The Third Assignment ("Tredje uppgiften")

ROYAL INSTITUTE OF TECHNOLOGY

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Technische Universität Graz
Graz, Austria

5 March 2008

What is expected?

Swedish colleges and universities have three assignments:

1. Teaching (education),
2. Research, and
3. "the third assignment".

Teaching historically included only education up through and including the masters degree (referred to as ‘undergraduate education’); while graduate education was considered part of research in the form of *research education*. In the latest proposition (“Resurser för kvalitet” †) all levels will be part of the education component.

†Resurser för kvalitet: *Slutbetänkande av Resursutredningen*,Statens Offentliga Utredningar, SOU 2007:81, *Stockholm, 2007,* ISBN 978-91-38-22827-2, ISSN 0375-250X

What is the third assignment?

"Högskolorna skall också samverka med det omgivande samhället och informera om sin verksamhet." (Högskolelagen 1997)

Roughly translates as: "Colleges shall also cooperate with the surrounding society and inform the public of their activities."

The original emphasis seems to have been to **inform** the public of **research results** (because of `the democratic significant of research-based knowledge').

The *evolving* third assignment!

The third assignment has evolved (e.g., in a recent Science Bill[†]) to explicitly mentioning increasing of collaboration with industry, public administration, organizations, culture, and popular education.

Today the goal seems to be to **foster an entrepreneurial spirit** in universities and colleges.

[†] FoU och samverkan i innovationssystemet (R&D and cooperation in the innovation system). Regeringens proposition 2001/02:2, p. 44

Overview of this talk

Some examples of how a faculty member in a Swedish university interprets this 3rd assignment.

In some cases the emphasis is on **proactively** trying to affect society using information and communication technology.

Informing the public

- Publications
  - Scientific publications
  - Textbooks
  - Web pages
  - Patents
  - Popular publications (I've not done well at this.)
- Oral presentations
  - Lectures (particularly for courses)
  - Talks at scientific & technical meetings
  - Talks in companies
  - Talks to government agencies, consultations, …

Collaboration with Industry

- Center for Wireless Systems @ KTH
- Industrial doctoral students
- Examiner for ~310 thesis projects (since 1994) (90% of these conducted in industry or another government agency)
- Students from courses (both degree & non-degree students)
- Visionary boards
- Management boards (or an advisor to the board)
- Consulting
- Patents

Center for Wireless Systems: Wireless@KTH

http://www.wireless.kth.se/

"… a research center in "Mobile Systems for Mobile Services" that together with researchers at KTH and its industry partners is developing this key field for Sweden and the Stockholm area."

"… interdisciplinary research projects in *collaboration* between academia and industry."

"An important role of the center is to bridge the gap between the design of services and systems and their commercial deployment."

Doctoral students

- 4 of 4 doctoral students who have completed at KTH were industrial doctoral students

versus

- 4 of 4 doctoral students who completed at Columbia University who were based at the university.

- 6 of 8 licentiate students who completed at KTH were industrial doctoral students (the other two left for industry following their licentiate), 5 additional licentiate students left for industry before completing their degree (two started their own companies), and 1 additional student became a professional volleyball player!

Doctoral students (some examples)

- J-O Vatn: waiting for something **not to happen** in a protocol is a bad idea ⇒ much faster DHCP, by avoiding unnecessary waiting for duplicate address detection (2nd advisor)

- Roch Glitho: distributed updates of user profiles
- Theo Kanter: explicit exchange of context information
- Joe Mitola III: Cognitive Radio - Applying AI to software defined radio
- George Liu: "we all walk in circles" or at least cycles ⇒ prediction of user movement

- John Ioannidis: Mobile*IP and swIPe (⇒ IPsec)
- Jonathan Smith: explicit parallel, distributed and reliable computation – speeding up even "non-parallelisable" code

- Bjärne Decker (Lic.): Erlang (the language) – Why telecom software is different
- Elisabetta Cararra (Lic.): MIKEY +SRTP

Examples of doctoral student's topics and their effects

Background: Radio Spectrum ⇔ $$$

Problems:

Many perceive that radio spectrum is in very limited supply

⇒ that it is highly valuable

Consider the >10^{11} € spent on 3G wide area cellular licenses (in Germany 44G€, UK £22.5G, France 13.5G€, ...)

Where G= 10^9

U.S. Frequency allocations

http://www.ntia.doc.gov/osmhome/allochrt.pdf

Reality check:

Problem (part a):

- Many perceive that radio spectrum is in very limited supply:

  False! There is plenty of spectrum, it is the allocation process which is at fault

  Put an antenna up, attach a receiver, and sweep through a wide range of frequencies and what do you find?

  ☺ Surprise: Very little of the allocated spectrum is in use!

Using these allocations

Spectrum is allocated in many (small) slices:

Problem:

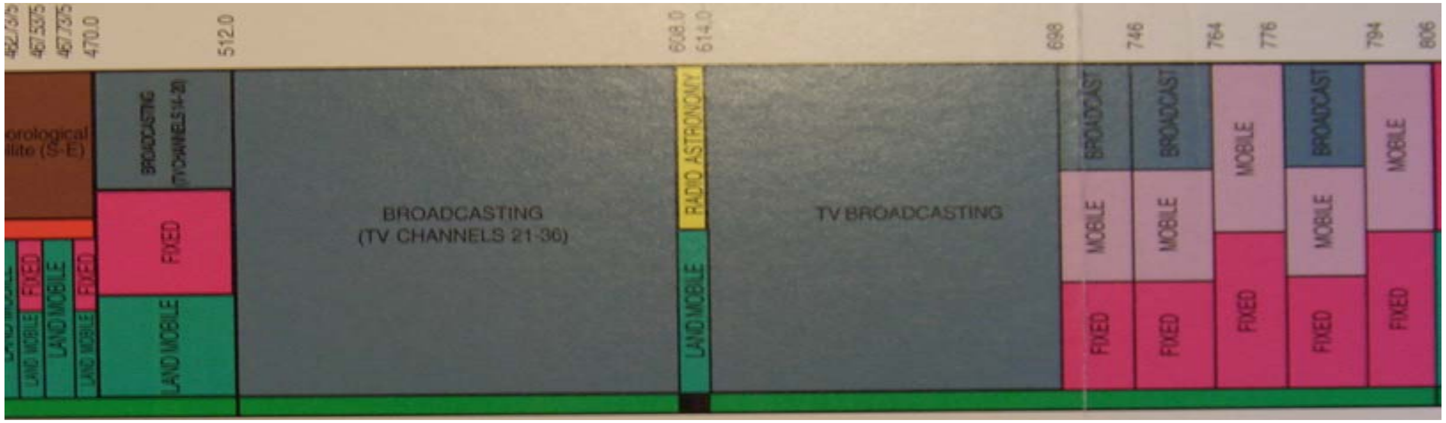
Each of these typically had a different modulation, coding, waveform, …

$\Rightarrow$ U.S. Military and others had a large number of different kinds of incompatible radios to utilize different parts of the radio spectrum

Solution: Software defined radios (SDR)

SDR name is due to J. Mitola III

Problem (part b): Assumption that this spectrum is highly valuable



Due to the transition to digital television broadcasts, much less spectrum is needed; hence US FCC, Swedish PTS, … are changing their frequency allocations for “TV”.

Questions:
- What to do with this spectrum?
- Who will get it? For how long will they get it?
- Should it be allocated in the same manner as before (i.e., for a specific purpose)?
  - Google (and others) propose open access **without** the operator controlling the equipment

Dynamic spectrum usage

- Bidding/renting/… - real-time markets for spectrum
- Moving out of the way of the primary user
  (using spectrum “white space”)
- Cooperative sharing of spectrum

Versus

- Spectrum underlays
  - Ultrawideband (UWB) radio – at low power per Hz, looks like noise to narrow band receivers (hiding)

Joe Mitola III: Cognitive Radio

Applying AI to software defined radios
(his M.S.E.E. was in 1974, doctoral studies in C.S. 1981-1985; started as a doctoral student at KTH in 1998)

Cognitive radios can:

- Cooperate to decide what they kind of radio they want to be **now**
  - **Requires a language for these radios to speak**
- Explicitly consider the importance of the user's task and what needs to be transferred & by when

Mitola’s major publications

- Joseph Mitola III and G. Q. Maguire Jr., “Cognitive Radio: Making Software Radios More Personal”, *IEEE Personal Communications*, Volume 6, Number 4, August 1999, pp. 13-18.
- Joseph Mitola III, *Cognitive Radio: Model Based Competence for Software Radios*, Licentiate thesis, Royal Institute of Technology (KTH), Sept. 1999.
- Joseph Mitola III, *Cognitive Radio: An Integrated Agent Architecture for Software Defined Radio*, Doctoral Dissertation, Royal Institute of Technology (KTH), 8 June 2000.
- Joseph Mitola III, *Software Radio Architecture: Object-Oriented Approaches to Wireless Systems Engineering,* John Wiley & Sons, October 20, 2000, 568 pages, ISBN: 0471384925
- Joseph Mitola III and Zoran Zvonar (editors), *Software Radio Technologies: Selected Readings*, 544 pages 1st edition, IEEE, May 15, 2001, ISBN: 0780360222
- Joseph Mitola III, *Cognitive Radio Architecture: The Engineering Foundations of Radio XML*, Wiley-Interscience, September 14, 2006, 473 pages, ISBN-10: 0471742449 and ISBN-13: 978-0471742449

FCC and Cognitive Radio

FCC Cognitive Radio Technologies Proceeding (CRTP)
ET Docket No. 03-108
http://www.fcc.gov/oet/cognitiveradio/

Rulemaking Releases:

- FCC Office of Engineering and Technology hosts a Workshop on Cognitive Radio Technologies on May 19, 2003
- FCC adopted a Notice of Proposed Rulemaking and Order that sets forth proposals and seeks comment on the use and applications for cognitive "smart" radio systems. December 30, 2003
- FCC Adopts Rule Changes for Smart Radios. March 10, 2005

Example: mobile computing

David Bantz and his group at IBM Research were looking at wireless network interfaces and pen input devices

Together with others I proposed a project to build an information portal using this technology – combined with a PC in a notebook form factor.

Problems

How to enable a computer which has no hard disk to boot and run an OS?

What OS should it boot?

How to enable a computer to communicate with other computers – despite the fact that it connects to the network at different locations?

How to allow users to interact with a device which only has a pen interface?

What applications should be written to demonstrate this new device?

Some of the solutions

Q: How to enable a computer which has no hard disk to boot and run an OS?

A: Network boot (BOOTP)

$\Rightarrow$ New problem, due to limited battery capacity all students would boot their machines at the start of class!

A: Multicast file distribution protocol – to distribute OS+initial in-memory file system

- J. Ioannidis and G. Q. Maguire Jr. The Coherent File Distribution Protocol. Technical Report RFC 1235, Network Working Group, June, 1991.

Q: What OS should it boot?

A: UNIX (actually several different versions – including IBM's)

Q: How to enable a computer to communicate with other computers – despite the fact that it connects to the network at different locations?

A: Mobile*IP $\Rightarrow$ Mobile IP

- To address the problem of maintaining connectivity (particularly TCP sessions) some mechanism was needed to break the binding between the IP address used to communicate with the device (anywhere) and the IP address which the device has at this particular location

Q: How to allow users to interact with a device which only has a pen interface?

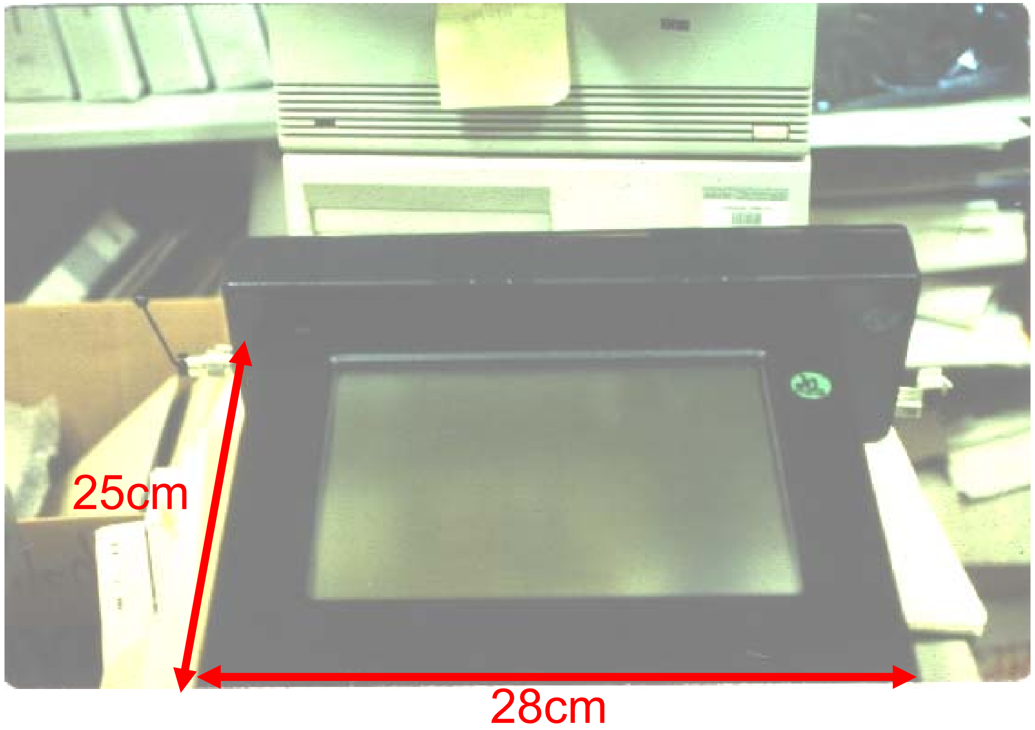
A: X windows + a virtual pop-up keyboard

Q: What applications should be written to demonstrate this new device?

A: Any application that would run under X windows (+Andrew Windowing system) vs. another group that in the same time (1 year) implemented just 3 applications

1989 - Student Electronic Notebook Project (IBM Research and Columbia Univ.)

Notebook computer with “paperlike” (stylus) input + DS-SS radio



D. Duchamp, S. Feiner, and G. Q. Maguire, Jr. Software Technology for Wireless Mobile Computing. IEEE Network. 5(6):12-18, November, 1991 $\Rightarrow$ **today’s Tablet PCs**

NB: It takes much longer to go from *ideas* to *widespread use*, than you might think & most of the problems are **not technical**.

John Ioannidis: Mobile*IP ($\Rightarrow$ Mobile IP)

- Mobile*IP ($\Rightarrow$ Mobile IP)
  - Based upon IP-in-IP encapsulation
  - Break the binding between a network address and point of network attachment
  - Introduced co-located care of address
  - home network routing optimization – using distributed

- Publications
    - John Ioannidis, *Protocols for Mobile Internetworking*, Doctoral Dissertation, Columbia University, 1993 (defended 20 Jan. 1993)
    - J. Ioannidis and G. Q. Maguire Jr., The Design and Implementation of a Mobile Internetworking Architecture. eds. Dejan S. Milojičić, Frederick Douglis, and Richard G. Wheeler, *Mobility Processes, Computers, and Agents*, Addison-Wesley Pub Co., ACM Press Series, February 1999, 365-377. {Reprint of J. Ioannidis and G. Q. Maguire Jr., The Design and Implementation of a Mobile Internetworking Architecture. USENIX Winter 1993 Technical Conference, pages 491-502. USENIX Association, January, 1993.}

    John Ioannidis, Dan Duchamp, and G.Q. Maguire Jr. "IP-based Protocols for Mobile Internetworking". SIGCOMM'91 Conference: Communications Architectures and Protocols, pages 235-245. Association for Computing Machinery, September,1991. http://doi.acm.org/10.1145/115992.116014

- The source code was made public.

John Ioannidis: swIPe ($\Rightarrow$ IPsec)

swIPe

- Based upon IP-in-IP encapsulation
- Introduced 3 entities: security processing engine, key management engine, and a policy engine
- Provided: data confidentiality, data integrity, and source authentication

John Ioannidis and Matt Blaze, "The Architecture and Implementation of Network-Layer Security Under Unix", Proceedings of the Fourth USENIX Security Workshop, October 1993, pp. 29-39.

http://citeseer.ist.psu.edu/60273.html and

http://www.tla.org/talks/swipe-26ietf.pdf (18 March 1993)

- The code was publically released.

Masters students + doctoral students

- J-O Vatn: **waiting** for something **not** to happen in a protocol is a bad idea ⇒ much faster DHCP, by avoiding unnecessary waiting for duplicate address detection
  - J-O Vatn, IP telephony: mobility and security, Ph.D. thesis, KTH, Stockholm, June 2005
  - Jon-Olov Vatn and Gerald Q. Maguire Jr., The Effect of Using Co-Located Care-of Addresses on Macro Handover Latency, Fourteenth Nordic Tele-traffic Seminar (NTS 14), Technical University of Denmark, Lyngby, Denmark, August 1998.
  - Jon-Olov Vatn, "Long Random Wait Times for Getting a Care-of Address are a Danger to Mobile Multimedia", 1999 IEEE International Workshop on Mobile Multimedia Communications (MoMuC'99), 15-17 November 1999, San Diego, CA USA.
  - Jon-Olov Vatn "An experimental study of IEEE 802.11b handover performance and its effect on voice traffic", Technical Report TRITA-IMIT-TSLAB R 03:01, Telecommunication Systems Laboratory, Department of Microelectronics and Information Technology, KTH, Royal Institute of Technology, Stockholm, Sweden, July 2003.

- Elisabetta Cararra (Lic.): MIKEY + SRTP
- I. Abad, Secure Mobile VoIP, Masters Thesis, KTH, June 2003 – implemented SRTP
- J. Bilien, Key Agreement for secure Voice over IP, Masters Thesis, KTH, December 2003 – Implemented MIKEY

- Erik Eliasson, Secure Internet Telephony: Design, Implementation, and Performance Measurement, Licentiate thesis, KTH, June 2006 (Björn Pehrson is the main advisor)

MIKEY & SRTP part of the open source minisip (see http://www.minisip.org). Minisip began as project by Erik Eliasson for a doctoral course in VoIP.

Other minisip extentions:

- I. Sanchez Pardo, Spatial Audio for the Mobile User, Masters Thesis, February 2005

Collaboration with Physicists, Physicians, ...

- Especially my wife,
  prof. Marilyn E. Noz, Ph.D., New York Univ.

Medical Imaging

Image registration

- M. E. Noz, G. Q. Maguire Jr., E. Lee, J. H. Schimpf, and S. C. Horii. Computerized Correlation of Tomographic Images. Proceedings of the 1984 International Joint Alpine Symposium, pages 85-88. IEEE, February, 1984.
  - Matching Positron Emission Computed Tomography (PET) images with Computed Tomography (CT) images

…

- H. Olivecrona, M. E. Noz, G. Q. Maguire Jr, M. P. Zeleznik, C. Sollerman, and L. Olivecrona, A New Computed Tomography-Based Radiographic Method to Detect Early Loosening of Total Wrist Implants,Acta Radiologica, 48:9, 2007, pp: 997 -1003.
  - Registering CT images with CT images, but not registering the prosthesis/implant

Example: medical imaging

Magnetic resonance imaging (MRI) is a **sensitive** method for detecting invasive breast cancer and can detect lesions in mammographically negative patients in up to 37% of cases.

MRI breast study shown on right, with Axial, Coronal, and Sagittal views.

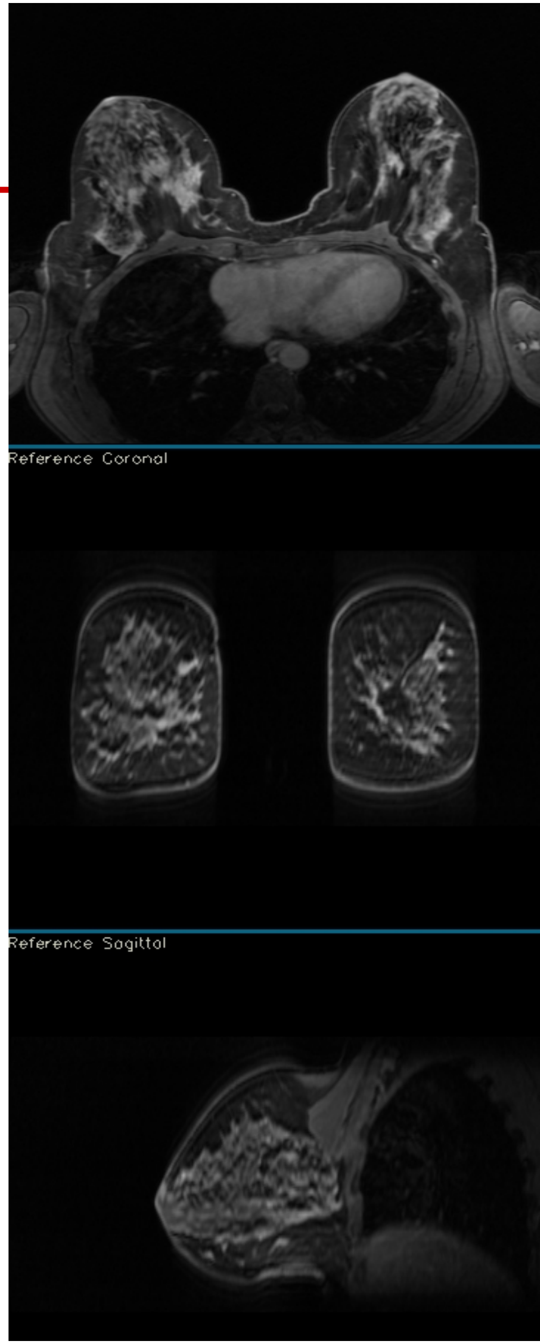
Problem

In lesion-by-lesion analysis,
the **sensitivity** is **88**%,
the **specificity** is **only 50%**

Axial

Coronal

Sagittal



Example: medical imaging

First attempt at a solution

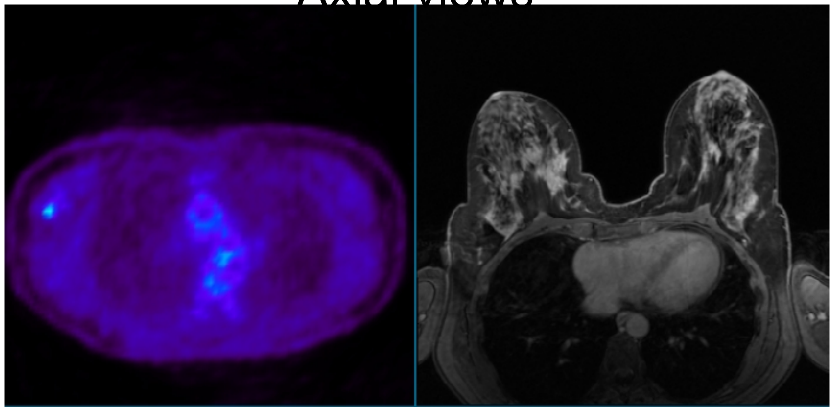
Patients with known or suspected breast cancer underwent a routine whole body [18F]fluoro-2-deoxy-D-glucose ([18F]FDG) positron emission tomography (PET) scan – as PET has a higher **specificity**.

Idea: Exploit image registration of the two modalities

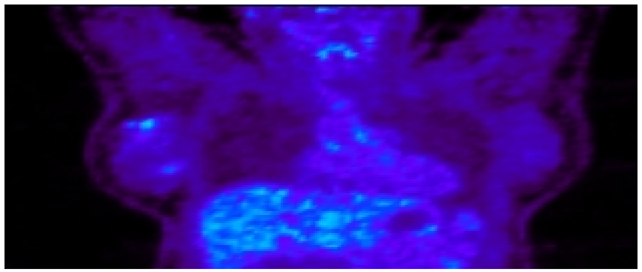
- G.Q. Maguire Jr., M.E. Noz, H. Rusinek, J. Jaeger, E.L. Kramer, J.J. Sanger, and G. Smith. Graphics Applied to Image Registration. IEEE Computer Graphics and Applications. 11(2):20-28, March, 1991.

Problem: The body deforms under the effects of gravity and the lack of good fiducials and the complex nature of the tissue means that simple registration does **not** work.

Axial views



Supine PET | Prone MRI



Supine PET coronal

Solution

To enhance the specificity of breast MRI, a prototype mammoPET apparatus was fabricated to allow positron emission tomography (PET) scans to be acquired in the same position as MRI scans, i.e., **prone**.

Fused PET/MRI scans increased the specificity of MRI up to 53% in this small group of patients.

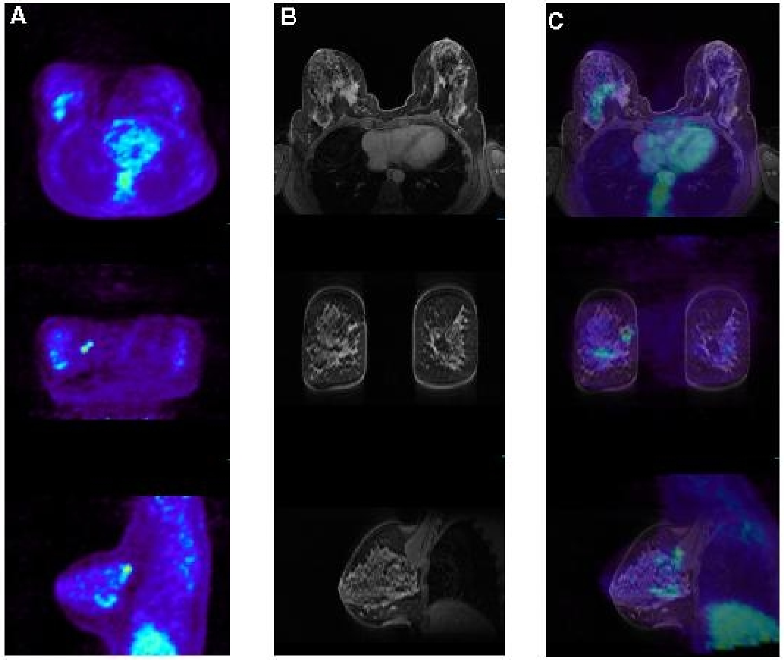
– L. Moy, F. Ponzo, M.E. Noz, G.Q. Maguire Jr., A.D. Murphy-Walcott, A.E. Deans, M.T. Kitazono, L. Travascio, and E.L. Kramer. Improving Specificity of Breast MRI Using Prone PET and Fused MRI and PET 3D Volume Datasets. Journal of Nuclear Medicine. 48(4):528-537 April, 2007

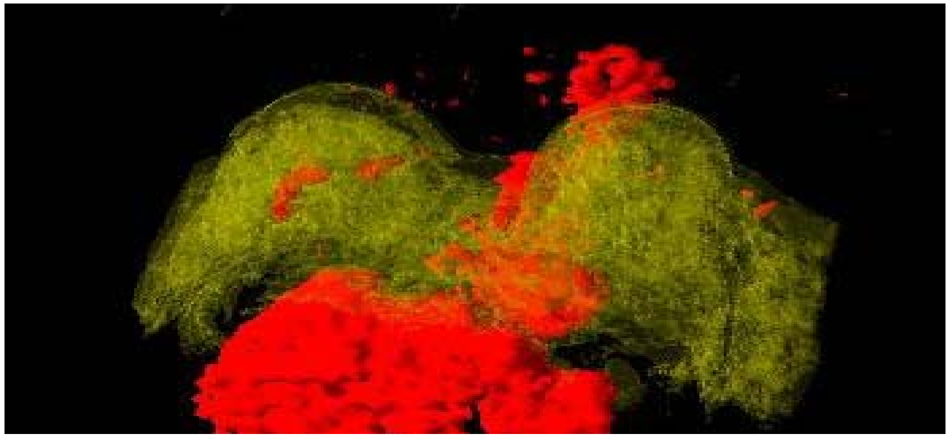
– L. Moy, M.E. Noz, G.Q. Maguire Jr., F. Ponzo, A.E. Deans, A.D. Murphy-Walcott,E.L. Kramer, Prone mammoPET acquisition improves the ability to fuse MRI and PET breast scans. Clinical Nuclear Med. 32(3):194-198 March 2007.

– M.E. Noz, G.Q. Maguire Jr, L. Moy, F. Ponzo, E.L. Kramer, Can the Specificity of MRI Breast Imaging be Improved by Fusing 3D MRI Volume Data Sets with FDGPET? IEEE International Symposium on Biomedical Imaging, 0-7803-8388-5/041388-1391 April 2004

From original idea to the latest results was more than 5 years.

PET MRI MRI+PET





prototype mammoPET apparatus

Medical imaging: First get the data

Context of the problem

- Jim Schimpf (at that time at NYU Medical Center - 1975) was taking a phantom around NY from one CT scanner to another to compare them – month by month.

Goal: To determine the best CT scanner in order to recommend it for purchase

Method: Each month he sat with a calculator and a stack of printouts of the pixel values and computed the values, variance, etc. in different parts of the image, then plotted these values on a graph

Root of the problem

Due to different (and proprietary) image formats it was **not** possible to easily read this data into a computer and automate the analysis.

Short term solution

- Decode the **vendor specific** formats
  - Getting the format required an nondisclosure agreement (NDA) + 1 man month per format to write a program to read this format
  - **Alternative**: Use images of known data, then examine the binary files with EMACS

Medical Images:early years

- Vendor specific formats
  - D.P. Reddy, G.Q. Maguire Jr., M.E. Noz, and R. Kenny. “Automating Image Format Conversion - Twelve Years and Twenty-five Formats Later”. H.U. Lemke, M.L. Rhodes, C.C. Jaffee and R. Felix (editors), *Computer Assisted Radiology - CAR'93*, pages 253-258. Springer-Verlag, Berlin, West Germany, June 1993.
- American Association of Physicists in Medicine (AAPM) format, AAPM report 10, 1982 [2]
  - Key-value pairs in ASCII
  - Uncompressed image
- Picture Archiving and Communications Systems (PACS) - 1982 [3,4,5]
  - Estimated 10^{14} bytes for a 10 year archive for a 700 bed hospital with 10^5 exams/year
  - Dr.-Ing. Dipl.-Phys. Christian Greinacher, Siemems AG – following my talk gave a number of reasons why “Siemens” would never implement a standard interface on their medical imaging equipment
- EEC COST-B2 adopted a standard based on my additions to the original AAPM format as the European standard for exchange of Nuclear Medicine images

$\Rightarrow$ You could read the descriptive information about an image with a text editor

Back to the original problem

Getting data out of the CT scanners (to compare)

Jim Schimpf, Marilyn E. Noz, Steve Horii, and I began looking at directly connecting the CT scanners to a network and transferring the images digitally

This not only enabled comparison of images for quality control, but by making the data available on general purpose computers it enabled image processing to be applied to this data ⇒

Picture Archiving and Communications Systems (PACS) – 1982

- B. S. Baxter, L. E. Hitchner and G. Q. Maguire Jr. Characteristics of a protocol for the exchange of digital image information. *First International Conference on Picture Archiving and Communication Systems (PACS) for Medical Applications*, pages 273-277. Society of Photo-Optical Engineers, January, 1982.
- G. Q. Maguire Jr., M. P. Zeleznik, S. C. Horii, J. H. Schimpf and M. E. Noz. Image processing requirements in hospitals and an integrated systems approach. *Ibid* , pages 206-213.
- G. Q. Maguire Jr., B. S. Baxter and L. E. Hitchner. An AAPM standard magnetic tape format for digital image exchange. *Ibid.*, pages 284-293.

Vendor and modality **independent** access to and processing of images ⇒

- first all digital Nuclear Medicine department 1982 (together with Bill Erdman – Radiology paper 1984),
- the first workstation based nuclear medicine system,
- GE visited ⇒ GE adopted workstations rather than (incompatible) special purpose computers for each modality, …
  - S. C. Horii, G. Q. Maguire Jr., M. E. Noz and J. H. Schimpf. A Unified Digital Imaging Display and Processing System. *Conference on Digital Radiography*, pages 340-346. Society of Photo-Optical Engineers, September, 1981.[1]

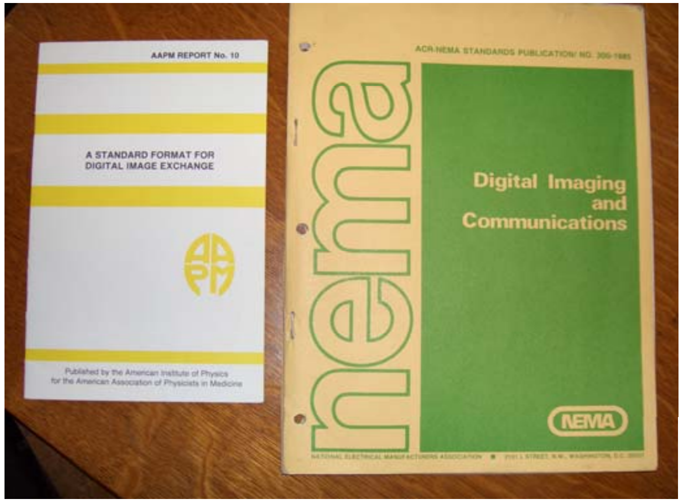
Medical Images: later & today

- ACR/NEMA 300-1985 Digital Imaging and Communication Standard (DICOM)
  - Required a special **hardware interface** (e.g., **a plug**)
  - **Binary format** – required you to buy a copy of the standard to know what the fields were
  - Introduced a minimal set of **commands**
- ACR/NEMA DICOM format v2 and v3
  - Binary format
  - Lots of proprietary vendor fields

Today: DICOM is standard, but due to vendor proprietary fields there is lots of data which is not accessible from other than the vendor’s own system

In fact, some descriptive/auxiliary information is no longer accessible as there are no longer any systems with software to read this proprietary data!

⇒ Saving information in the original format and reformat on the fly or as necessary ⇒ Interformat (a commercial program) [6,7,8]



Haptic interaction

- Force feedback – rather than simply moving the pen about – it can push back
- Requires **low** latency – 1kHz control loop!
- Fun for gaming
- Cost below 2k€ for the device on the left and below 100€ for haptic mice, joysticks, steering wheels, etc.
- **Hypothesis**: Using haptics can significantly decrease time to perform some tasks
  ⇒ saving $$$

  – Eva Anderlind, "Haptic Feedback for Medical Imaging and Treatment Planning",M.S. Thesis, Royal Institute of Technology, School of Computer Science and Communication, TRITA-CSC-E 2006:077, June 2006. http://www.nada.kth.se/utbildning/grukth/exjobb/rapportlistor/2006/rapporter06/anderlind_eva_06077.pdf
  – E. Anderlind, M.E. Noz, E-L. Sallnäs, B.K. Lind, G.Q. Maguire, Jr. The Value of Haptic Feedback for Medical Imaging and Treatment Planning. ESTRO 25, Liepzig, Germany, October 8-12, 2006.
  – E. Anderlind, M.E. Noz, E-L. Sallnäs, B.K. Lind, G.Q. Maguire, Jr. “Will Haptic Feedback Speed up Medical Imaging? An Application to Radiation Treatment Planning”, Acta Oncologica (in press).

Conclusions

Computer science[§] can be a lot of fun, but it is more fun if you enjoy it with others and help others.

$\Rightarrow$ The third assignment flows naturally from trying to help others and communicating what you enjoy doing.

The idea of the third assignment is not only relevant to Sweden, but is appearing in many other guises. See for example, Lewis Terman, “President’s Column: For the Benefit of Society”, The Institute, IEEE, March 2008, pg. 9, begins:

> “One of my major areas of focus this year is the application of engineering, science, and technology to societal problems. This is something that the IEEE must be concerned about, and it’s part of the recently adopted IEEE Envisioned Future strategy platform, which recognizes that by addressing societal issues, the IEEE can affect global prosperity and the quality of life. …”

[§]Here I use the term in the broad sense, including Teleinformatics, Telematics, Informatics, etc.

Acknowledgements

- Thanks to all of my students, colleagues, and collaborators (*especially* my wife) for many wonderful years of fun!

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1. S. C. Horii, G. Q. Maguire Jr., M. E. Noz and J. H. Schimpf. A Unified Digital Imaging Display and Processing System. *Conference on Digital Radiography*, pages 340-346. Society of Photo-Optical Engineers, September, 1981.
2. B. S. Baxter, L. E. Hitchner, and G. Q. Maguire Jr. A Standard Format for Digital Image Exchange. American Association of Physicists in Medicine Series, Report number 10. N.Y., N.Y., 1982. 11 pages.
3. B. S. Baxter, L. E. Hitchner and G. Q. Maguire Jr. Characteristics of a protocol for the exchange of digital image information. *First International Conference on Picture Archiving and Communication Systems (PACS) for Medical Applications*, pages 273-277. Society of Photo-Optical Engineers, January, 1982.
4. G. Q. Maguire Jr., M. P. Zeleznik, S. C. Horii, J. H. Schimpf and M. E. Noz. Image processing requirements in hospitals and an integrated systems approach. *First International Conference on Picture Archiving and Communication Systems (PACS) for Medical Applications*, pages 206-213. Society of Photo-Optical Engineers, January, 1982.
5. G. Q. Maguire Jr., B. S. Baxter and L. E. Hitchner. An AAPM standard magnetic tape format for digital image exchange. *First International Conference on Picture Archiving and Communication Systems (PACS) for Medical Applications*, pages 284-293. Society of Photo-Optical Engineers,1982.
6. G.Q. Maguire Jr., and M.E. Noz. Image Formats: Five Years after the AAPM Standard Format for Digital Image Interchange. *Medical Physics.* 16:818-823, September/October, 1989.
7. D.P. Reddy, G.Q. Maguire Jr., M.E. Noz, and R. Kenny. Automating Image Format Conversion - Twelve Years and Twenty-five Formats Later. H.U. Lemke, M.L. Rhodes, C.C. Jaffee and R. Felix (editors), *Computer Assisted Radiology - CAR'93*, pages 253-258. Springer-Verlag, Berlin, West Germany, June 1993.
8. David Paul Reddy, Marilyn E. Noz, Gerald Q. Maguire, Dahlia Garza, and Steven Horowitz. On-demand Conversion of Proprietary Image Formats to DICOM 3.0. H.U. Lemke, K. Inamura, C.C. Jaffee, and M. W. Vannier (editors). *Computer Assisted Radiology - CAR'95*, pages 1339-1345. Springer-Verlag, Berlin, West Germany, June 1995.