Future Challenges in Medical Informatics

- Ubiquitous Healthcare IT and Omics-based Medicine-

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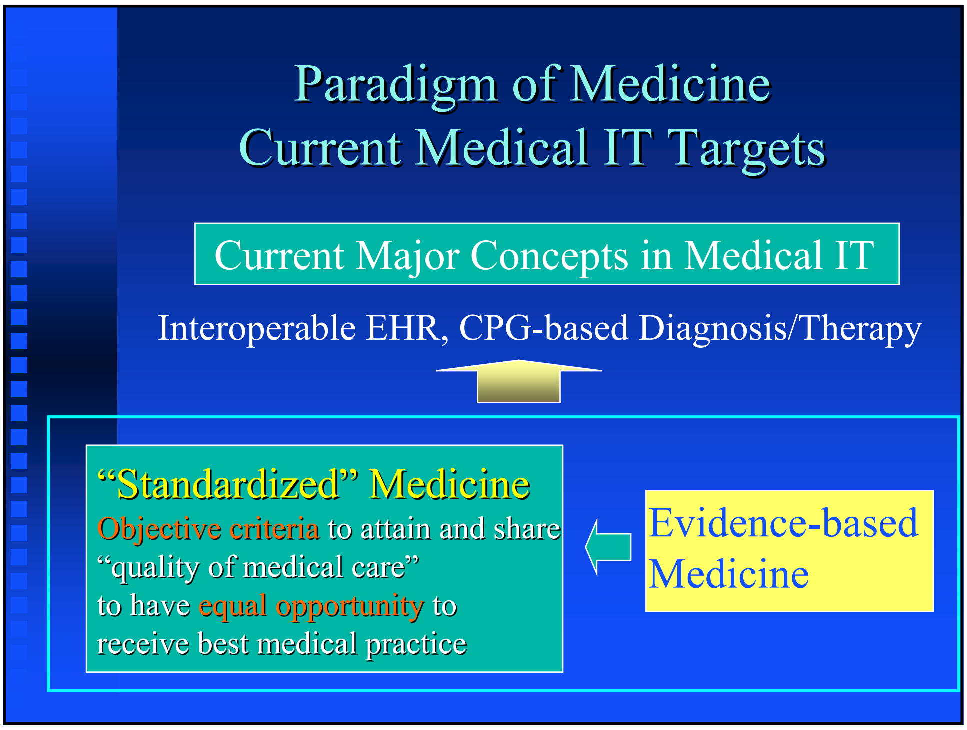
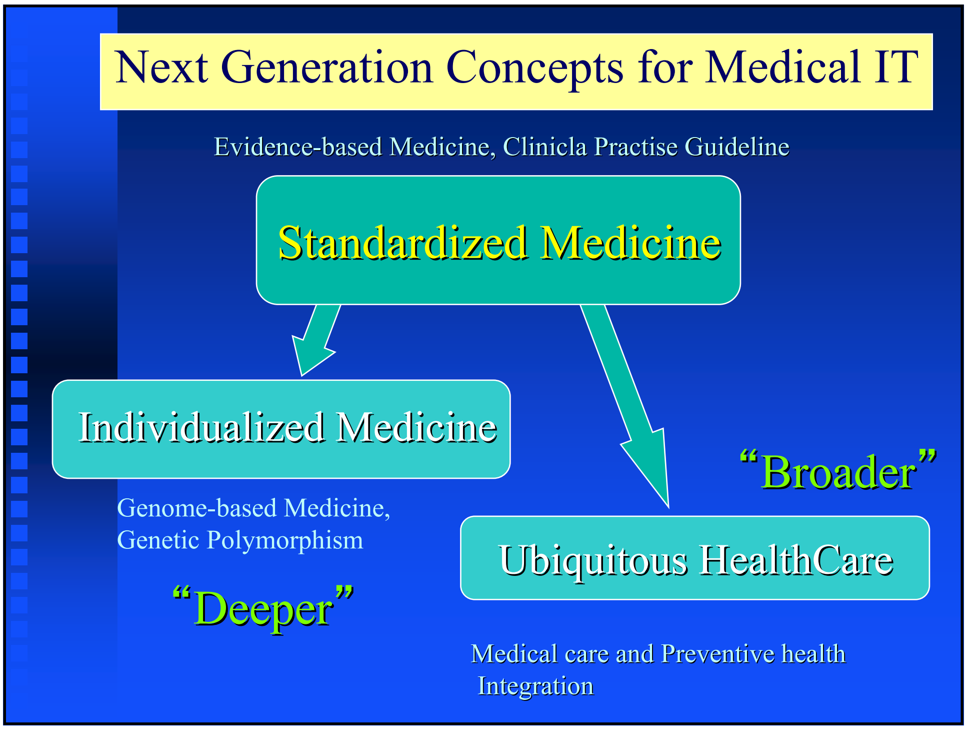
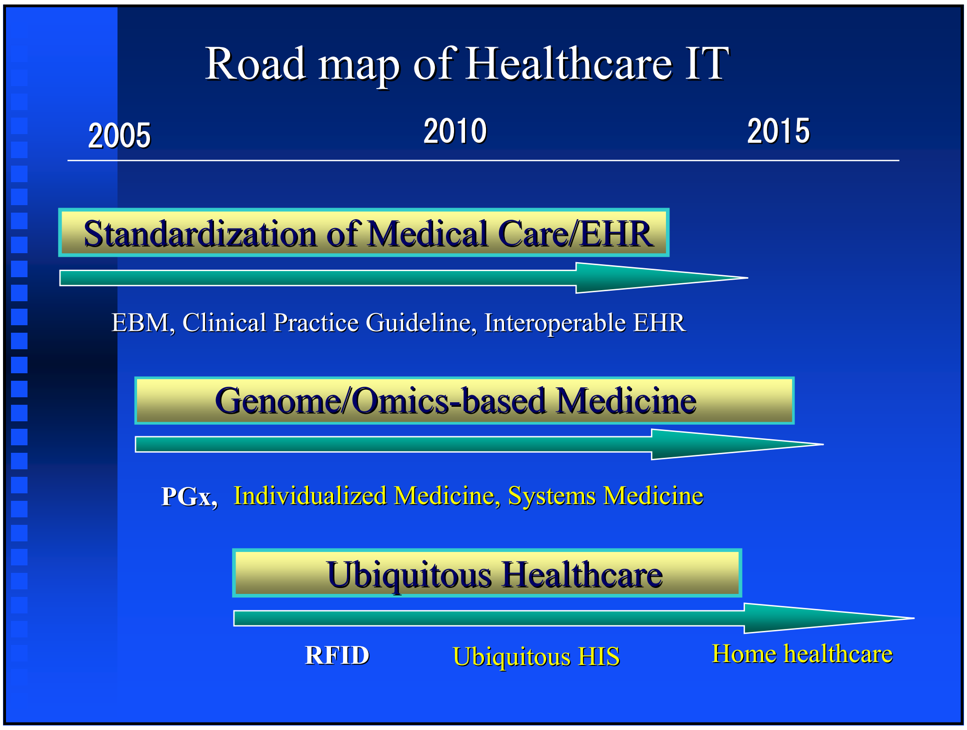
Challenges in Medical Informatics?

- Target disciplines we should tackle in coming age to extend and deepen our medical informatics field?
- Medical Informatics, Medical IT
  - It started with hospital-based technology primarily to implement clinical system.
  - Now, new paradigms of medicine are to be considered with deep relations to "information",

    such as, genomic medicine, standardization of medicine, ubiquitous healthcare IT and so on.
- Various Challenges are there, but we should think about them in relation to questions of what will be the key concept of future medicine.
  - Key paradigm of 21th cent. Medicine


Paradigm of Medicine
Current Medical IT Targets
Current Major Concepts in Medical IT
Interoperable EHR, CPG-based Diagnosis/Therapy
"Standardized" Medicine
Objective criteria to attain and share
"quality of medical care"
to have equal opportunity to
receive best medical practice
Evidence-based
Medicine


Next Generation Concepts for Medical IT
Evidence-based Medicine, Clinicla Practise Guideline
Standardized Medicine
Individualized Medicine
"Broader"
Genome-based Medicine,
Genetic Polymorphism
Ubiquitous HealthCare
"Deeper"
Medical care and Preventive health
Integration



Medical Informatics in Genome/Omics based medicine

“Genome medical informatics”

A new discipline of Medical informatics

supports the clinical realization of

Genomic Medicine

“Genomic Medicine”?

Medical Practice,

prevention, diagnosis, therapy and prognosis

based on Genomic information

Genomic Medicine and Informatics

Genomic Medicine

New!

Vast amount of Genomic/ Molecular data

Clinical-Patho physiological ordinary data

Should be supported

Genome Medical Informatics

(Clinical bioinformatics)

What kind of new possibility does genomic information bring about to clinical medicine?

well-known, most important contribution of genomic medicine

Medical Care can be Individualized

Tailor-made (individualized) medicine

- Genomic Polymorphism

  Human genome contains individual difference

  SNP

  Single Nucleotide Polymorphism

  One for 1000 bases, 0.1% , 3M to 10M bp

  Other types Micro-satellites, VNTR

- Individualized Medicine

  Disease susceptibility

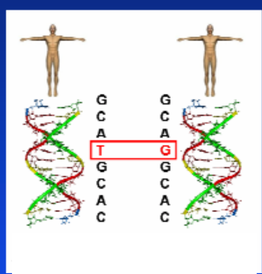
  Personalized genomic typing

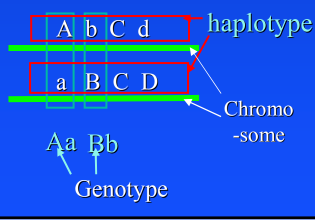
  Drug responsibility

  Phamacogenetics/genomics

  Hapmap project

  Haplotype DB project



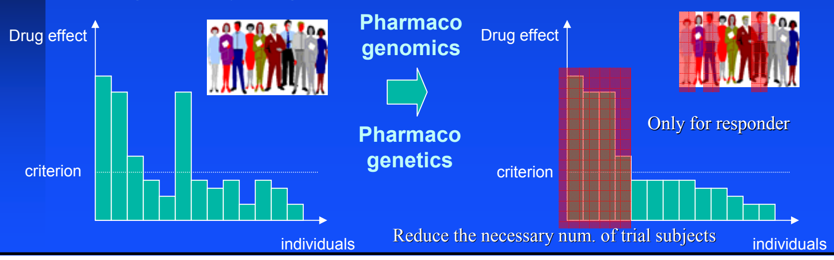


Drug will be administered depending on the individual genotyping

- Pharmacogenetics/genomics
  - Individual difference in drug response sometime causes serious side-effects
    - Irressa for lung cancer
  - Avoid useless drug administration (side-effect)
- DNA pre-diagnostic test for drug responsibility
  - FDA guidance recommends
  - Drug metabolism enzyme CYP450 60kinds
  - Herceptin for HER2 receptor for breast cancer

Tailor-made Drug Administration

Drug effects vary among individuals



What to do to support the genomic medicine

Genome Medical Informatics

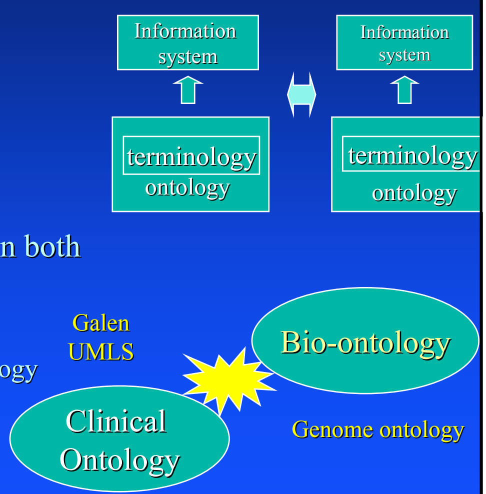
To adapt clinical information system to genomic medicine

- to organize clinico-genomic patient information
  - clinico-genomic ontology, genomic EMR
- to develop genomic healthcare information system
  - genomic preventive medical care

An example of Challenges in Genome Medical Informatics -Clinico-genomic ontology-

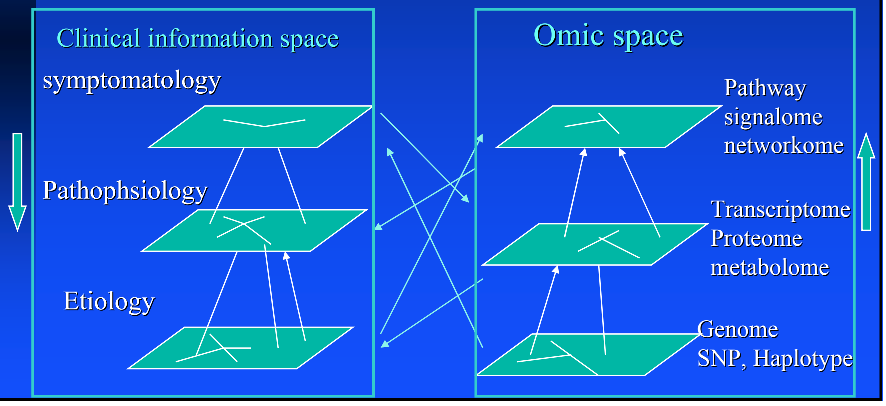
Ontology mismatch between Clinical thinking and Omics

- Ontology
  - System of Controlled vocabulary
  - Concepts and relations which support genomic medicine
- Excellent ontologies separately developed in both fields
- Mismatch
  - Between Clinical ontology and Bio-ontology



Clinical thinking and "Omic space"

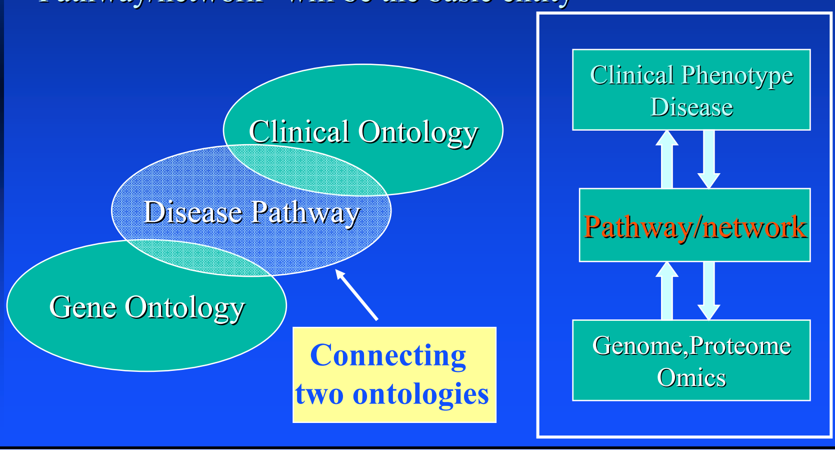
- Clinical thinking (Top down)
  - Organs and diseases are units of concepts
  - Traditionally disease is defined on pathological, morphological base
  - Relations are causal, attributable, consequential
- Omics world (Bottom up)
  - Molecular function and their functional relation to other molecules
  - Products of gene expression are units of concepts



Integrated clinico-genomic ontology

Comprehensive framework to join these two paradigms is requiredd

"Pathway/network" will be the basic entity



So far we are concerned with current state of GMI, But

Genomic Medicine is now revolutionarily changing

Omics-based medicine

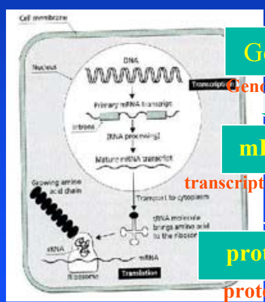
Genomic Medicine, Now extended to call Omics-based Medicine

Omics-based Medicine
Genome/Omics Medicine

Omics data

Genome/ics:
whole genetic information
Transcriptome/ics:
whole mRNA
Proteome/ics:
whole functioning proteins
Metabolome/ics:
whole metabolites

-omics



Gene
Genome
mRNA
transcriptome
protein
proteome

Then, what kind of new possibility does omics information bring about to clinical medicine?

Other than the individualization information

Omics information provides

Detailed and Comprehensive molecular information about current diseased states

Omics are provided by high-throughput equipments
DNA chip/microarray (transcriptome),
TOF-MS (proteome) etc.

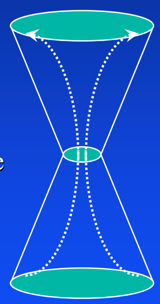
- Detailded Information
  - for subtypes/detailed structures of disease
  - Unobservable from conventional clinico-pathological tests
  - Detailed Diagnosis and Accurate Prognosis,
  - Early detection of disease
- Comprehensive Information
  - Wholistic understanding of disease
  - Leads to Systems pathology

For example

Omics data provides clinically and pathologically unobservable information

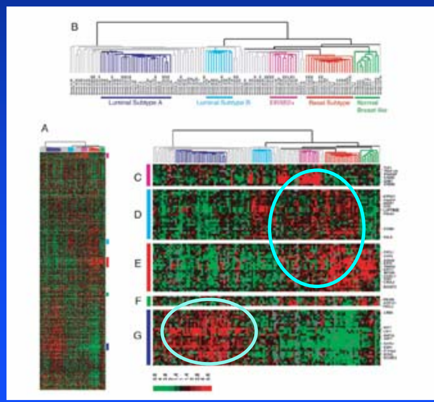
Same in pathology and clinical symptom
But different in Prognosis

Differences of Prognosis,
Disease Course



Pathology, Tissue
Same looking

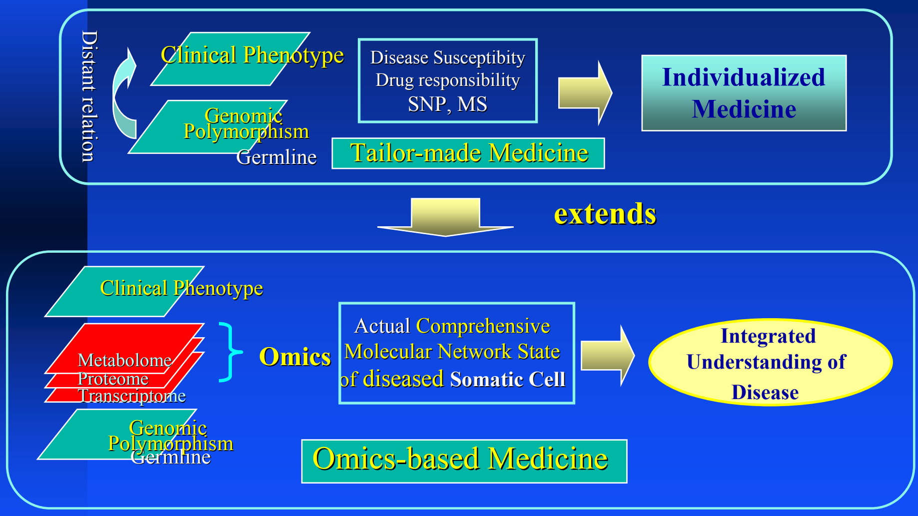
Abnormality in Molecular Network



Breast cancer

What is difference of Omics-based Medicine from Conventional Genomic medicine, or "Tailor-made Medicine"

Omics-based Medicine



Omics-base medicine Includes but extends. Empahsis on comprehesiveness

What kind of approach is necessary to fully utilize the Omics data for clinical diagnosis/therapy?

I propose…..

“Systems pathology”

Comprehensiveness of Omics data makes possible
to understand a disease as an integrated whole
Try to find disease mechanism behide the omics data

- System theory of disease
- Disease: systems failure of bio-process

Systems Pathology
Understand disease as disturbed systems

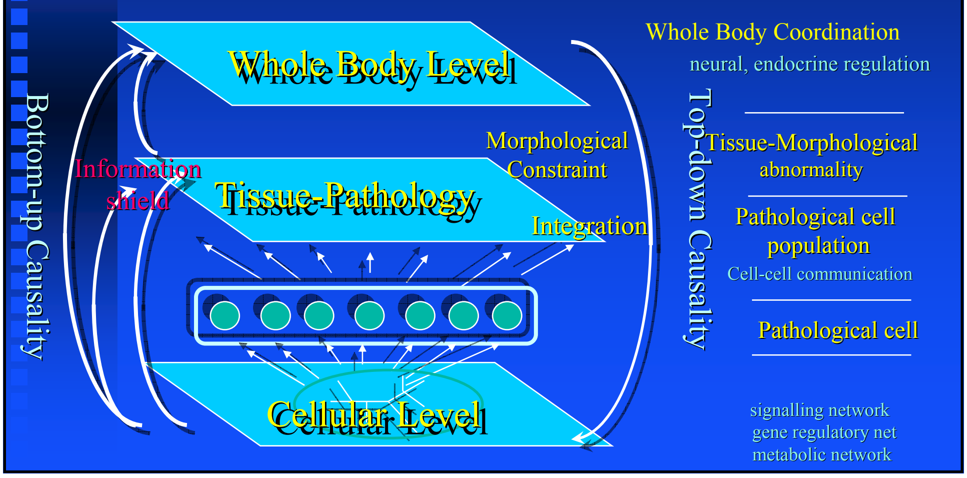
Normal pathway to Disease Pathway

Disease organizes itself → Formation of Disease pathway

The first key concept of systems pathology

Disease is hierarchically organizated integrated system

Clinical Level



Example: Hypertension

- Blood pressure raises by some abnormal supporting mechanism at early stage
  - Neural regulation
  - Hormonal regulation
- But after several months, if this condition is sustained, the genetic activity begins

to start capillary vascular remodeling

to sustain hypertension (adaptation by gene expression)

What does Omics-based Medicine bring about to clinical medicine

Individualization of Healthcare

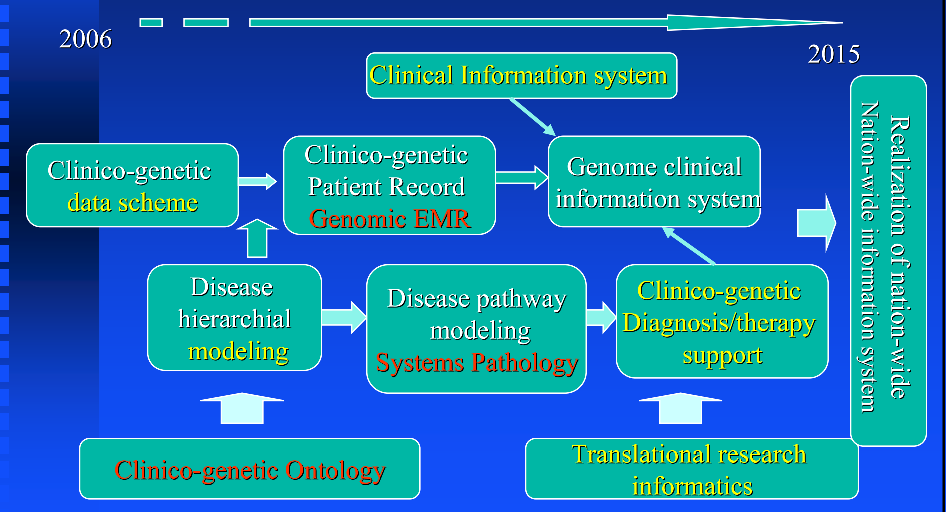
Specially drug administration

Comprehensive (system) understanding of disease

With omics data and systems approach

Road map of Genome Medical Informatics

Road map of Information system for genomic medical informatics



Ubiquitous Healthcare IT

Ubiquitous Healthcare IT

Healthcare IT Environment
where Anyone can receive Best Medical Care
"Anywhere, & Anytime"

Extension of Healthcare IT

From Conventional HIT
build on the wired network information system

To open/distributed environmental HIT
build on the wireless/open ad-hoc network

Concept of

Ubiquitous Computing & Network

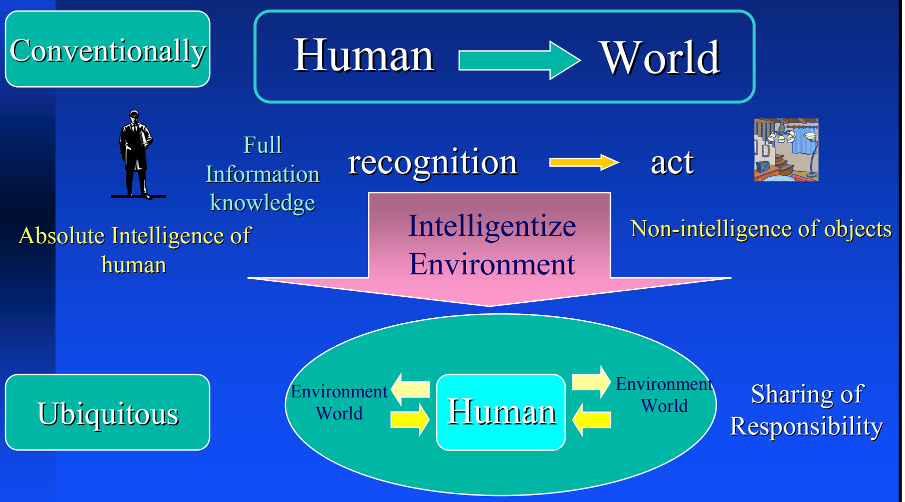
From Medieval Theological Concept "God exist anywhere"
(Xerox MarkWeiser1986)

Computer chips and networks are embedded in the daily environment so that users utilize them without any consciousness where they are.

■Invisible
■Embedded discernibly in the environment

Distribution of Computing into the Environment

Innovative Concept of Ubiquitous IT
in the human commitment
to his environment



Sharing of Information/knowledge

Key Concepts of Ubiquitous IT

- Autonomous
  - Unconscious, no need for human operation
- Context Awareness
  - Works depending on the situation

Sharing of the information and responsibility
with environmental computing and monitoring

Symbiosis between human and
machine intelligence

Conscious-free
Safe and Secure life

Ubiquitous Healthcare IT

**Application of Ubiquitous IT
To Healthcare**

"Ubiquitous Hospital IS"

Total IT-ization, Prevention of Medical Error

Emergency, Disaster IT

Ad-hoc distributed ubiquitous network

Ubiquitous Home Healthcare

IT-zation of Home Healthcare

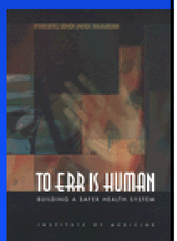
“Ubiquitous HIS” is the 4th generation of HIS

Ubiquitous Hospital Information System

- Excess-responsibility of Medical personnel
  - Should be liberated from Myth of Infallibleness
- “To err is human” （IOM report）
  - Deaths from medical error:44000 to 98000 (The 6th cause of death in US）
  - Cannot prevent by human efforts such as repetitive confirmation or checklist

Intelligentize Total Hospital Space

Automatically support the prevention of medical error by environment intelligentization



Ubiquitous IT-ization of Hospital

Total IT-ization of Hospital

IT-ized Gap still remains
in conventional HIS/EMR

Prevention of Medical Error

Intelligentization of medical practise
environment

Generations of Hospital Information Systems

The 1st generation Departmental Systems

～75 Accounting, Financial system

Laboratory, pharmacy

The 2nd generation Order-entry systems

～85 Labo test order

Drug administration order

The 3rd generation EMR(Electronic Medical Record)

～95 Clinical Findings

image, schema,critical path

Limitation of Conventional HIS/EMR-S

Conventional
Information System

Field of Medical Practice

Physian→injection order→Nurse

Nurse→Injection→Patient

Conventional HIS

Field of Medical Practise

Next generation HIS

Extend the information system to spann the IT-net to cover the field of medical practice

HIS/EMR-S

Space Intelligentization

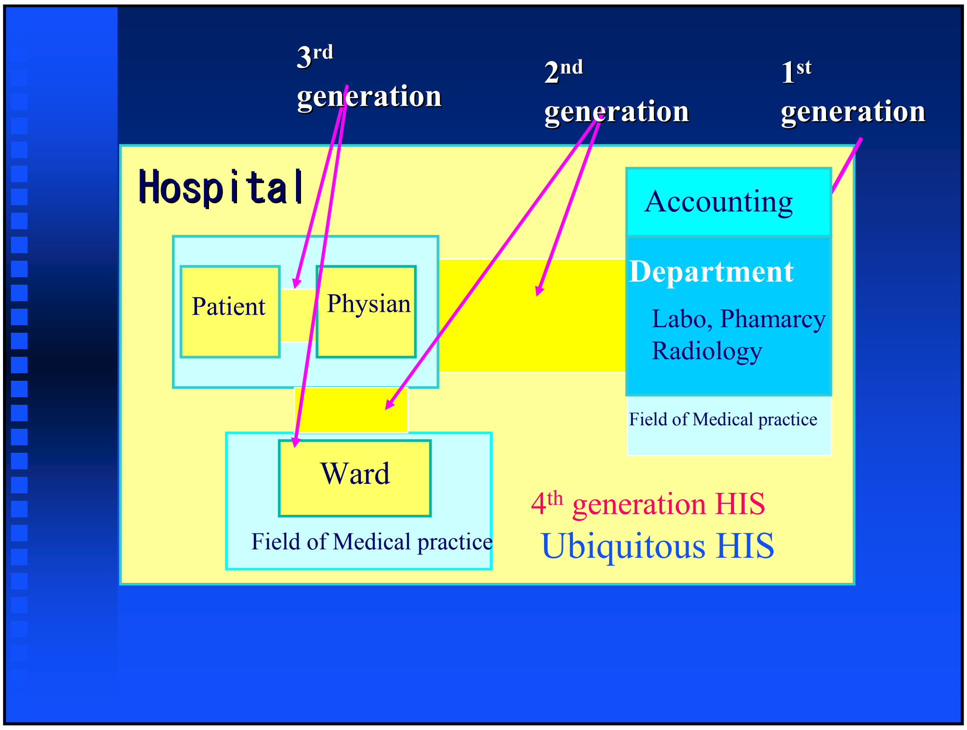
Intelligent Space

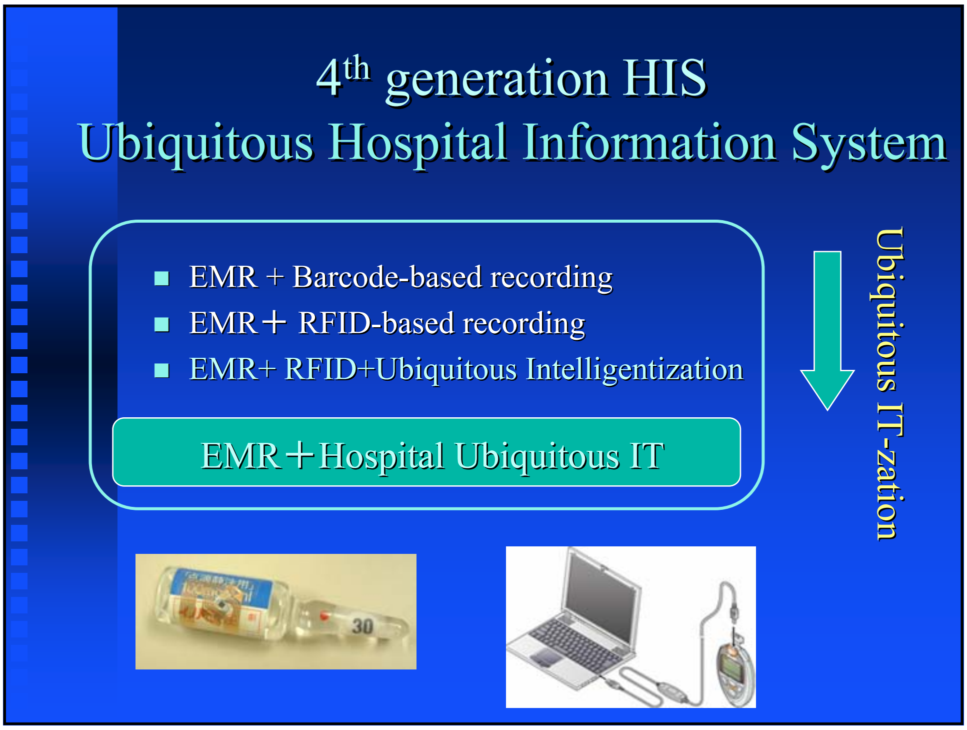
Initial trial

Recording of Execution by Bar-codes
Nurse－Injection－Drug－Patient Wrist Band
（International Medical Center of Japan POAS）

But Barcode: not autonomous and without multiple recognition

⇨ Expectation for IC-tag, RF-ID


3rd generation
2nd generation
1st generation
Hospital
Accounting
Department
Labo, Phamarcy
Radiology
Field of Medical practice
Patient
Physian
Ward
Field of Medical practice
4th generation HIS
Ubiquitous HIS

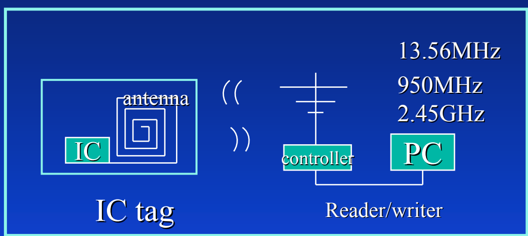

4th generation HIS
Ubiquitous Hospital Information System
EMR + Barcode-based recording
EMR＋ RFID-based recording
EMR+ RFID+Ubiquitous Intelligentization
EMR＋Hospital Ubiquitous IT
Ubiquitous IT-zation
30

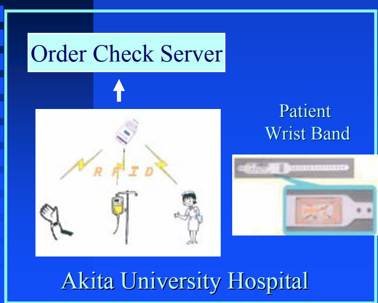
Stages of Ubiquitous IT-ization

- Elemental stage: Automatic Identification
  - Automatic Identification of Objects
    Drug and Medical material, Patient by RFID
- Advanced stage: Environment Intelligentization
  - Ubiquitous Monitoring of
    - Patient Pathophysiological State (Vital sign etc)
    - Patient Physical/Behavioral State (Location Movement etc)
    - Medical Staffs' Medical Practice (Location, Acts)
  - Sensor-attached IC-tag for monitoring patient/staff information
  - Intelligentization of Hospital Environment
    - Administration of hospital space

Elemental Stage: Identification

1. Efficient SCM
2. Prevention of Medical Error





Smart Medicine Cabinet

Monitors the medicine that is placed in or taken out by a patient or pharmacist and displays information about prescriptions, incompatibilities or recalled drugs.

Department of Computer Science
Institute for Pervasive Computing,
Swiss Federal Institute of Technology Zurich

Smart Surgical Kit

The usage of bandages and swabs during a surgical operation is monitored and the usage status is displayed to avoid leaving any operation tools in the patient.

Department of Computer Science
Institute for Pervasive Computing,
Swiss Federal Institute of Technology Zurich

Intelligentization of Total Hospital Space

Total IT-ization of Hospital =

Conventional HIS/EMR +

Intelligentization of Hospital Space

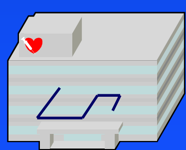
Ubiquitous Monitoring of

Patient Pathphysiological /Behavioral State

Medical Staffs' Pratise

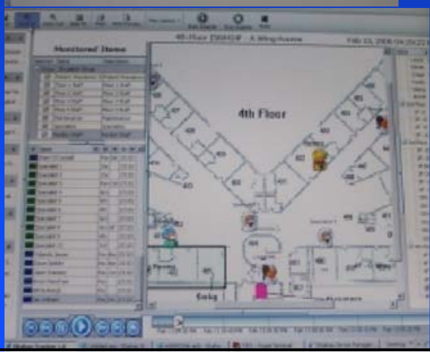
Ubiquitous Position Sensing

- Location-sensor
- Ubiquitous Motion Monitoring
  - Efficient administration of staffs in ER・ICU
  - Administration of clean area and infectious space
  - Space recognition and Tag-based identification



IntraHospital Location Tag

Monitor



Active Tags

Monitoring Patient Vital sign

Temperature sensor

Respiration sensor

ECG sensor

pCO_2,pO_2 sensor

Other Vital sign sensor

RFID

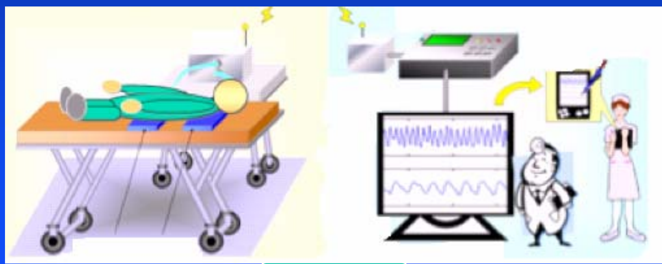
Active, passive

Smart stretcher

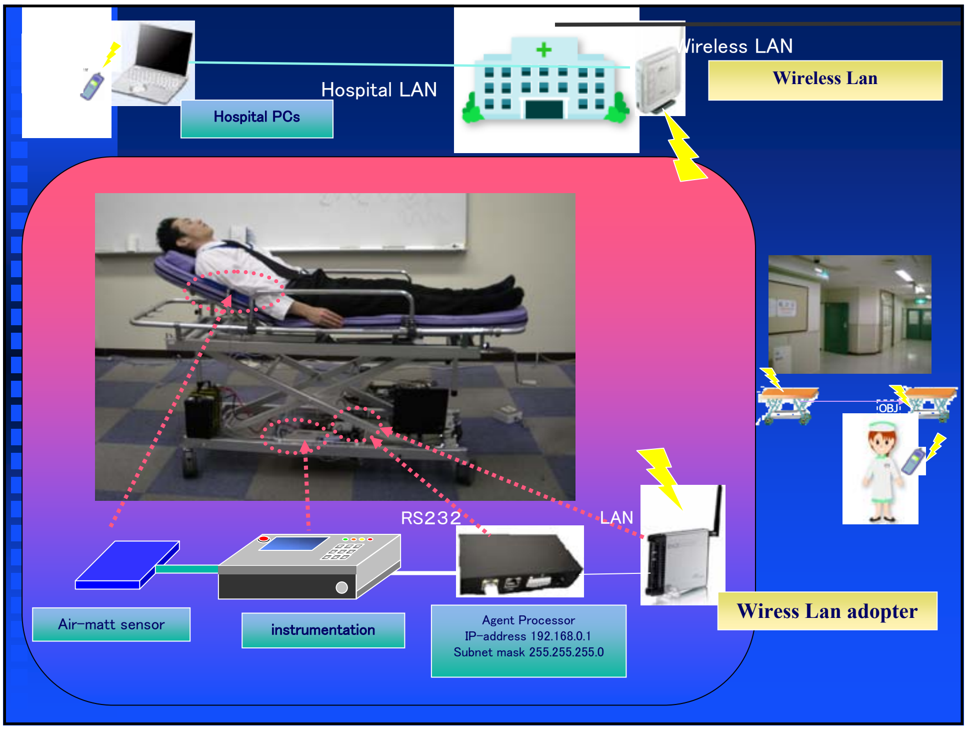
Continuous monitoring of vital signs

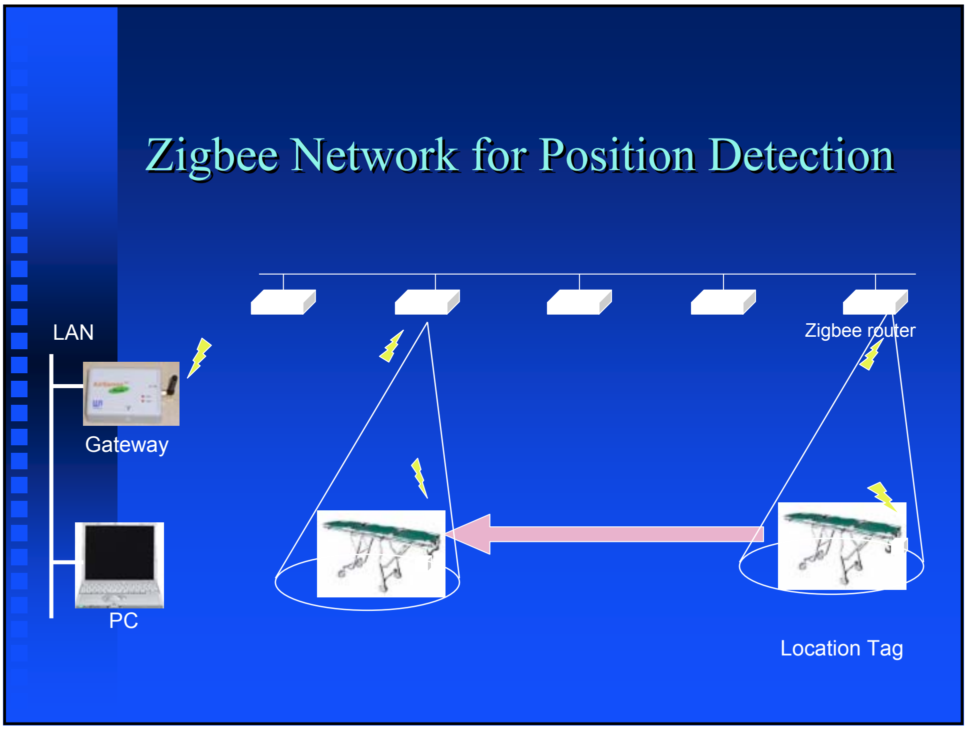
Automatic vital sign monitoring

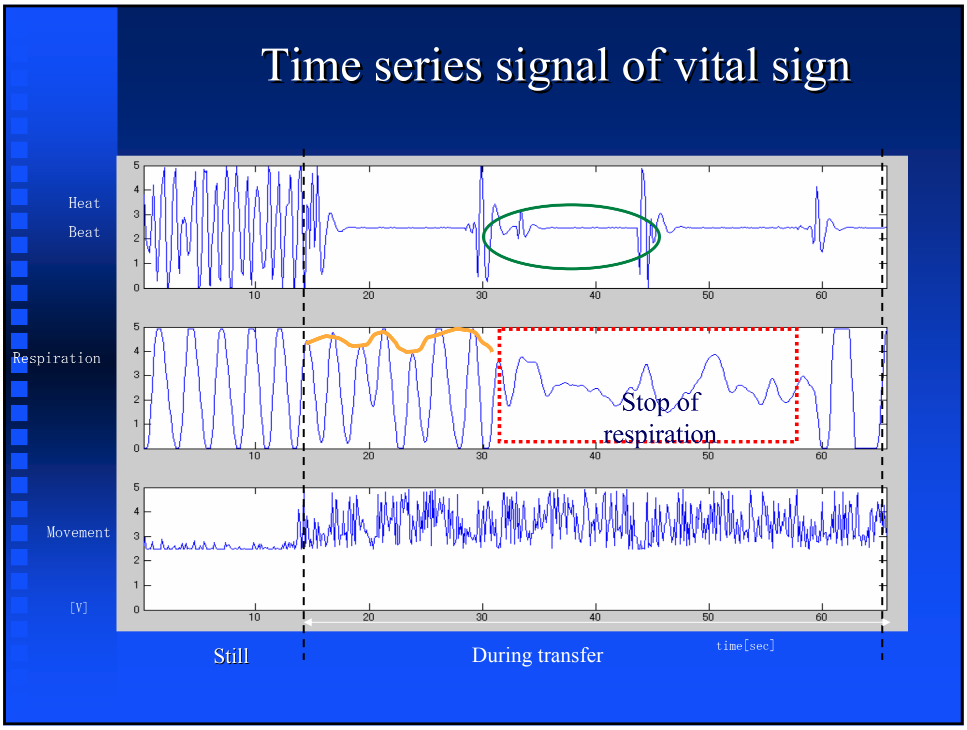
transmitter Wireless Network receiver



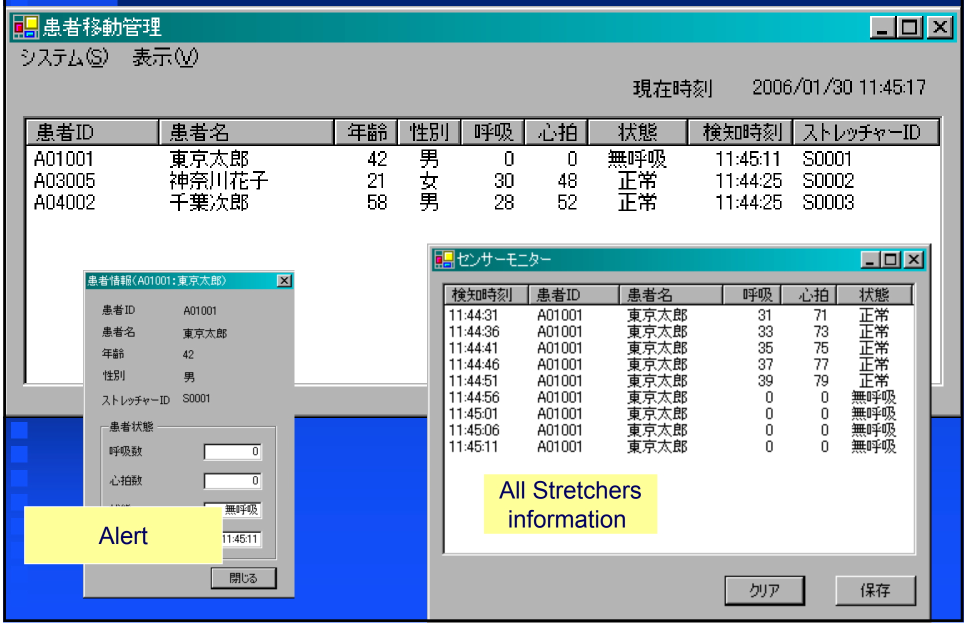
transfer




Zigbee Network for Position Detection
LAN
Gateway
PC
Zigbee router
Location Tag

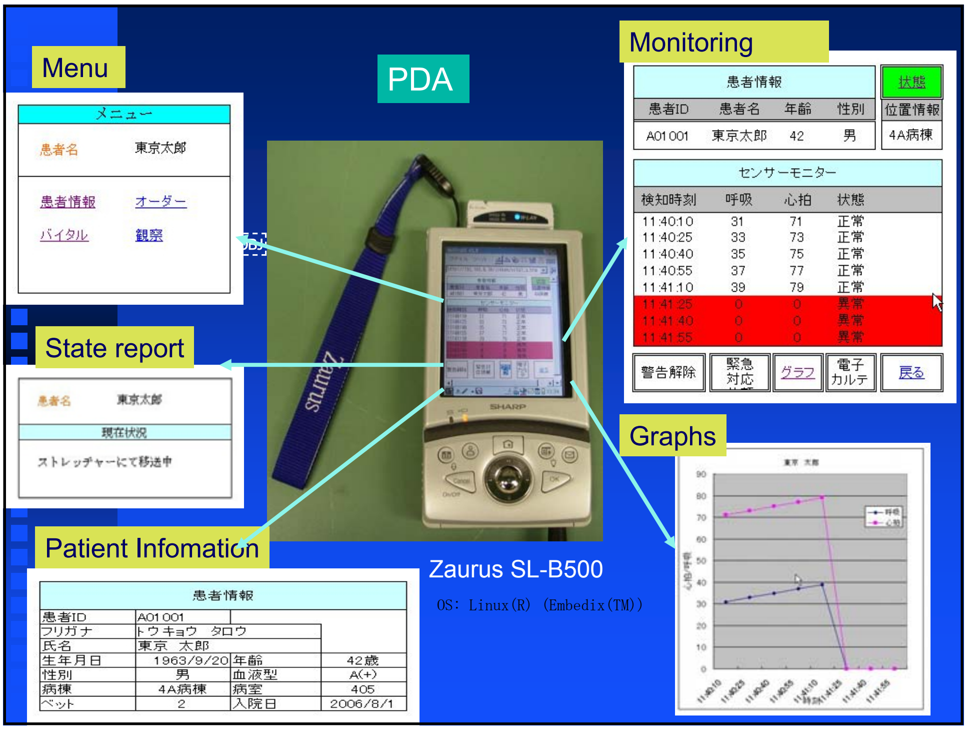

Time series signal of vital sign
Heat
Beat
Respiration
Movement
[V]
Stop of
respiration
Still
During transfer
time[sec]

Alert systems



Smart stretcher

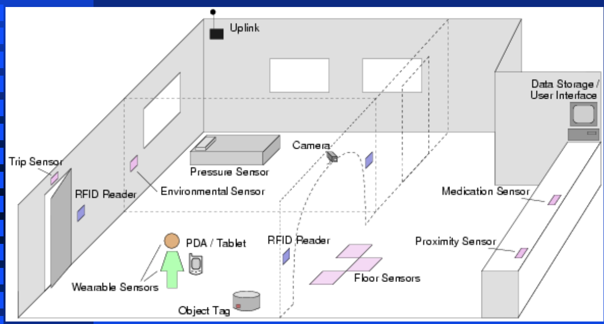
Respiration Wireless Monitor



Continuous Location monitor of smart stretcher (Monitor Image)

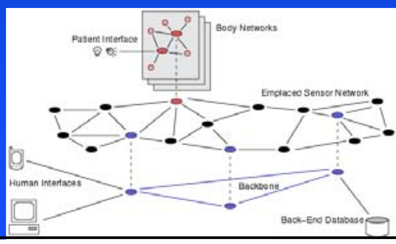
Home Healthcare IT

Home Healthcare IT

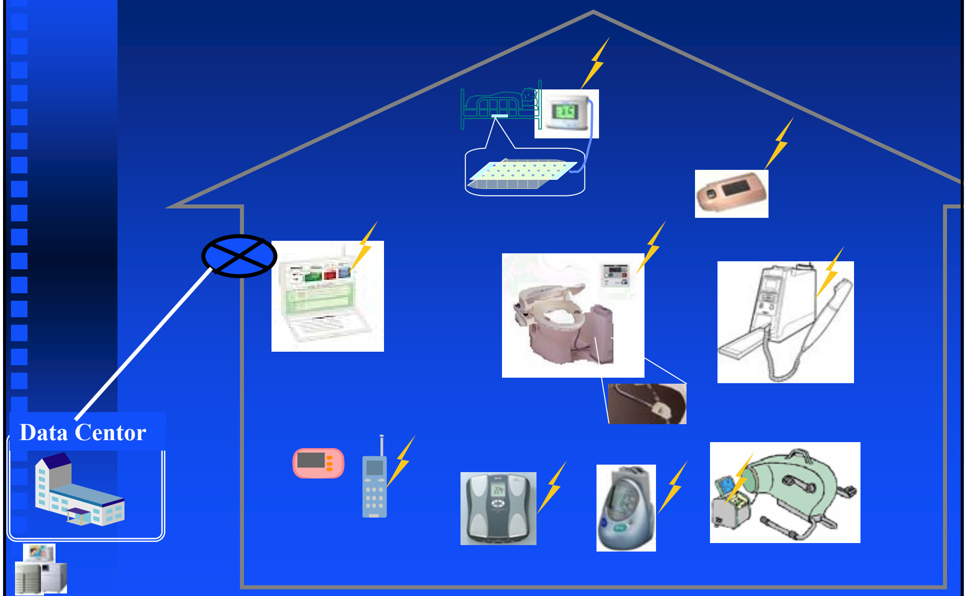


Virginia University

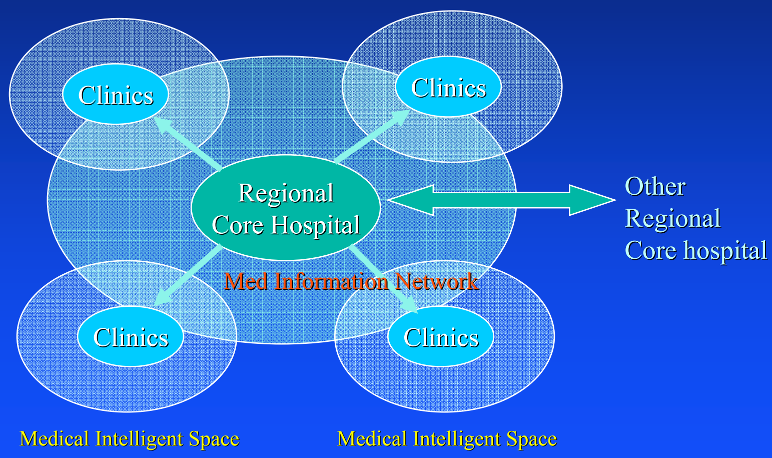
WWBAN: Wearable wireless body area network (Mayo)



Home Healthcare Devices



Structure of Medical Information Sphere

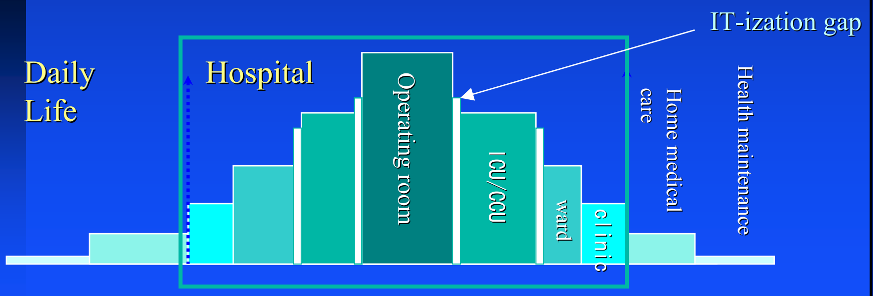


Medical Intelligent Space

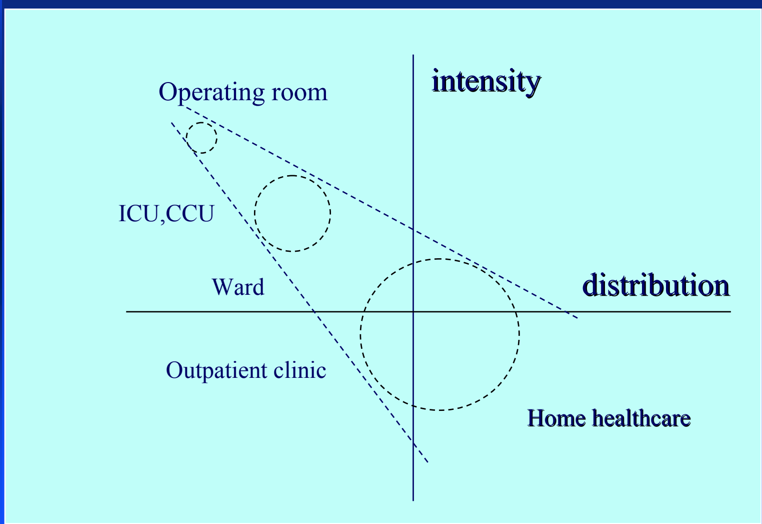
Medical Intelligent Space

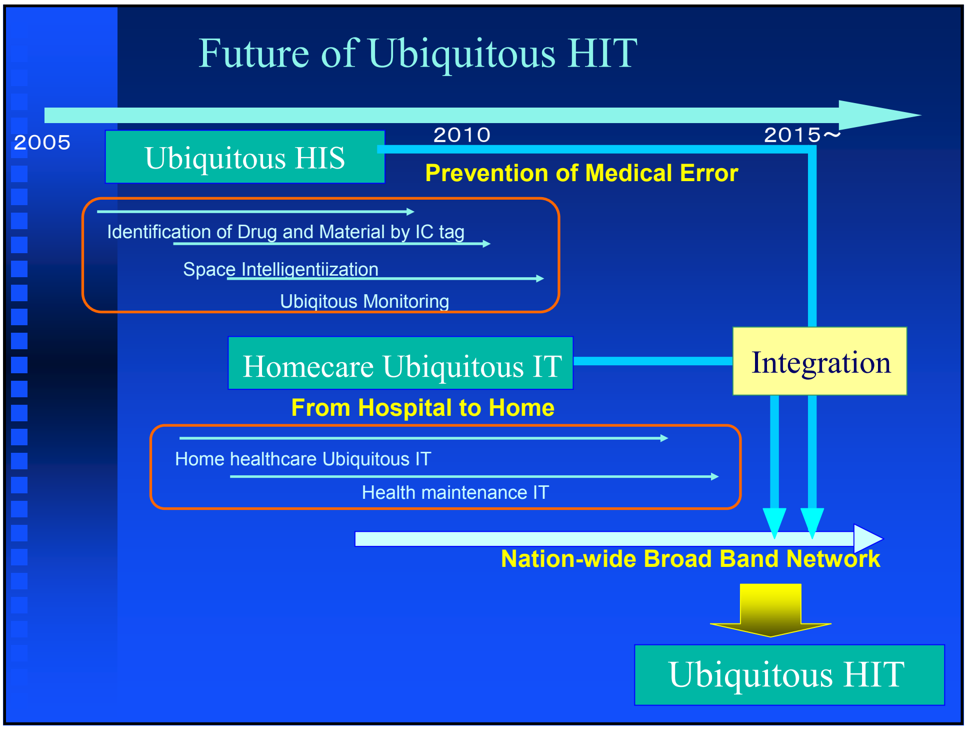
HTTH: Hospital to the Home

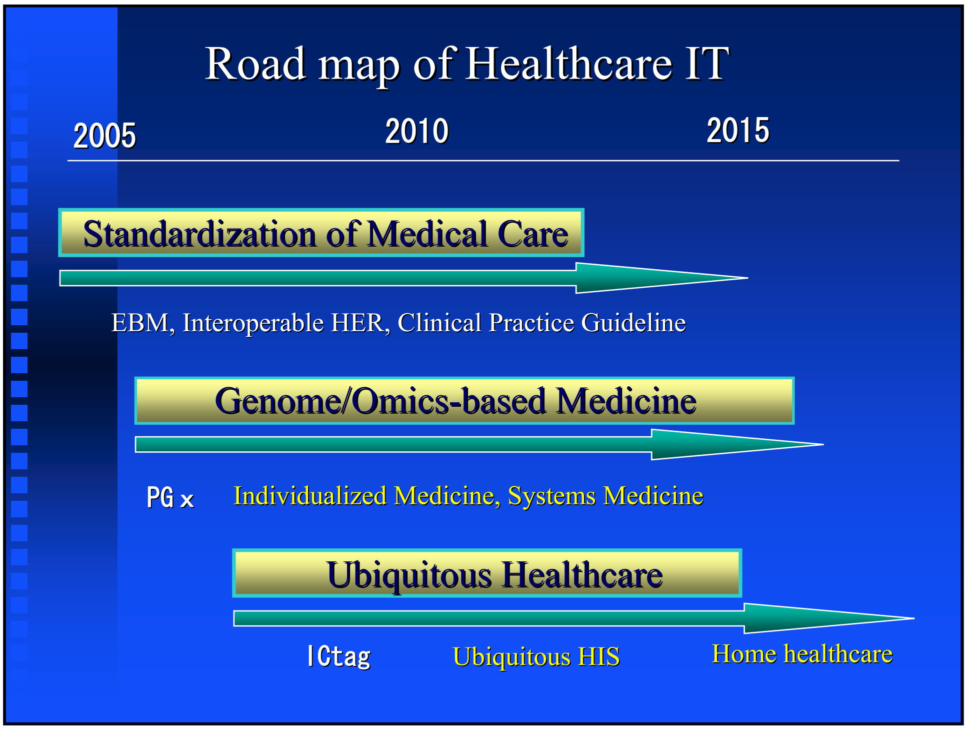
- Intensity and distribution of MI
  - Operating room: Most dense MI-Space
  - ICU, CCU, Ward, Outpatient clinic, Home care



Intensity and Distribution of Medical Information




Future of Ubiquitous HIT
2005
2010
2015～
Ubiquitous HIS
Prevention of Medical Error
Identification of Drug and Material by IC tag
Space Intelligentiization
Ubiqitous Monitoring
Homecare Ubiquitous IT
Integration
From Hospital to Home
Home healthcare Ubiquitous IT
Health maintenance IT
Nation-wide Broad Band Network
Ubiquitous HIT


Road map of Healthcare IT
2005
2010
2015
Standardization of Medical Care
EBM, Interoperable HER, Clinical Practice Guideline
Genome/Omics-based Medicine
PGｘ
Individualized Medicine, Systems Medicine
Ubiquitous Healthcare
ICtag
Ubiquitous HIS
Home healthcare

Thank you for attention