Healthcare Information Modeling and Representation for 3D Smart Cities

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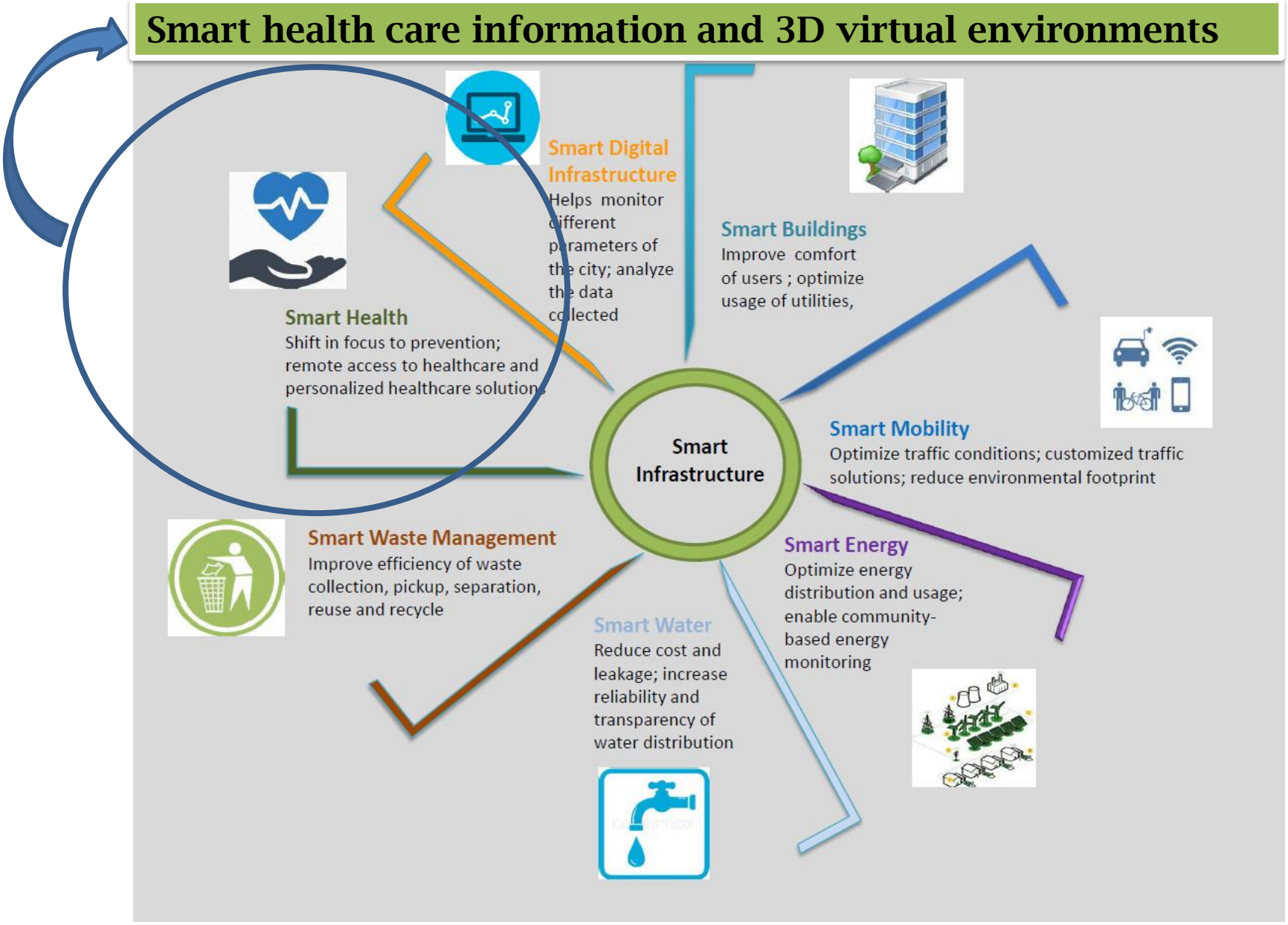
Definition of Smart City

- "A smart sustainable city is an innovative city that uses information and communication technologies (ICTs) and other means to improve quality of life, efficiency of urban operation and services, and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social, environmental, as well as cultural aspects"

  ITU study group on SSC

UNCTAD (United Nations Commission on Science and Technology for Development), 2016

Smart health care information and 3D virtual environments



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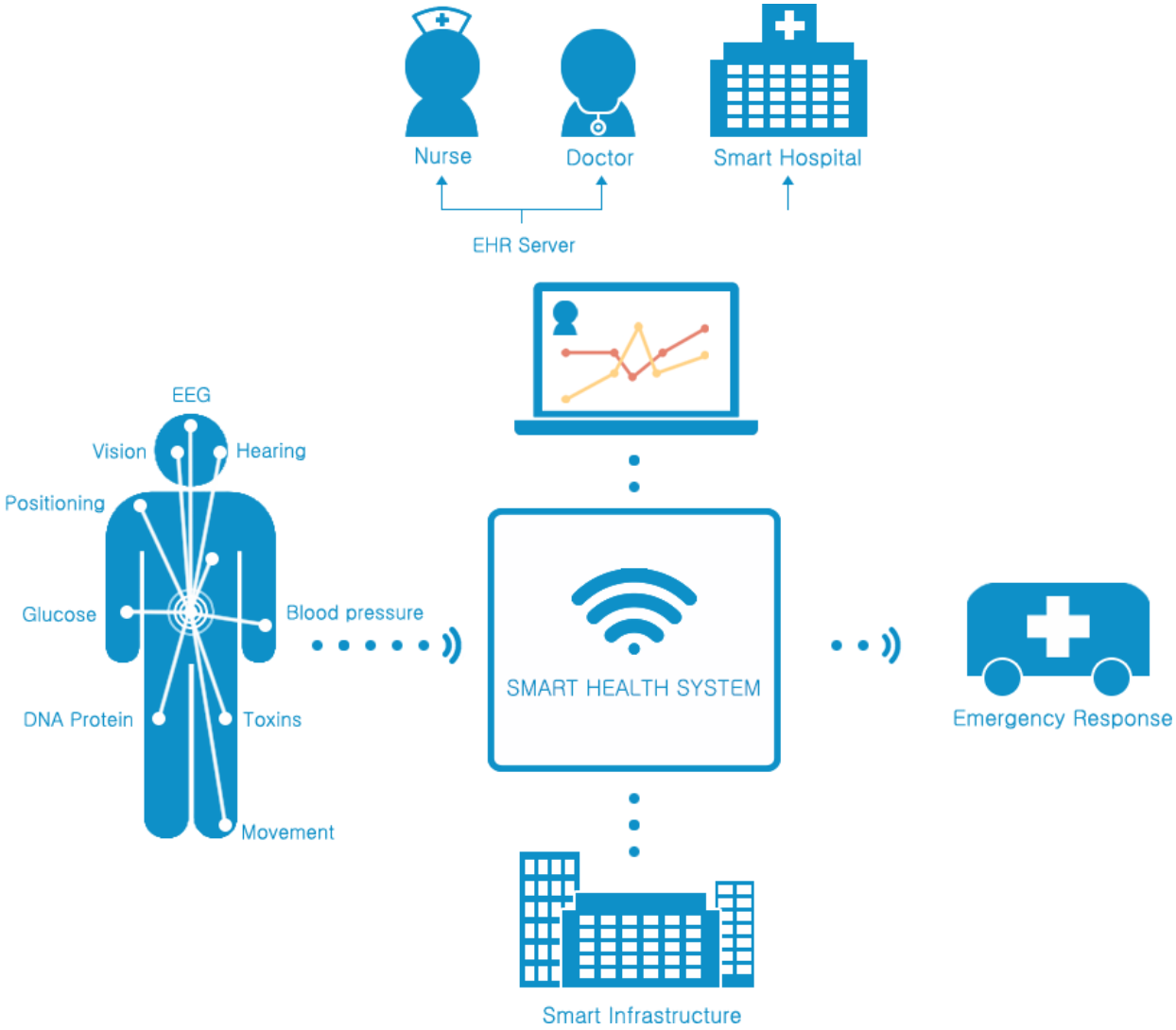


Concept of smart city health system

Health Information Services

- Health Information Services are responsible for the collection, processing, storage, retrieval, and dissemination of patient information, in both paper and electronic format, to facilitate an optimal level of direct and indirect patient care, and for research, quality improvement, hospital, Local Health District and Department of Health management and decision-making purposes (https://www.nslhd.health.nsw.gov.au/Services/Directory/Pages/HIS.aspx)

Visualization for digital healthcare information systems

Healthcare Information Sensors

- Wearables such as digital watches, Fitbits, etc. embedded in or worn on clothes and accessories
- Ingestibles embedded in pills that get dissolved
- Blood sampling sensors such as glucose meters
- External sensors such as pulse oximeter and blood pressure cuffs
- Epidermal sensors such as digital tattoos and patches
- Tissue embedded sensors such as pacemakers and defibrillators

Functions of Health Information Sensors

- Health monitoring
- Safety monitoring
- Home rehabilitation
- Care assessment
- Early detection of disability

Health Information with Sensors

- Fitbit Surge
  - https://www.fitbit.com/us/surge
  - Tracks walking steps and sleep, and notifies of incoming phone calls and text messages
  - Recognizes heart rate using embedded heart rate monitor, and traces outdoor activity using GPS

Health Information with Sensors

- OMNIFIT Ring
  - http://www.omnicns.com
  - Smart healthcare platform which manages mental health with a one-stop process of a virtual circle of measurement
  - Monitors and manages sleep habits
  - Uses PPG sensor and motion sensor

- Sleep-doc
  - http://www.omnicns.com
  - Aids sleep by checking light, illumination, and active mass, and by capturing calories burned
  - Provides information about health and sleep habits
  - Monitors sleep pattern and lifestyle

Health Information with Sensors

- PIP
  - https://thepip.com/
  - Provides feedback of stress levels
  - Teaches a method to improve mood, via smart phone app
  - Measures skin conductivity

- Withings Blood Pressure Monitor
  - https://www.withings.com/eu/en/health-monitors
  - Measures heart rate and blood pressure, and counts walking steps
  - Connected to blood pressure monitor

Health Information with Sensors

- AliveCor Heart Monitor
  - https://www.alivecor.com/
  - Mobile phone based electrocardiogram
  - Implemented by having the user place fingers on two ellipse electrodes

- Viatom Checkme
  - https://www.viatomtech.com/checkme-pro
  - Portable medical tricorder multi-tool
  - Traces ECG and measures pulse frequency, oxygen saturation, and blood pressure

Health Information with Sensors

- Muse headband
  - http://www.choosemuse.com/
  - Displays interaction with smart phone or tablet using brain waves, and monitors stress management
  - Increases concentration and decreases stress using brain waves

- Gymwatch Fitness Tracker
  - https://www.gymwatch.com/en/
  - Counts walking steps, and measures calorie usage, sleep quality and amount, heart rate, and posture change during running
  - Notifies of incoming phone calls and text messages

Health Information with Sensors

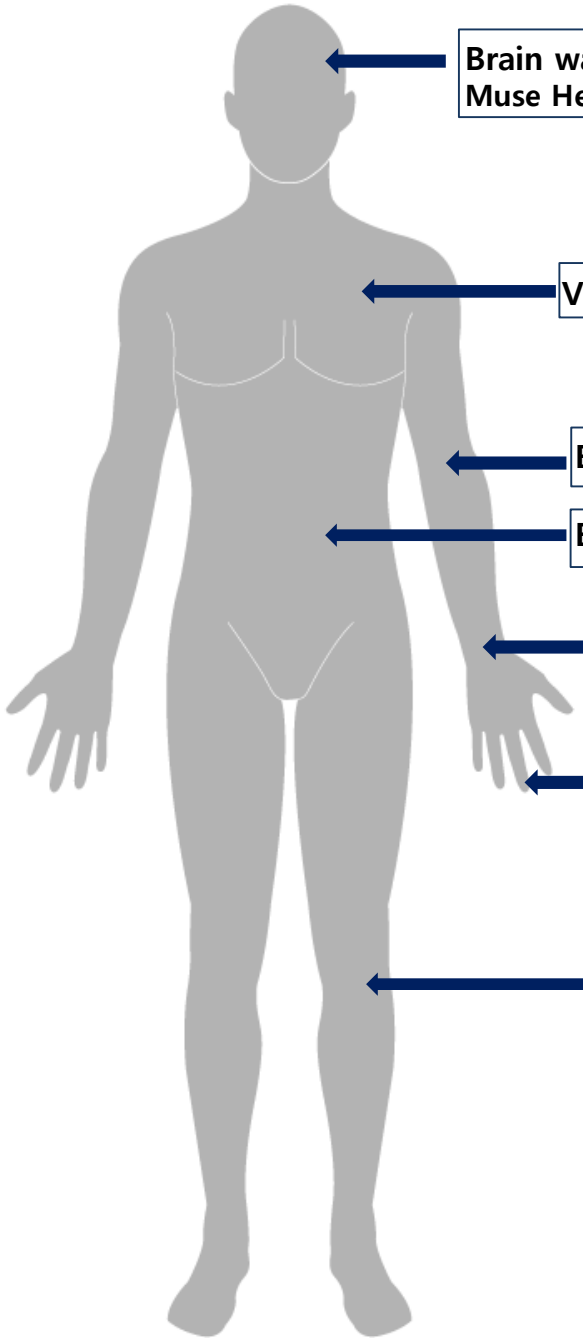
- Valedo Back Pain Therapy Kit
  - https://www.valedotherapy.com/de_en/
  - Self management of backache
  - Home rehabilitation treatment
  - Consists of a gaming platform that helps reinforcement of waist muscles, and a cloud platform for transferring and monitoring information

- HealthPatch
  - http://www.medibiosense.com/products/healthpatch/
  - Smart healthcare device that records vital signs that medical doctors and observers can monitor
  - Monitors ECG, heart rate, breathing rate, skin temperature, and activity status

Apple Watch Function and Patents

- Heart rate vs ECG (4th)
- AF - atrial fibrillation (4th)
- Fall detection (4th)
- Patents
  - Sleep apnea detection
  - Measuring blood oxygen saturation
  - Oxygen saturation
  - Wrist worn accelerometer for pulse transit time (ptt) measurements of blood pressure
  - Light-based shielding detection
  - Parkinsonism monitoring
  - Reference switch architectures for noncontact sensing of blood glucose
  - Sensors and data treatment algorithm

Healthcare Information Parameters - Body parts



Brain waves: stress, brain function, brain health ▶ **OMNIFIT Ring, Muse Headband**

Vital signs ▶ HealthPatch

Blood pressure ▶ Withings Blood Pressure Monitor

Backache management ▶ Valedo Back Pain Therapy Kit

1) Heart rate ▶ AliveCor Heart Monitor, Viatom Checkme
2) Exercise, health status ▶ Fitbit Surge, Gymwatch Fitness Tracker
3) Light amount, light wave ▶ Sleep-doc, Pebble Time

Pulse wave: arteriosclerosis
Skin conductance ▶ PIP

Chronic pain ▶ Valedo Back Pain Therapy Kit

Blood test
1) diabetes: blood sugar
2) pulmonary emboliform: D-dimer
3) myocardial infarction: CK-MB, troponin
4) cardiac insufficiency: B-type natriuretic peptide (BNP)

Health information modeling and representation

- Definition of health components of a normal, healthy person
- Health components list, parameters, related sensors, sensing location of body, brand name, and normal range of data
- How to apply or synchronize these values to a person in a smart city
- How to represent personal health information in 3D smart cities

Physiological Sign	Sensors		Location	Wearable Devices
Electrocardiogram (ECG) (mm/s)	ECG sensor		Cardiovascular Abnormalities	BODYGUARDIAN, PREVENTICE, Zephyr Shirt, Visi Mobile, QardioCore, BioPatch
			Chest & Ribs	
			Wrist	Apple watch 4th gen., VISI MOBILE, Helo LX
			Body (Anywhere)	Zephyr BioModule
Heart Rate (beats/m)	Pressure sensor		Wrist	Zeblaze Blitz, Blocks, GoBe
	Optical sensor	Photo plethys-mography (PPG)	Wrist	HELO LX, Empatica E4 Wristband
			Chest & Torso	EQ02 Lifemonitor
	Infrared sensor		Wrist	Heart Rate Monitor, Atlas Fitness Tracker
			Chest & Torso	EQ02 Lifemonitor
			Ear	AquaPulse, Dash Earphones, Iriveron
	Accelerometer		Wrist	HELO LX, Samsung Gear Live, Blocks
			Chest & Torso	EQ02 Lifemonitor
			Ear	Dash Earphones, Iriveron
			Body (Anywhere)	Zephyr BioModule, Biopatch, The Nymi Band, Pebble2
			Hand	Oxstren
			Torso	Hexoskin, Bioharness 3

Physiological Sign	Sensors	Location	Wearable Devices
Heart Rate (beats/m)	Pulse oximeter	Wrist	Helo LX, Visi Mobile
		Ear	Dash Earphones, Lumafit
		Body (Anywhere)	Zephyr loose fit shirt
		Finger	iHealth Pulse Oximeter
		Feet	Owlet Baby Monitor
	Electrical sensor = Electrocardiogram (ECG) 방법	Wrist	Phyode W/Me, Helo LX, Visi Mobile,
		Chest	Polar H7, Qardio Qardiocore
		Body (Anywhere)	Zephyr Biomodule, Zephyr Loose Fit Shirt, Biopatch, Zio XT Patch
		Torso	Hexoskin, Bioharness 3
	Touch-activated electrocardiogram sensor		
	Gyroscope	Wrist	Helo LX, Atlas Fitness Tracker, Microsoft Band1&2, Fitbit Surge, Samsung Gear Live, Blocks, Zeblaze Blitz, The Nymi Band, Pebble2,
		Body (Anywhere)	Zephyr BioModule
		Hand	Oxstren
	Image sensor		
	Piezoelectric sensor	Neck	REF1420610, Embla Systems Inc.

Physiological Sign	Sensors		Location	Wearable Devices
Blood Pressure (mm/Hg)	Microelectromechanical sensor (MEMS)			
	Photoconductivity			
	Piezo-resistive pressure sensor			
	Capacitive pressure sensors		Wrist	Microsoft Band1&2
			Body (Anywhere)	Kenzen Patch
	Optical Sensor	Photoplethys-mography (PPG)	Wrist	Helo LX
	Potential difference sensor			
	Pressure sensor		Body (Anywhere)	Zephyr BioModule, Zephyr Loose Fit Shirt
			Wrist	Helo LX, Visi Mobile
			Arm	Withings Blood pressure monitor

Physiological Sign	Sensors	Location	Wearable Devices
Respiration Rate (breaths/m)	Piezoelectric sensor	Neck	REF1420610, Embla Systems Inc.
		Chest	Piezo Crystal Effort Sensor 1370Kit, Piezo Crystal Effort Sensor 1387Kit, Piezo Beltless Effort Sensor 1390 (SleepSense Inc.,)
		Abdominal	
	Triboelectric sensor		
	Piezo-resistive sensor		
	Gyroscope	Body (Anywhere)	Zephyr Loose Fit Shirt (body everywhere), Zephyr BioModule
		Wrist	Helo LX
		Hand	Oxstren
	Accelerometer	Body (Anywhere)	Zephyr Loose Fit Shirt (body everywhere), Zephyr BioModule, Biopatch
		Wrist	Helo LX
		Hand	Oxstren
		Torso	Hexoskin, Bioharness 3
	Image sensor		
	Acoustic sensor	Neck	

Physiological Sign	Sensors		Location	Wearable Devices
Blood Oxygen Saturation (SpO2) (%)	Optical sensor	Photoplethysmography (PPG)	Wrist	Helo LX,
	Pulse oximeter		Wirst	Visi Mobile
			Body (Anywhere)	
			Ear	Dash Earphones
			Fingers	iHealth Pulse Oximeter
			Head	Neuroon
Blood Glucose (mg/dL)	Electromagnetic sensor		Finger	HELO LX, INSULET OMNIPOD, EyeSense, Medtronic Continuous Glucose Monitoring(CGM), Dexcom G4 Platinum, GlucoWatch, SCOUT
	Electrochemical sensor			
	Enzymatic sensor			
	CVD-grown graphene FET glucose sensor			
Skin Perspiration (μS/cm)	Epidermal-based sensors		Sweat gland	Basis Peak
	Fabric/flexible plastic-based sensors			

Physiological sign	Sensors	Location	Wearable Devices
Capnography (mm/Hg)	Capnography device to perform CO2 gas quantification	Below the nose	MediByte, TcCO2 (Transcasive Capnography) - Electrochemical electrode or oximetry principles
		Capillary blood flow	
Body Temperature (**℃**)	Photoconductivity		
	Pyroelectric sensor		
	Piezoelectric sensor		
	Resistive temperature detectors(RTDs)		
	Thermistor		
	Thermostat		
	Thermopile		

Physiological sign	Sensors		Location	Wearable Devices
Body Temperature (°C)	Temperature sensor		Wrist	HELO LX, Blocks
			Body (Anywhere)	Zephyr Loose Fit Shirt, Zephyr BioModule
			Chest, Torso	EQ02 Lifemonitor, Hexoskin
			Head	Neuroon
			Chest	Qardio Qardiocore
	Thermometer		Wrist	Helo LX, Blocks
			Body (Anywhere)	Zephyr BioModule
			Chest, Torso	EQ02 Lifemonitor, Hexoskin
			Head	Neuroon
			Chest	Qardio Qardiocore
Blood Volume Pulse (%)	Optical sensor	Photoplethys-mography(PPG)	Under skin	VasoTrain Blood Volume Pulse Biofeedback Device
			Face	

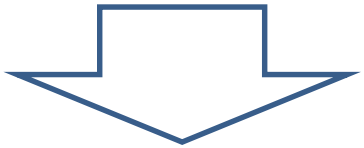
Conclusions

- Standards work items
  - Health care information modeling for 3D Smart City environment
    - 3D health care information modeling
    - 3D health care sensor data monitoring and management interface
      - Real-time monitoring
      - Real-time location, orientation, and health data representation
      - Sensor information parameters in 3D virtual environments
    - 3D health care information systems

- How to use
  - Evaluation of a smart city using a virtual human model
    - For example, effectiveness of the city function to a healthy vs. unhealthy person
  - Evaluation of an emergency transportation system for CVD patients

Smart Health

- Remote access to healthcare
- Personalized healthcare solutions



Healthcare information model in 3D virtual environments

Pros and Cons of Using Health Information Sensors

- Pros
  - Easy to design
  - High reliability
  - Scalable flexible systems
  - Minimum of interconnecting cables
  - High performance
  - Small rugged packaging
- Cons
  - In wired smart sensors, complexity is much higher and, as a consequence, the cost is also high
  - Required use of predefined embedded function during the design of the smart sensor
  - Requires both actuators and sensors
  - Sensor calibration has to be managed by an external processor