Medical Informatics  
IT VT2001  

Introduction to Medical Informatics  
- an overview -  
Sabine Koch

Medical Informatics  

What?  
Development and application of ICT-based methods for acquisition, representation, processing, presentation, communication and management of data, information and knowledge in medicine and health care.

Medical Informatics  

Why?  
• increasing amount of health and medical information  
• economic benefits  
• enhanced quality and efficiency of health care

Medical Informatics  

How?  
The goal of health and medical informatics (HMI) is to enhance quality and efficiency of health care by systematic use of information and communication technology, reducing economic and financial resources, if possible.

Interdisciplinarity  

Health and medical informatics (HMI) is an interdisciplinary discipline that is studied from the point of view of  
• medicine  
• computer science  
• technical and natural science  
• resource and work-flow management  
• economy  
• ethics  
• law

HMI and adjacent specialties  

natural science & technical specialties  
Health and Medical Informatics  
Medical specialties  
social and economical specialties
HMI and adjacent specialties

- Medical specialties
  - Medicine
  - Dentistry
  - Nursing
- Health and Medical Informatics
  - Dental Informatics
- Biomedical Engineering
  - Biomedical Statistics
- Social and economical specialties
  - Pharmacy
  - Biology
  - Biomedical Engineering
  - Computer Science

Biomedical Engineering

Usage of physical and technical principles in order to solve biomedical problems especially with regard to diagnosis and therapy

Biomedical Engineering

Typical developments:
- Imaging devices
  - e.g. Nuclear magnetic resonance tomography (MR)
  - Computer tomography (CT)
  - Position emission tomography (PET/SPECT)
- Biosignal monitoring hardware
  - e.g. Electrocardiogram (ECG)
  - Electroencephalogram (EEG)
- Radiation therapy equipment (e.g. Gamma knife)
- Surgical instrumentation
- Other devices, e.g. dialysis, laboratory analysis

Bioinformatics

- Cooperation of biology, biochemistry, genetics and computer science
- Application of computer science methods and concepts to biological science
- Analysis of biological systems

Bioinformatics

Typical activities:
- Human Genome Project
- Molecular databases
  - e.g. EMBL: gene sequencing
  - SWISSPROT: protein information
  - KEGG: info about biochemical reactions
  - TRANSPATH: info about signal pathways
- Drug design
- Simulation of cell organisms

HMI range of applications

- Health information systems
- Health administrative systems
- Biomedical- and biomedical image processing
- Modeling and simulation of complex biomedical systems
- Information coding, classification, indexing and retrieval
- Knowledge representation and medical decision support
- Biomedical statistics and epidemiology
- Telemedicine
- Virtual reality
Health information systems

- Hospital information systems (HIS)
- Primary care information systems
- Radiology information systems (RIS)
- Picture archiving and communication systems (PACS)
- Other departmental information systems

Hospital information system

**Purpose**
Provide the right information at the right time and the right place in order to allow for effective and efficient job performance of health care personnel in a hospital

**Requirements**
- acquire, process and present patient-specific data
- coordinate and facilitate communication
- provide short and long-term planning decisions

Hospital information system

**Functional model** (Friedman/Martin)
1. Core systems = patient oriented administration
2. Business and financial systems
3. Communication and networking
4. Department management system
5. Medical documentation systems
6. Medical support systems

Hospital information system

**Administrative functions**
- Patient oriented functions
  - Patient scheduling
  - Patient admission and discharge
  - Clinic and waiting list management
  - Billing
  - Statistics
- Non patient oriented functions
  - Financial management
  - Stock management
  - Management of personnel and human resources

Health administrative systems

An administrative system (in its widest sense) could cover the totality of administrative, demographic, social, healthcare and clinical data contributing to decision making processes within the healthcare system

**Tasks**
- Patient administration
- Health care cards
- Patient authentication
- Data protection and privacy
- Data analysis and evaluation (e.g. demographic data)

Health administrative systems

**Features**
- Common administrative solutions to specific problems related to the health sector, regardless of environment (e.g. health centres, hospitals, nursing homes)
- Use of generic products, e.g. financial services, scheduling programs, graphics and statistical programs
Biosignal- and biomedical image processing

Purpose of biosignal analysis
Derivation of information for diagnosis and patient monitoring

Bio(logical) signals
- electric (e.g. nerve cell, heart)
- mechanical (e.g. heart valve sound)
- chemical (e.g. blood)

Biosignal analysis

Steps of biosignal analysis
1. Signal acquisition
2. Transformation and reduction (noise elimination) of the signal
3. Computation of diagnostically significant signal parameters
4. Signal classification and interpretation

Applications
- Electroencephalogram (EEG)
- Electrocardiogram (ECG)
- Electromyogram (EMG)
- Spirogram

Medical image processing

Purpose of medical image processing
Derivation of information for diagnosis, therapy planning, clinical documentation and patient motivation

Medical images
- photographs
- radiographs
- ultrasound
- CT, MRI, PET, SPECT, DSA
- gamma camera images
- cell images

Image processing steps
1. Image acquisition
2. Image transformation (pre-processing)
3. Image segmentation
4. Feature selection
5. Image classification

Applications
- Image enhancement
- Image restoration
- Image recognition
- Image compression
- Image registration
- 3D Visualisation
- Multimodal image analysis and processing
Modeling and simulation of complex biomedical systems

- Processes and systems are modelled and simulated to get insight into the structure and behaviour of the systems (e.g. disease course simulation)
- Models and simulation can also be used to support a process or a function of the system under consideration (e.g. intensive care monitoring)

Mathematical modeling

Transformation of knowledge about a system’s structure and behaviour expressed as verbal description into formalised and unambiguous description expressed in mathematical language

\[ \frac{dn}{dt} \] Substance is distributed between intravascular and extravascular space and it is eliminated by a process occuring in close contact with blood plasma.

Model types

- Continuous-state models
  - Classical physics and chemistry - differential equations
- Discrete-state models - queue systems
  - “Particle” physics and chemistry - statistics and discrete algorithms
- Mixed-state models
  - Some parts are continuous and some parts are discrete

Real systems are neither continuous nor discrete - the models are

Information coding, classification, indexing and retrieval

Classification

Systematic order of terms according to predefined features; each term is classified, i.e. belongs to a certain class
\( \rightarrow \) useful for statistical data analysis

Nomenclature

Systematic order of terms according to predefined features; each term is indexed by a defined number of indices
\( \rightarrow \) useful for data retrieval

Medical coding systems

- ICD (International classification of diseases)
- ICD-O (- oncology)
- ICPC (International classification of primary care)
- SNOMED (Systematized nomenclature of medicine)
- CPT (Current Procedural Terminology)
- DRG (Diagnosis Related Groups)

Standards for medical data exchange

EDIFACT
Electronic Data Interchange for Administration, Commerce and Transport:
- Standard for exchange of patient-related data (mostly Europe)

HL7 - Health Level 7:
- Standard for exchange of patient-related data (mostly USA)

DICOM (ACR-NEMA)
Digital Imaging and Communication in Medicine:
- Standard for transmission of images and image-related data between imaging devices and health information systems as HIS, RIS and PACS
Knowledge representation and medical decision support

Types of knowledge
- **Formal knowledge**
  - based on cognition or deduction
  - source: medical literature
- **Experimental knowledge**
  - based on recognition or induction
  - source: clinical experience

Dilemma:
Adaptation of general medical knowledge to a specific patient case
- **data quantity**
  - complex, heterogeneous data in a variety of sources
  - high demands for knowledge retrieval, navigation and visualisation
- **data quality**
  - medical knowledge is often unstructured, inconsistent and ambiguous
  - high demands for standardisation of medical knowledge and quality assurance measures

Medical decision support (Shortliffe)
- **Clinical algorithms**
  - e.g. alert functions in patient monitoring
- **Clinical databases with analytical functions**
  - e.g. drug-drug interactions
- **Mathematical pathophysiological models**
  - e.g. compute effect of drug infusion
- **Pattern recognition systems**
  - e.g. classification of type of white blood cells

Biomedical statistics and epidemiology

**Biomedical statistics**
Development and application of statistical methods in medicine and biology

**Tasks**
- survival analysis,
  - e.g. studying time of clinical onset, death or healing
- clinical trials
  - e.g. pharmaceutical experiments
- longitudinal studies
  - e.g. diminution of infection risk after vaccination
Biomedical statistics and epidemiology

Epidemiology (part of biomedical statistics)
The study of health and disease in large human populations

Tasks
• understanding the relationship between health risks and influencing factors, e.g. lung cancer - smoking
• special statistical methods necessary because the data is mostly based on observations instead of planned trials
• Problem: spurious correlations / fallacies e.g. child birth - storks

Telemedicine
The usage of telecommunication and information technology in order to fulfil health care services independently of the location of the health care provider, the patient, the data/information or the medical equipment needed

Telemedicine - examples (1)
• Telediagnosis: Diagnostic interpretation for the patient of a remote physician (e.g. Telecardiology)
  - interactively when patient is present (Telepresence)
• Teleconsultation: Remote access on specialist knowledge for second opinion (e.g. Teleradiology)
• Telemonitoring: Remote monitoring of non hospitalised patients (e.g. Fetal monitoring)
• Tele Home Care: Health care services in the patient’s home (e.g. older patients, chronic diseases)

Telemedicine - examples (2)
• Teleeducation: Remote patient / professional education
• Telecooperation: e.g. physician / laboratory or cooperative diagnosis between experts
• Remote clinical sessions: e.g. remote diagnosis
• Remote database access: e.g. laboratory results, epidemiological data
• Telesurgery: Robotic surgery guided by a remote expert

Virtual reality
Applications in medicine
• Diagnosis
• Treatment planning
• Therapy
• Patient information and rehabilitation
• Education and Training

Virtual reality - Diagnosis
Transparent volume visualisation
Virtual reality - Diagnosis

Interactive dynamic simulation and analysis

Virtual reality - Treatment planning

Intuitive interaction mechanisms

Virtual reality - Therapy

Computer manufactured mechanical templates

Planning

CAM Template

Surgery

- Stereo-lithography
- Machine milling

Virtual reality - Patient information

Haptic simulator for tooth brushing

Quelle: http://www.ipr.ira.uka.de/~salb

Virtual reality - Patient information

Haptic simulator for tooth brushing

Haptic manipulation

Quelle: http://www.ipr.ira.uka.de/~salb
Virtual reality - Education and training

- Presentation of otherwise impossible views
- Realistic visualisation of rare clinical cases and scenarios
- High availability
- Reproducibility and comparability
- Enhanced communication

VoxelMan - 3D Anatomy

- Data: “The Visible Human Project”
- Segmentation of anatomical structures
- Shading of situations
- Semantic database

Collaborative net based learning in VR environments