Challenges in High-Tech, illustrated in the medical domain

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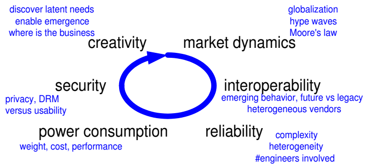

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Abstract

A short description is given of the medical domain, which is used to illustrate what technical challenges are present in high-tech development organizations.
A top list of technical challenges: Market dynamics, reliability, interoperability, security, power and creativity is presented and every challenge is briefly discussed.
The potential roles for new technical people are described and the future career possibilities.

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1 The medical domain

Philips Medical Systems is one of the top three suppliers of medical imaging equipment, ranging from Ultrasound to X-ray systems and MRI scanners. Figure 1 shows 2 examples of conventional X-ray systems:

- The Easydiagnost URF, a universal X-ray workhorse, and especially strong in gastro-intestinal examinations
- Integris Allura Cardio-Vascular, an high end cardio vascular intervention system, amongst others used for catherterizations.

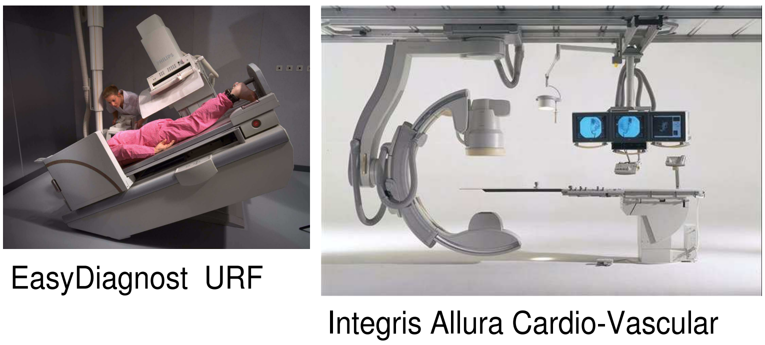

Figure 1: Conventional X-ray systems

Figure 2 shows the imaging results of this type of systems. The Thorax image is a very high resolution image of the Thorax (heart lung area), which is used quite frequent in the clinical practice. The cardio vascular images are typically used during the intervention itself and are shown on a collection of high resolution high brightness monitors. Contrast agents are used to make the vessels are clearly visible.

MRI is a more recently developed imaging modality. Figure 3 shows an Intera MR scanner. The center of the system is a huge strong superconducting magnet. The patient is positioned in the bore of the magnet. Accessibility of the patient is very important, claustrophobic feelings must be prevented.

The concurrent application of magnetic gradient fields and RF fields provides spatial information about hydrogen atoms, which via a reconstruction process is transformed in visible images. Figure 4 shows a typical MR image (right hand side). MR and CT scanners acquire *volume* information, every image is a cross section of the body. This volume information can also be used for other visualizations, the left hand side of figure 4 shows an example based on CT images.

These systems are sold to hospitals and clinical centers, to be used by professional clinical personnel. The numbers of systems sold per years is several hundred systems per year, with prices in the range of 100k$ to 1M$.

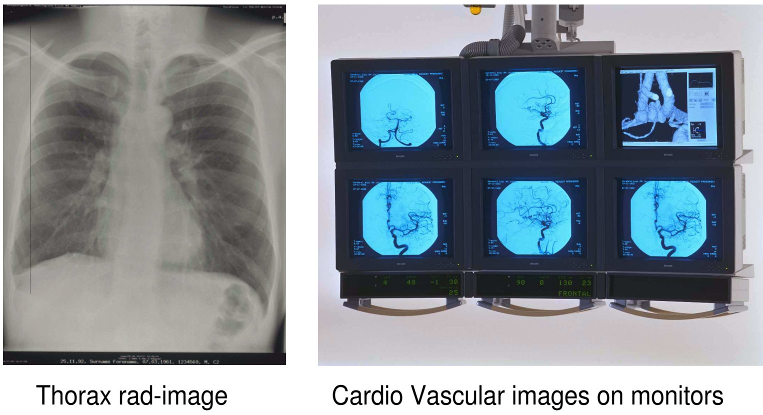

Figure 2: Typical X-ray results

Figure 3: Magnetic Resonance Imaging, MRI scanners

virtual endoscopy based
on CT images

MRI image
of the brain

Figure 4: Results from CT and MRI scanners

2 Challenges

The world of high tech product development faces a number of challenges, summarized in figure 5.

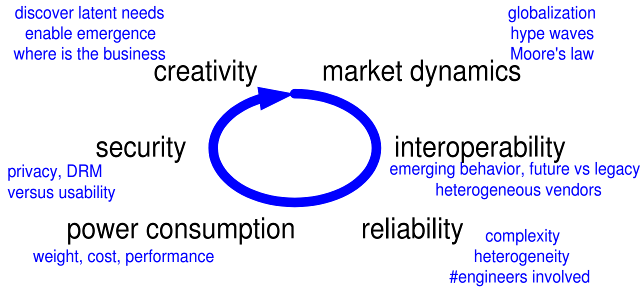

Figure 5: Hit list of challenges

2.1 Market dynamics

The market is changing continuously and the frequency of changes is high. Figure 6 shows several forces operating on the PMS market.

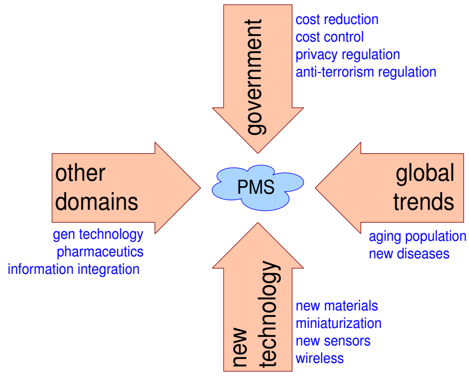

Figure 6: Market dynamics in medical

Companies from other domains are changing the playing field. Especially gen technology (early risk indication, preventive examination and therapy?), pharmaceutics (focused and localized application of medicines) will change the clinical field quite a lot.

Information Technology suppliers and service providers, integrate all types of information and applications in networks of systems. This integration enables new applications and also influences the conventional system boundaries and function allocations.

Government have a strong influence on the health care systems. Current trends are towards cost reduction and cost control in attempt to keep health care provisions affordable for the entire population. At the same time increased privacy awareness and concerns result in new and more regulations, with far stretching consequences for most clinical systems. The current threat of terrorism will also influence system requirements.

A global trend is an aging population, which has a considerable impact on the consumption of clinical services. Also new diseases appear, which creates unforeseen needs.

The rapid advance in many technology areas (for example new materials, miniaturization, new sensors, and wireless) opens up many new possibilities.

2.2 Interoperability

Systems get more and more directly connected. In the past humans linked the different systems together, applying intelligence and adaptations were needed. In the electronic age the adaptation must take place in the systems themselves.

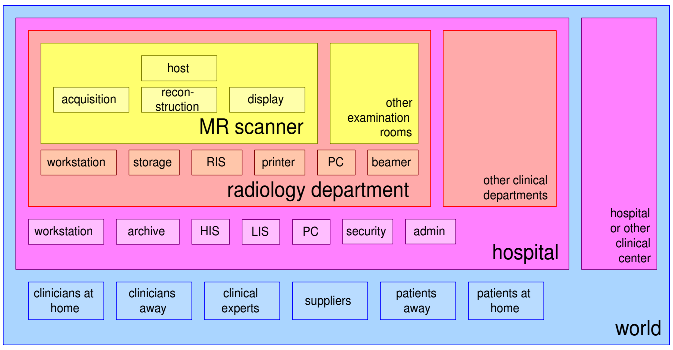

Figure 7: Interoperability: systems get connected at all levels

Figure 7 shows that systems all levels in the hospital get connected. Connectivity is not sufficient to justify the integration cost, only if systems interoperate in a useful way true added value is created.

An additional challenge for interoperability are the many dimensions in which interoperability is required, as shown in figure 8:

- applications
- languages, cultures
- vendors
- media, networks
- standards
- releases

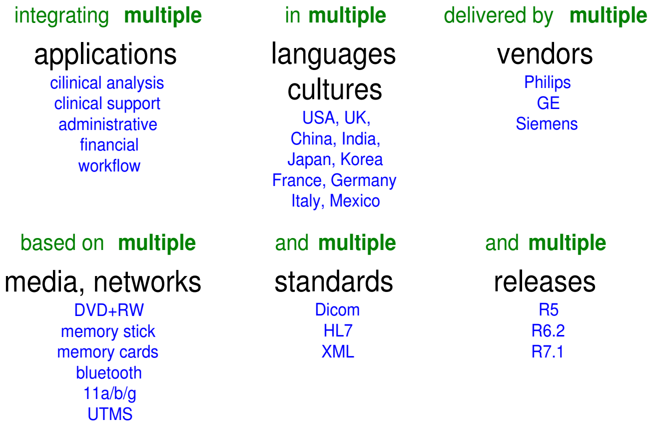

Figure 8: Multi dimensional interoperability

2.3 Reliability

The amount of software (and technology) in products is increasing exponentially, as shown for televisions in figure 9. Many other products show the same growth in the amount of software: Cardio Vascular X-ray systems, MRI scanners, wafer-steppers.

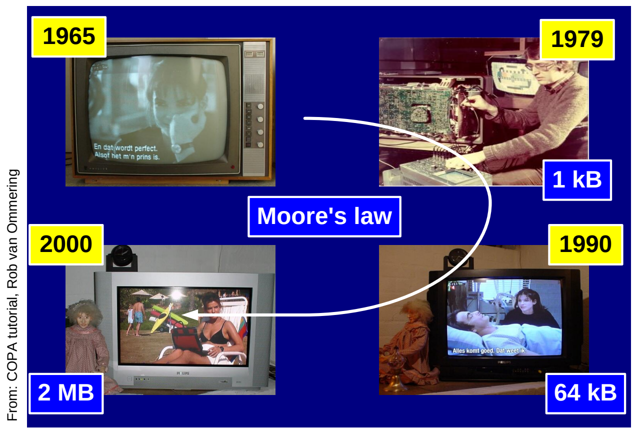

Figure 9: SW increase in televisions

Software is far from errorless. Studies of the density of errors in actual code show that 1000 lines of code typically contain 3 errors. In case of very good software processes and mature organizations this figure is 1 a 2 errors per kloc, in poor organizations it can be much worse.

Incremental increase of the code size will increase the number of hidden errors

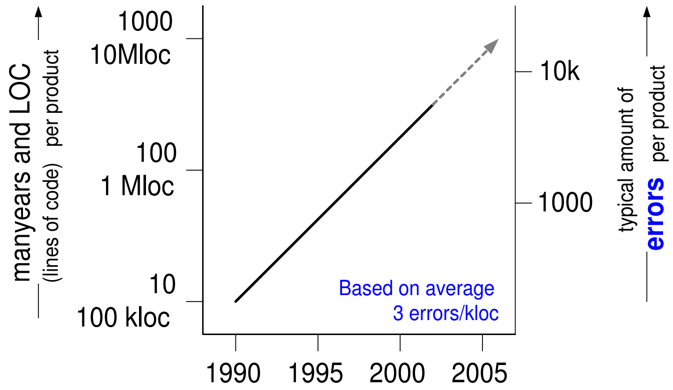

Figure 10: Increase of software threatens Reliability

in a system also exponentially, as shown in figure 10[1].

2.4 Power consumption

Many technological improvements show an exponential increase: circuit density, storage capacity, processing power, network bandwidth. An exception is the energy density in batteries, which is improved, but much less dramatically. The power usage of processing per Watt has improved significantly, but unfortunately the processing needs have increased also rapidly. Overall the power consumption of for instance PC's is more or less constant.

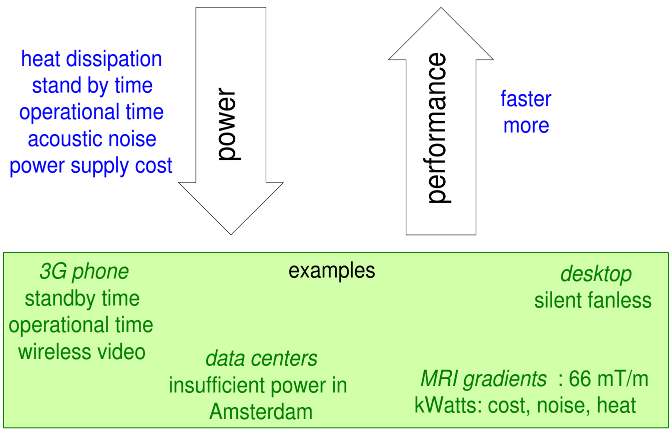

Figure 11: Power consumption and dissipation

[1]Simple systems, which already contain fatal bugs are appearing: for instance software vending machines, which need a power down when the software is crashed.

Figure 11 shows these opposing forces: the need for less power consumption and for more performance. There are multiple reasons to strive for less power consumption:

- less heat dissipation, easier transport of waste heat
- increase stand by time
- increase operational time
- decrease acoustic noise of cooling
- decrease power supply cost

Power consumption plays a role in all domains, for example in GSM phones (standby time, operational time, wireless video), data centers (Amsterdam cannot accommodate more data centers, due to the availability of electrical power), MRI gradients (faster switching of higher gradient fields, amplifier costs, acoustics and cooling are significant technical challenge) and desktop PC's (where a current trend is to silent fanless desktops).

2.5 Security

Several stakeholders have significant different security interests. Figure reffig:DYOFsecurity shows 3 categories with different interest and security solutions:

- Government and companies, which implement restrictive rules, which can be rather privacy intrusive
- Consumers, who want to maintain privacy and at the same time usability of services[2]
- The content industry, who want to get fair payment for content creation and distribution. Their solution is again very restrictive, even violating the right of private copies, and characterized by a paranoia attitude: every customer is assumed to be a criminal pirate.

All stakeholders are confronted with threats: pirates, thieves, terrorists, dictators, et cetera. The challenge is to find solutions which respect all the needs, not only the needs of one of the stakeholders. Another challenge is to make systems sufficiently secure, where a little bit insecure quickly means entirely insecure. Last but not least is the human factor often the weakest link in the security chain.

2.6 Creativity

The rapid technology development has changed the nature of product creation challenges. Several decades ago the main challenge was to get the desired perfor-

[2]Which can be quite conflicting. Who may have access to your medical data? Do you still want to control this access in case of emergencies?

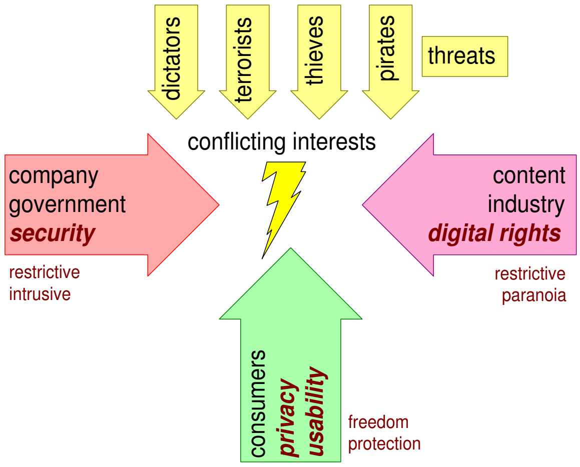

Figure 12: Security conflicting interests

mance at all; Can we **do** it? This shifted to the problem of realizing the performance within practical constraints, such as cost, power and size; Can we **make** it?

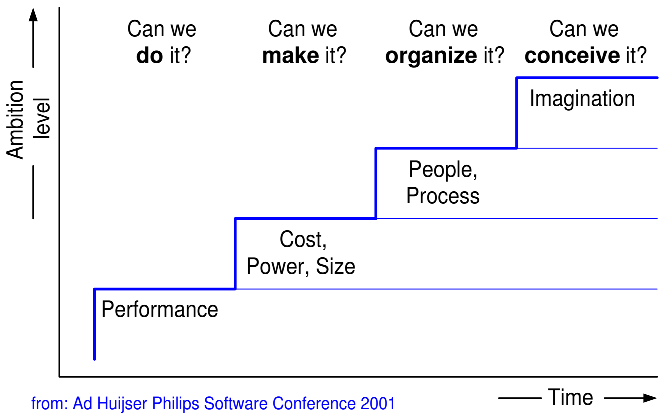

Figure 13: Creativity as limiting factor

The next challenge was to create the product with large amounts of people in a limited amount of time. Processes are a means to create products in large teams; Can we **organize** it? Today many well defined applications and services can be realized, the real problem has shifted to which applications and functions are needed? Which services can be used to sustain a business? Can we **conceive** it?

3 Future roles

Hundreds of engineers work together to create new products and product families. How could you fit in this (figure 14)?

Figure 14: How do you fit in this?

These modern development teams consists of many specialists, see figure 15 in one of the conventional disciplines, such as mechanics, electronics, physics or software. These engineers are embedded in an industrial environment with all kinds of industrial disciplines, such as logistics, purchasing, service, quality assurance, application, product managers, and project managers.

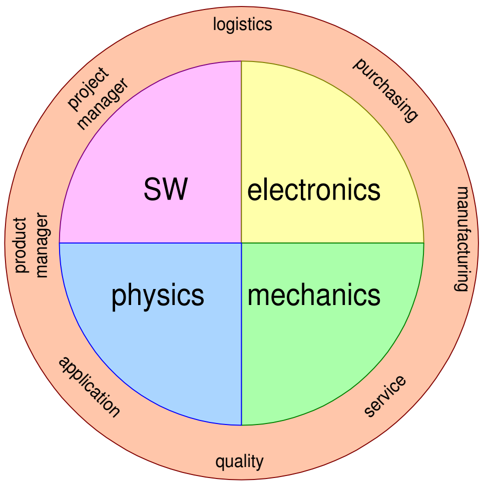

Figure 15: Multi disciplinary teamwork

What career prospectives do you have?

Figure 16 shows an example of a dual or multi ladder approach present in most modern high tech companies. Engineers can grow into a managerial function: line

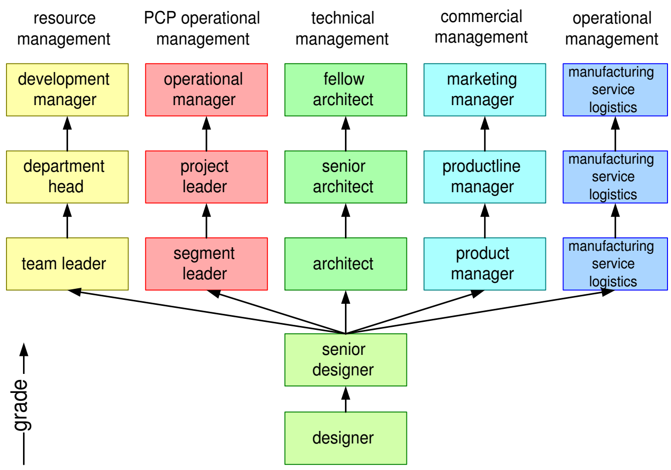

Figure 16: Multi ladder career paths

or resource management (responsible for people, process and technology) or PCP operational management (responsible for project results). Another direction for growth is the commercial direction: product manager or marketing manager.

Technical careers are also possible, either as a world class specialist or as a broad technician: architect. Figure 17 shows that both specialist and generalists are needed. The challenge for the generalist is to maintain sufficient depth in one technical discipline, the so called root.

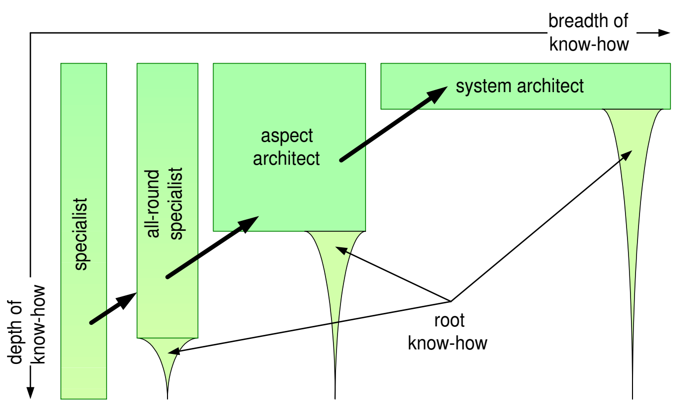

Figure 17: Technical specialists and generalists are needed

The development of architect follows more or less the path shown in figure 18. The first step is to establish a root by really experiencing one technology. The next step is broadening of the technical scope, by working with different technologies.

After some time the (potential) architect gets aware of the importance of the

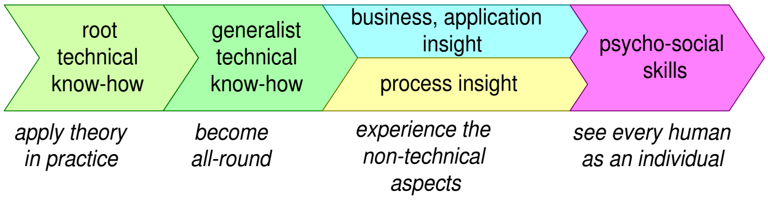

Figure 18: Growth Path Architect

non-technical aspects, such as business and application and the aspects of working with large multi-disciplinary project teams. Again one more step in maturity is the development of individual oriented psycho-social skills.

4 Conclusion

More and more engineers are needed to develop today's products. Figure 19 shows this trend, where the challenge for the industry is to discontinue this trend, so that we can work in manageable size teams.

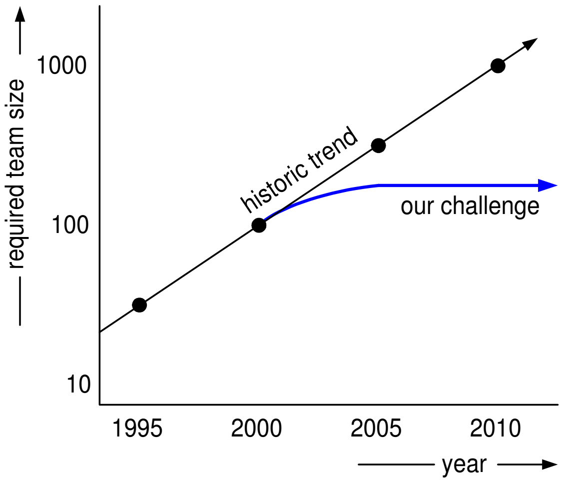

Figure 19: More designers are needed all the time, unless we become significantly better in creating software intensive products

We need an influx of new creative talented people, to man the development teams of the future, which have to tackle the challenges presented before.

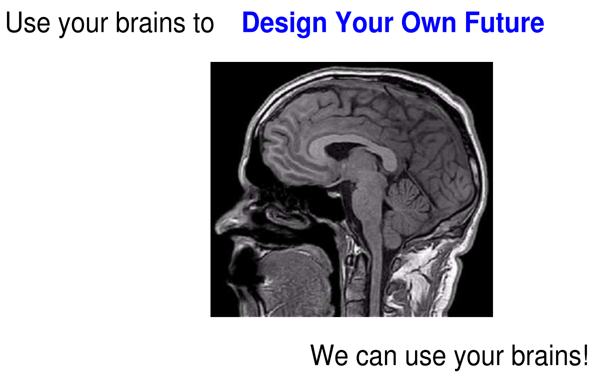

Figure 20: Conclusion

You have to make up your own choice, take our needs into account!

References

[1] Gerrit Muller. The system architecture homepage. http://www.gaudisite.nl/index.html, 1999.

History

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- text added
- status changed to concept

Version: 0.1, date: February 6, 2003 changed by: Gerrit Muller

- replaced teamsize figure

Version: 0, date: February 3, 2003 changed by: Gerrit Muller

- Created, no changelog yet