Imaging systems and Telemedicine

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Imaging and Imaging informatics

Just about any source of spectral energy is used to create images.

Various parts of the body impose different modalities.

Today, digital methods are being used in all cases, so the informatics aspect of imaging becomes ever more important.
Roles for imaging in medicine:

Diagnosis
Assessment and planning
Guidance of procedures
Communication
Education and training
Research
Tasks for imaging informatics - the four steps of image processing

- Image generation
- Image management
- Image manipulation
- Image integration
Image generation-techniques and their history

Energy sources:
Visible light, e.g. diaphanoscopy, microscopy
X-ray (Roentgen 1895): film-based and digital radiography
Radioactive isotopes in nuclear medicine imaging
Ultrasound (echosonography), around WW II
Magnetism: Nuclear magnetic resonance
Image generation-techniques and their history

Reconstruction methods:
Contrast radiography introduced in 1902 to overcome problem of structure overlay in standard radiography
Angiography (cardioangiography) in 1923
X-ray (Roentgen 1895): film-based and digital radiography
Radioactive isotopes in nuclear medicine imaging
Ultrasound (echosonography), around WW II
Magnetism: Nuclear magnetic resonance, post WW II
Image generation-techniques and their history

Higher Dimensionality:
Many radiographic techniques, even without aid of computations, allow for some sort of 3D visualization.

Ultrasound, however, needs to have a 3D locating device to be attached, giving position and orientation of slice in space. In the 1970s, visualization used vector graphics based on
## Image generation - Current status of methods

| Table 14.1. Comparative imaging parameters for alternative imaging modalities. |
|-----------------|------|-------|------|------|------|
|                  | CR   | MRI   | CT   | US   | NM   |
| Pixels per image | 2,048 × 2,560 | 256 × 256 | 512 × 512 | 512 × 512 | 128 × 128 |
| Bits per pixel   | 12   | 10    | 12   | 8    | 8    |
| Typical number of images per study | 2 | 100 | 60 | 30 (plus dynamic series) | 30 |
| Bytes per study$^a$ | 20 million | 12 million | 30 million | 7.5 million (for static images only) | 0.5 million |
| Contrast resolution | Low | High | High | Low | Low |
| Spatial resolution | High | Low | Moderate | Moderate | Low |
| Temporal resolution | Low | Low | Moderate | High | High |
| Radiation | Moderate | None | Moderate | None | Moderate |
| Portability | Some | No | No | Yes | Yes |
| Physiological function | No | Yes | No | Yes | Yes |
| Cost | Moderate | High | High | Low | Moderate |

CR = computed radiography; MRI = magnetic resonance imaging; CT = computed tomography; US = ultrasound; NM = nuclear medicine.

$^a$ We assume that 2 bytes are needed per pixel for images that have a pixel depth of 10 or 12 bits.
Current trends in imaging:

- 3D
- PC based image handling
- Display of function
Image management- Basic Concepts

Image acquisition: analog vs. digital

Storage requirements: hardcopy vs. softcopy, storage space, compression, input modalities…

Image transmission: integration of distributed viewing stations, online image databases, simultaneous viewing… using broadband coaxial or fibreoptic cable

Standardization of formats: TCP/IP is dominant low- level protocol used in medical imaging. Vendor- neutral format is DICOM.

Display capabilities: consoles must match analog viewing stations, flexible viewing format…

Cost: some modalities are more easy for digitalization => only partial implementation of PACS in many departments and less cost reduction than anticipated.
Image management-
Picture archiving and communication system (PACS)
PACS: still only a few available worldwide, but number is growing

Teleradiology: growing possibilities, sometimes limited by licensing of specialists within …

Image manipulation - Basic concepts

Image processing: transformation of several images into one, or into an abstract representation of contents, e.g. 3D volume image from 2D slices, labeling...

Global processing: computations on entire image to enhance visibility etc.

Segmentation: extraction of regions of interest by edge-detection of feature detection, and maybe input into automated classification.
Image analysis- current status

Completely automated image analysis does not exist! But applications support ease of use of medical images

Image enhancement: uses global processing, e.g. for CT windowing, unsharp masking (local contrast enhancement), temporal substraction e.g. DSA

Screening: uses global processing, segmentation, feature detection, and classification to preselect images for detailed review, e.g. PAP smears => company NeoPath, product AutoPAP approved by FDA.

Quantitation: uses global processing, segmentation to characterize meaningful regions of interest, e.g heart shape as functional indicator.

3D reconstruction & visualization: uses global processing and segmentation, volume rendering or surface rendering

Multimodality image fusion: uses all above techniques to create a composite visualization that contains anatomical and functional images from several sources. Primary problems to solve are registration and visualization.
Integration of images and information

Images must be considered as only part of the total, patient related data, and the information generated must be integrated in the treatment plan.

Information flow must be two-way - from imaging specialists (e.g. radiologist) to clinician and vice versa.
Integration of images and information

Multiple screens from a tool for radiation treatment programming. Dpt. of Radiology, University of Washington
Summary medical imaging

Imaging has evolved into an essential part of managing the individual patient’s diagnosis and treatment.

Information flow must be two-way—from imaging specialists (e.g. radiologist) to clinician and vice versa.

Digitalization has greatly improved the facilities to generate high quality image output, store image in a cost effective and space saving way, and transmit images.

Main future challenge is extraction of knowledge from the image by automated methods.
What is Telemedicine?

*Telemedicine* is an umbrella term that encompasses any medical activity involving an element of distance.
Definitions of Telemedicine

Telemedicine is defined by the Telemedicine Information Exchange (1997) as the "use of electronic signals to transfer medical data (photographs, x-ray images, audio, patient records, videoconferences, etc.) from one site to another via the Internet, Intranets, PCs, satellites, or videoconferencing telephone equipment in order to improve access to health care."

Reid (1996) defines telemedicine as "the use of advanced telecommunications technologies to exchange health information and provide health care services across geographic, time, social, and cultural barriers."
History of Telemedicine

1906: Einthoven investigates the possibility of transmitting ECG signals by telephone: “Le Telecardiogramme”. Arch Int Physiol 1906; 4: 132

1920s: Telegraphic consultation for ships

1924: First exposition of Telecare
History of Telemedicine

1955: Telepsychiatry: closed circuit TV in the Nebraska Psychiatric Institute, linked with Omaha veterans Affairs Hospitals in Omaha in 1977

1967: Occupational health services for airport employees and travel advice at Massachusetts General Hospital

1960s: NASA records and transfers biometric data from space to earth.
History of Telemedicine

1970s: Paramedics in remote Alaskan and canadian villages linked to town hospitals via satellites

1977: Memorial University Newfoundland (MUN) gets active in medical teleeducation, using low end technology.

1984: North-West Telemedicine Project, Australia

1989 NASA Space bridge to Armenia
Telemedicine vs Traditional Medical Services

E-health is not a replacement of existing medical and health care services, but it is an additional tool to improve access to existing facilities and resources.

E-health or Telemedicine can be considered a strategic tool for facilitating international health care delivery.
Telemedicine vs Traditional Medical Services

Many countries face the problem of having to provide medical care to people working or living in remote or inaccessible places that do not allow them to use traditional health care services.

Over the past years, there has been an explosion of interest in the use of E-health solutions in developing countries.
Who needs Telemedicine?

Any patient who does not have easy access to health care because of

Distance

Preparation, transportation

Medical conditions

Emergency situations

Social conditions
Who needs Telemedicine?

Any **physician** who feels unable to provide state of the art medicine because of

- Isolated setting
- Need for specialist/ second opinion
Who needs Telemedicine?

Any national or regional government that feels unable to provide state of the art medicine because of:

Lack of qualified staff
Lack of resources
Large area to cover
Applications for Telemedicine (1/3)

Equitable access to quality health care services

People at remote and rural areas will receive better treatment

Patient with rare disease will receive second-opinion consultation and more opportunity to get an efficient treatment
Applications for Telemedicine (2/3)

Increased access to continuing medical education and training

Reduces professional isolation among doctors and other health care staff located remote and rural areas

Provides an advanced medical services in emergencies
Applications for Telemedicine (3/3)

Organization of epidemiological surveillance groups

Creation of specialized Regional and National databases

Multi-country training in public health
Summary

E-health is having and will continue to have a skyrocket growth in the near future.

E-health solutions are fastest and most cost-effective to fill the gap created by the lack of highly qualified experts in different fields of medicine in remote and rural areas.
Summary 2

Telemedicine holds great promise to improve the provision of health care to a wide range of patients, in particular in developing countries and in rural and remote areas.

Telemedicine will be one of the main tools for trade in health care services.
Summary 3

Based on successful cases, telemedicine has to be included in professional education programs of medical schools in order to make its use as natural as the use of telephones today.
Example 1

Mozambique Project: January 1998 – First ITU Telemedicine project was implemented in Mozambique, connecting two hospitals (one in Maputo, the capital of the country, and the second – in Beira) for teleradiology.
Example 2

**MISSION:** Medical Imaging Support via Satellite Integrated Optical Network
Example 3

Georgia Statewide Telemedicine Program

started 1991

The system supports numerous clinical functions, including both initial and follow up consultations, established specialty clinics, and emergency consultations. More than 7000 consultations have been conducted to date, providing access to more than 45 medical specialties and subspecialties, as well as allied health and nursing specialties. The majority of requested medical specialties are pediatrics, psychiatry, pulmonology, hematology/oncology, family medicine, dermatology, infectious diseases and neurology.
Example 4

Telecardiology

Use of simplified ECG monitors that adapt to mobile telephones, transmitting ECG signals for remote analysis, and can be linked to GPS systems.
CARDIOVIT AT-4 Tele

Product Information

Unique independence with Telemedicine
Latest technique in Telemedicine guarantees highest mobility and yields unbeatable profit for private consultation or emergency situations.

The ideal device for ambulances, first aid, home visits or to fulfill ECG requirements in any remote area.

Features:
Large 3-channel preview LC-display
One-button transmission of 12-lead ECG
Optional computerized ECG interpretation
Splash proof, robust Samsonite case
Data transmission via modem or GSM mobile phone to defined receivers within seconds, using standardized SCP report
Data transmission via satellite phone (Inmarsat)
Possibility to receive evaluated data and diagnostics from computing station
Automatic transmission with or without printout
Integral thermal battery, printer & charger with external mains connector
Autonomous battery power for more than 1 hour
Data sending & receiving capability
Summary

Telemedicine may help to bring high quality medical care to previously underprivileged regions.

Applications are available already.

Main technical challenge is how to transfer data.
Questions you should know to answer

What are the roles of imaging in medicine?
What are the four steps of image processing?
Give an example how these steps can be applied by an image-analysis program that looks for lung cancer.
What does segmentation mean in image processing?
How is “telemedicine” defined?
Compare telemedicine with traditional medical services.