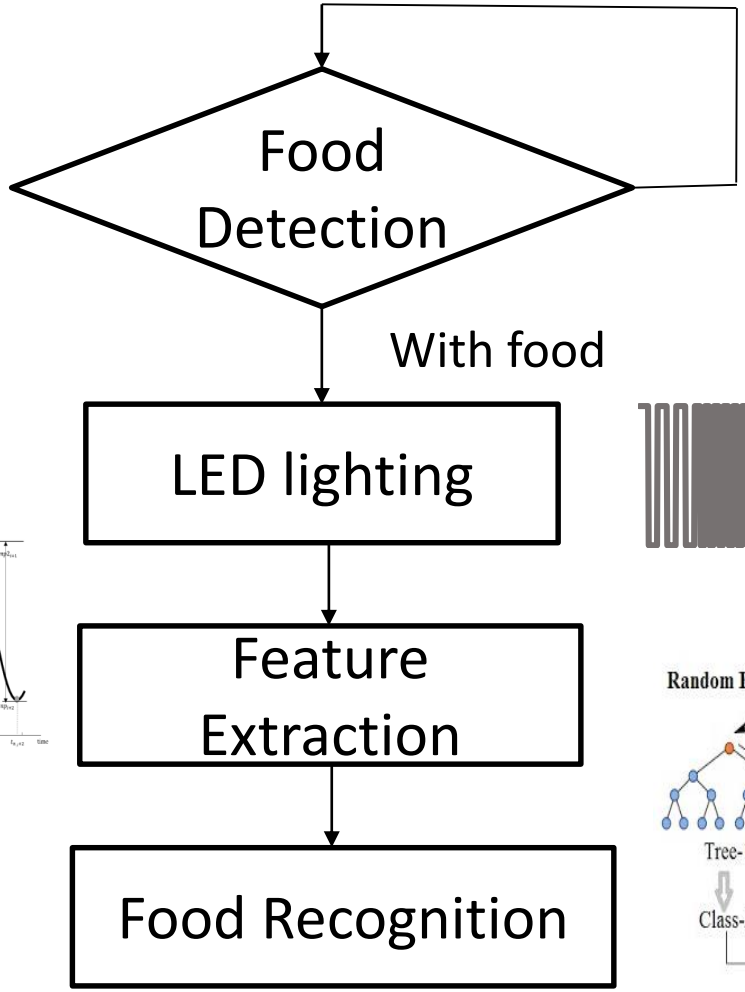
Smart Utensils

Smart utensils provide opportunity to track what we eat

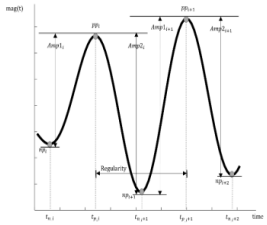
Light Reflected Depends on the Chemical Properties of Food

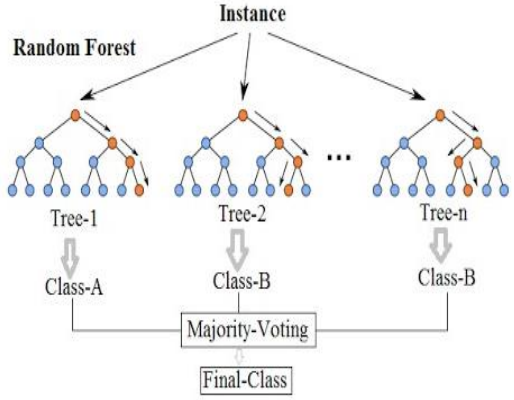


System Design



12 LEDs, 4 in visible bands, 8 in near-infrared bands





For now, we can classify 20+ foods with very high accuracy (>95%)

3) Walking Assessment -- Heel Problems

- The heel (hind-foot) is a central mechanism in foot biomechanical movement during gait, and is also a common site of foot pain

[Internal causes]

- Plantar fasciitis
- Overweight
- Weakness of the heel fat
- Arthritis in the heel joint

[External causes]

- Long-time standing
- Wearing hard-soled footwear
- Bad foot gesture

Motivation

- Monitoring the pressure under heel can be important for patients and even normal users

EMED@Novel

FootScan@RSScan

MatScan@Tekscan

F-scan@Tekscan

Pedar@Novel

Plate-based systems

- High manufacture and installation cost
- Restricted to research laboratories or medical clinics

In-shoe systems

- Heavy calibration burden to overcome drift of pressure transducers overtime
- Limited life-span: unfordable for continuous daily usage

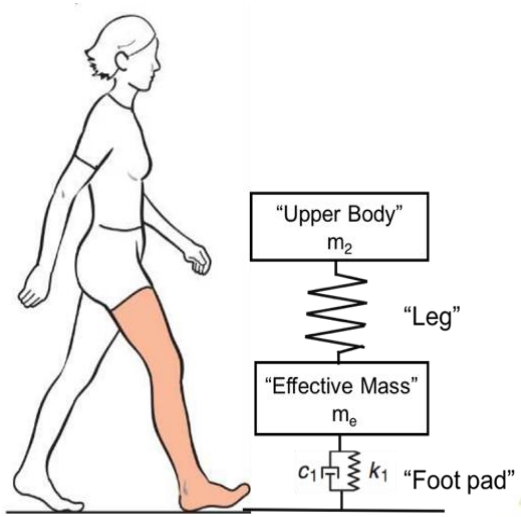
Observation

- Heel strike is a process of collision between the foot pad and ground
- Collision force is generated by inertial change of partial human body
- **[Impulse-momentum theorem]** The change in momentum(the product of the mass and velocity) of an object equals the impulse (the product of force and time)

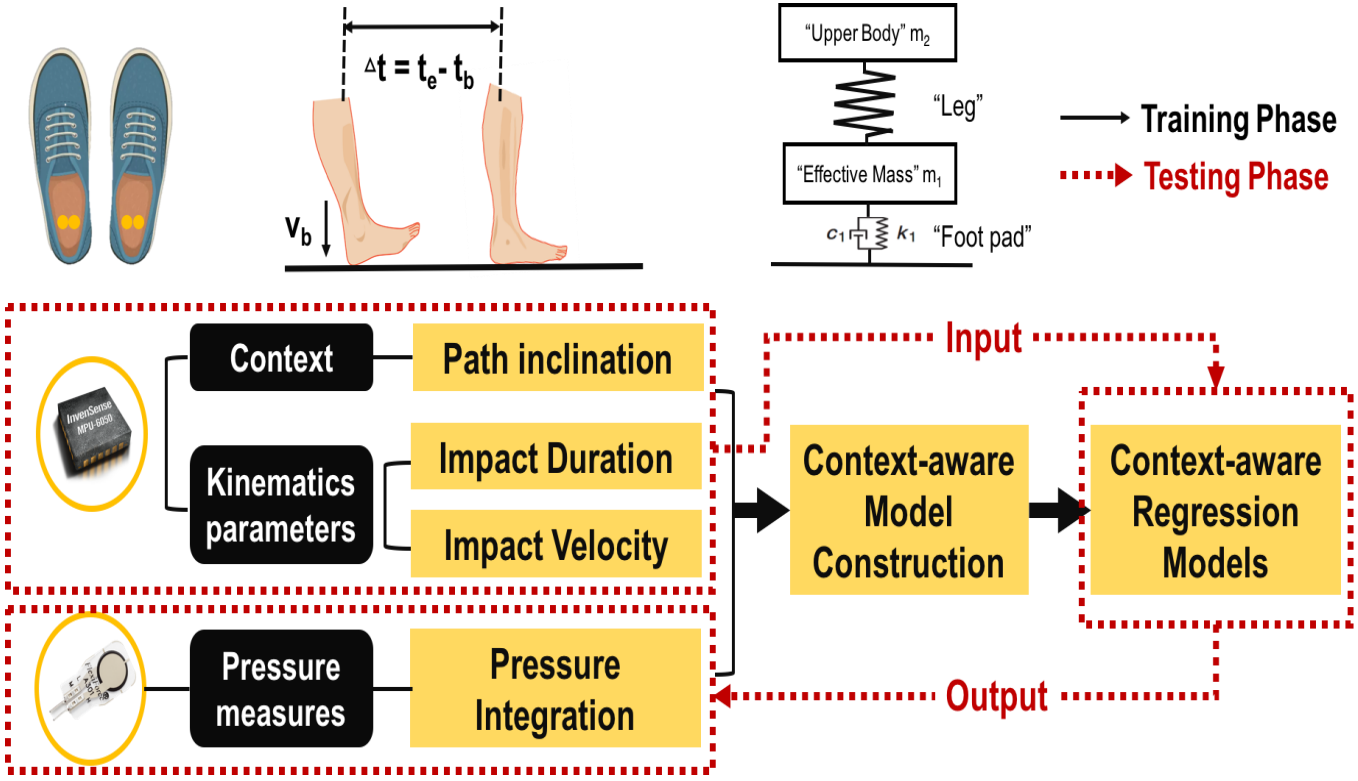
$$\int_{t_b}^{t_e} (F_G - M_e g)dt = M_e(v_e - v_b)$$

$$\int_{t_b}^{t_e} F_G dt = M_e(\Delta v + g\Delta t)$$

Pressure Measures **Kinematics Parameters**



Heel-Guard: IMU-based Heel Pressure Monitoring through Momentum-Impulse Analysis



- 10 participant, 5 paths with different textures and inclines, self-selected speed
- Our system achieves ~ 0.1505 normalized root-mean-square error

H. Chen, C. Huang, and Q. Zhang, "HeelCare: Inferring Heel Pressure from Inertial Signals", submitted to ACM Ubicomp, 2018.

CONTENTS

Networked Hospital Service Model

Diseases Treatment + Outside Hospital Management = End-to-End Health Management

Hospital

Treatment within Hospital

Cloud Computing

Remote health monitoring platform and Healthcare IoT

健康小屋

Health Station

Networked Hospital

Health Service extended outside hospital

Chronic Disease Management, Follow-up, Health Consultation, Check-up Booking

Periodical Healthcare Management

Patients

- Abnormal vital sign
- Time for re-checking

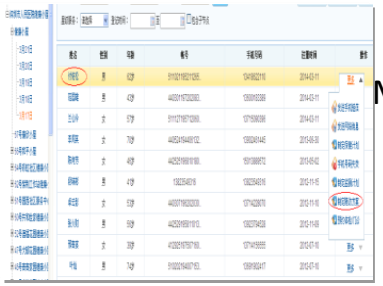
Health Station

Hospital

Confirmation

Assign to Health Station

Finish consultation and back to health station for daily management



Create management task

GP

Daily Management

- Vital sign monitor
- Healthy lifestyle tracking and suggestion
- Med&Pill reminder
- Chinese med suggestion
- Re-check suggestion

Health-carer

Use Case in Shenzhen

The first “Networked Hospital” based on Cloud Platform

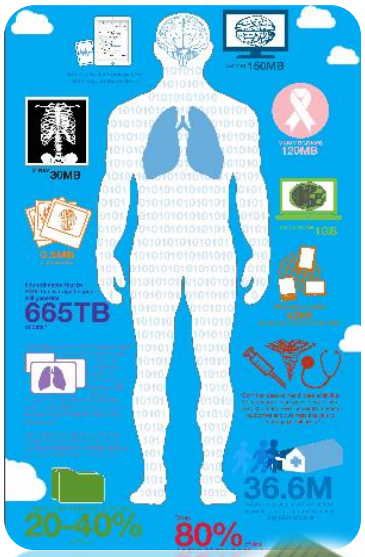
Based on Shenzhen People’s hospital, leveraging the remote monitoring IoT platform to achieve the end-to-end healthcare management

- Aims at disease classification management, based on general practitioners, with clinical experts as the core, and health stations as extensions to guide patients to obtain reasonable medical treatment, and provide end-to-end medical care services
- In 2016, 660K person-times of services were provided for out-patient and post-physical examination users
  - Continuous tracking and management of 60K person-times for common chronic diseases (diabetes, hypertension)
  - Continuous follow-up management of early cancer prone populations for 8 common cancers (lung cancer, cervical cancer, colon cancer, liver cancer, thyroid cancer, breast cancer, prostate cancer, and gastric cancer)

Enjoyable Personalized Service from End-Users

Always available personalized healthcare service from big health data

Personalized Pill Reminding



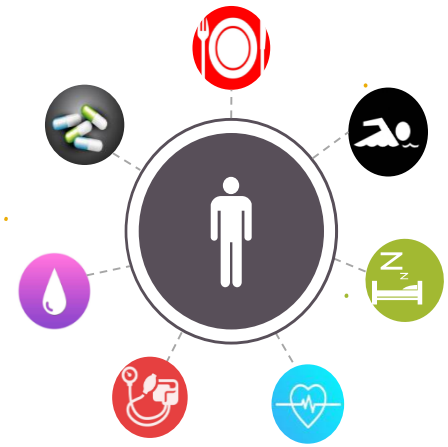
Personalized Excising

Personalized Health Insurance Planning

Personalized Food

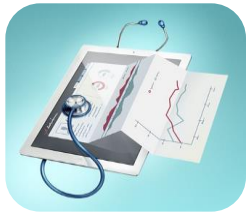
Vision

Through the combination of science/technology and medical science, promote the development of intelligent life-cycle health management



Vital Sign Monitoring
Daily Behavior Monitoring

Material/IoT Technology



HIS Record
Check-up Record

Big Data Technology

Data Mining and Analysis

AI Learning Technology

- Disease Prediction, Risk Assessment
- Personalized Treatment Plan Recommendataion
- New Way for Treatment

Thanks!

Contact: qianzh@cse.ust.hk