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Medical Imaging and Computer Games

- The medical imaging sector needs
- The computer game sector
- Technical solutions in medical imaging sector

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CCPgames
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Abstract: This project studies the synergies between the two both very different and very similar sectors: medical imaging and computer games. There are many computer game industries in the Nordic countries. Already in Sweden there are 87 commercial companies in the area. This is a high technology fast growing industrial sector. In reconstructive surgery, a surgeon shall, during hard time pressure, redesign tissue to a new shape with high demands on function as well as aesthetic. To their help the surgeons, until very recently, had extremely primitive tools. It is almost unbelievable that they succeed at all. Training of future surgeons is time consuming and expensive. Mistakes tend to become sad. Training cannot be done on the real hardware. The future surgeon has to stand behind the experienced surgeon for a long time and this passive training cannot be planned as the patients come randomly. Simulations tools can speed up education and surgeon skills. While the computer game market build their economy on the sales of huge market volumes with a low cost of about 30€ per item the medical market has a low sales volume and thus high unit costs. With this in mind and rather similar techniques behind the products was it recognised to be worthwhile studying the synergies between the sectors. The conclusions have been that the synergies are not that strong that we generally recommend game companies to try the medical market, but to be prepared by a rough understanding of the market. The indirect synergies by similar technologies built up is strong and we recommend research programmes directed to the area as the Nordic countries are industrial frontiers in computer games, haptic technologies and rapid manufacturing of implants and the medical application has positive humanitarian and society economic effects.
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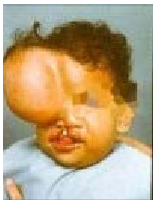
Summary

Main objectives
There are many computer game industries in the Nordic countries. Already in Sweden there are 87 commercial companies in the area. This is a high technology fast growing industrial sector. History has shown that market progress in computer game industry including hardware is important for the cost and technology development of other digital technology sectors. The reason for this is the high turnover for the sector in combination with its market profile with extremely many customers, where each one only can afford very small costs. One example is that the Swedish game manufacturer Digital Illusions sold military war simulator programmes to the Swedish Defence that should have been too expensive to develop without the help of the enormous game market.

The challenge for the small game developer is to be able to sell his ideas to the big publisher as it use to be the publisher who takes the economic risks. An exciting network project over discipline boundaries is a god start point for strong game ideas.
In reconstructive surgery, a surgeon shall, during hard time pressure, redesign tissue to a new shape with high demands on function as well as aesthetic. To their help the surgeons, until very recently, had extremely primitive tools. The patient’s damage or deformity is pre-studied slice by slice from CT-scans, which give a very poor 3D-understanding. During operation, the surgeon is limited to the poor information from the patient’s open wound, with all its blood that limits the visual understanding. Usually there are nerves or other critical obstacles that necessitate for a perfect precision. It is almost unbelievable that they succeed at all. Still today most surgical operations are carried out as described above, but a fast technology development is going on.

Surgery and flying have a lot in common. The training is time consuming and expensive. Mistakes tend to become sad and expensive. Training cannot be done on the real hardware. The future surgeon has to stand behind the experienced surgeon for a long time and this passive training cannot be planned as the patients come randomly. Neither can this passive training be focused on special difficulties on demand. Simulation tools for surgeons is as important as flight simulators.

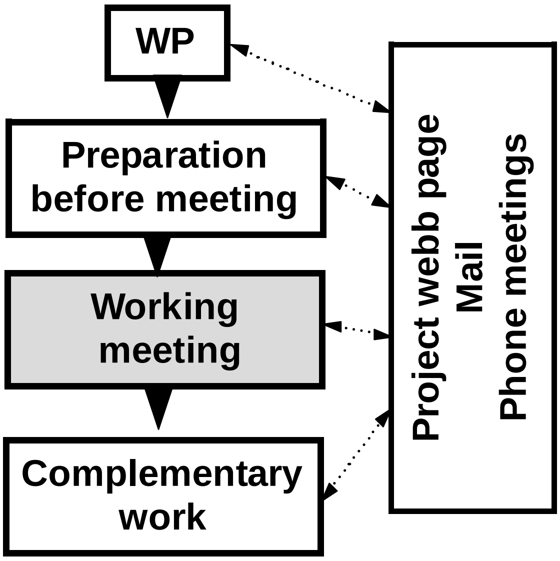
Summary

Medical problems:
o Need for better 3D information
o Need for more efficient education
o Need for cost reduction and user interface improvement through mass production
o Need to speed up development by Nordic cooperation
o Need for dissemination to more surgeons as well as economic decision makers
Game industry problems:
o Need for new and better inputs to computer game ideas

o Business chances

This project looks on the synergy effects between the two sectors. Can a cooperation between the two sectors result in new business chances, money to save and a faster progress?

Method/implementation



The work in the project was organized according to the figure above. The work was divided into workpackages. A workpackage leader was nominated for each workpackage who prepared an initial study. The result was then discussed during working meetings with brainstorming character. Usually this resulted in a need for some complementary work.

Results

A fast development is going on within a broad spectra of advanced medical imaging techniques that is making a small revolution within surgery. Used in the best way these techniques can:

- Give a better and longer life for human beings
- Lower hospital and society costs
- Increase quality and lower cost for surgeon education

The technical possibilities are almost unlimited. Technically there are similarities between medical imaging and computer games. In both sectors there is a rapid development of 3D-imaging techniques. The economic and commercial barriers are trickier. The main difficulties for achieving synergies are found in that the TV and computer game has an annual worldwide turnover of 10 –15 billion euro while medical education software is just a thousand of that. Added to that are the huge cultural differences between the sectors, thus is it easy to understand that game developers will not normally be attracted of the medical education market. However there are always special cases for special individuals or companies where a cooperation within the medical area can be interesting.

Commercially there is a huge difference between the two sectors. Medical Imaging solutions are usually sold in small numbers with a high price tag, while computer games are sold in giant volumes with a low cost to each customer.

The Nordic countries are well suited for research and industrialisation of advanced medical imaging products as we have a high concentration of computer game industries and has a leading role in the haptic industry as well as in rapid manufacturing technologies for individual implant design and production. We have also front end surgeons experienced in the new possibilities.

Conclusions and recommendations

Efforts within medical imaging will pay back in huge humanitarian benefits and society economic savings. The Nordic countries can reach a world front position in the area as we have an industrial frontier position within haptic technologies, computer games and Rapid Manufacturing technologies for individual human bone implant production.

We have recognised that most success stories come from a good cooperation between research projects and commercial interests.

We thus recommend that research programmes in the Nordic countries highlights the complete road from simulators in surgeon education, pre-operational planning, implant design and too implant manufacturing by Rapid Manufacturing. Three areas should be specially focused:

- Haptic design of implants
- Simulation
- Rapid Manufacturing of implants

For individual game developers, without the help of research programmes, we do not, as a standard recommendation, recommend an involvment in the medical area, but to get a rough knowledge of the possibilities to be able to judge when commercial possibilities are attractive.

We have recognised that the market size for educational software are so limited that the business idea: “Keep it simple” is more successful than more advanced solutions on peak technology level. Human beings has a good ability for imagination, why it is enough with logic solutions. They do not need to be logic and realistic.

For all people busy with education and strategic sales development we do recommend a study of the success criteria’s behind games. They include some basic principles that should be more widely practiced.

The Medical Imaging Sector needs

In terms of medical imaging, development these days is impossible to cover for anyone who is not working exactly within the field. The five main areas where better medical imaging techniques can make a revolutionary development within human care are:

- In surgeon education
- In pre-operation communication, planning and preparation
- Design and production of fixtures for more exact and safe operations
- Design and production of implants
- Increased home treatments

Surgeon education is time consuming and expensive as you cannot train on the real object. Simulation tools and high quality 3D information is crucial for an efficient education. The time to teach a student to be a surgeon should be possible to reduce with a year or more, the student should have the possibility to train on a bigger variation of specific cases and it should be possible to achieve a better control over that the student really has got the necessary skills.

Physical 3D models are used for

- Communication with the patient and relatives before decision to operate
- Communication between surgeons with different specialities in complex operation planning
- To plan complicated operations
- Models and fixtures that will be used during the operation itself or to prepare implants

Until recently the surgeons had to build their view of the patient tissue on slice by slice pictures from CT or MR scanners. Realizing the complex reconstructive, almost artistic, work that the surgeon has to do under hard time pressure and with a strong demand for non-failure results is it surprising that good 3d imaging technologies has not before now.

Three dimensional models now starts to be widely used. In fact 3D models have become such an integrated part of treatment planning in complex cases that they in some hospitals and some Nordic countries are no longer considered news. Certainly, there are some disciplines where that is not the case yet, or hospitals, where the 3D models have not yet become the gold standard, but these should today just be considered slow starters. 3D models are here to stay, but there is still a need to spread the skill and knowledge needed for increased use of physical 3D models. There is also a need to develop the techniques for more complex applications like models of the moving heart.

The pricing, though, is still a matter of conflict, and as in most fields within medicine, economy is the everyday language and the headline under which everything else follows. For the individual department to get paid for their costs are there a code system with standard prices for different treatments and extra costs, but there is still a lack of codes for the 3D models. While there are established rules about CT scans, MRI:s et c , 3D models still hang under the running budget of every department. 3D models should be sorted under the same fiscal umbrella as any image shaping diagnostic procedure. The main obstacles for a broader use of 3D models are lack of codes to debit the cost on, spread of information and enthusiasm among hospitals and the computer skills of some surgeons.

There is a huge under utilisation of current technical support. The technique is there to use 3D information in a vast array of situations. Unfortunately, it appears that many surgeons and other doctors do not grasp the current development within image technology. There is a large need for further computer training among many doctors, if the utilisation of 3D technology shall get the volume it deserves. Rome was not built in a day.

The next natural step is to produce scaffolds in reconstructive surgery. Either a scaffold can be used as a building frame for body cells as such or a frame can be built in biologically active substances enriched with growth factors and substrates. The medical and technological frontlines are not yet at a level of combat, but they are indeed building up some strength. Here, also, is a challenge, in arranging meeting opportunities for basic researchers in sometimes diverging fields working on the same issues. Network becomes more and more important. The currently finished NI project is such a network building project that will prove beneficial down the line, and probably in areas that we cannot quite identify today. Medicine today needs technology to develop further. Technology has lots of answers to medical needs without always knowing that. Multidisciplinary projects like the current NI project fuse these areas together. What comes out of it we may live to see.

As an increasing percentage of the population in the Nordic countries are getting old and need more hospital care is it an economic necessary to increase the possibilities for the patients to treat themselves in their homes. There is an increase for simple videos and other illustrative media that can help the patient to increase their ability to treat themselves in cases where a hospital visit is not absolutely necessary.

The Computer game sector

The World computer and TV game industry has an roughly estimated turnover of 10 - 17 billion €. The Nordic countries are well positioned in the sector, already Sweden has 129 computer and TV game developers with a yearly turnover of 170 million €. Added to this comes subsuppliers and webb game sites. The market has an impressive annual increase of 20 %.

The On-line games sector has the fastest growth. The sector turnover was estimated to 1.9 billion dollars in 2003 and is estimated to be 10 billion dollars in 2009. This corresponds to a yearly growth of 32% close to the maximum growth figures an industrial sector can have.

The computer game company is usually small. The biggest game company in Sweden has a turnover of just above 200 million SEK, but most of the companies are very much smaller. The development is usually paid by the publishers, which are much bigger companies. The first challenge for the game developer is thus to find and present an attractive concept for the publisher to get an order to produce a game. When the order is signed comes the next challenge: to produce the game. This is usually a very hard work under time pressure. The interest for secondary business ideas like medical imaging is under this period very low.

The game developer is usually paid two ways, by a fixed sum for the game development and a royalty on each game. Sometimes they also earn royalty from competitors using their game engine, a tool for producing the game.

The typical development cost for a game was recently 1 million euro, is now 4 million euros and is estimated to soon be 10 million euros. This will increase the demand on the companies. Most games are developed for more than one “platform”. A platform can be Windows-PC or a TV-game box. The platforms change by time and to learn a new platform is sometimes a huge challenge.

An important factor in the competition is the game engine they use. The choice and development of the game engine closely relates to the 3D quality and feeling of realism by the gamer. Even though there are free game engine to load down on the internet have the more successful game developers developed their own engine or adds on to an already existing engine.

Technical solutions in Medical Imaging sector

There are a lot of different medical imaging technologies emerging on the market

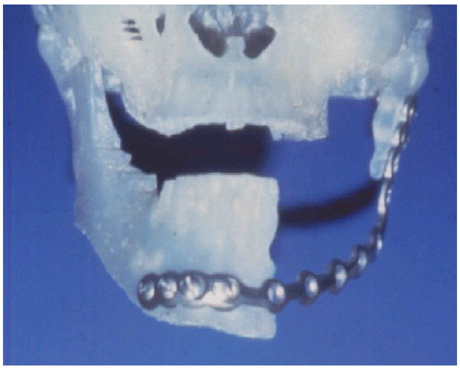
- A haptic tool is an input device to a computer that makes it possible to not only see 2D or 3D pictures of the object, but also sence them. The technique is used to by surgeons to form an implant in digital clay. In the next step is it possible to produce these as physical implants by Rapid Manufacturing, a set of tool less production techniques direct from digital data.
- Physical models of a patients damage, un-aesthetic or malformed tissue can be produced by tool less production direct from patient's CT- or MR- scanned images to help the surgeon or surgeon team to plan the operation.
- Direct tool less production of tailored implants from modified scanned patient data is a emerging technique under fast development and early pre market evaluation. These products are well suited for Nordic research and commercial development.
- Medical simulations is usually used for training purposes, but can also be used for advanced reconstructive surgery to test the summary effect of successive changes and to predict the look of a face after a change in the under laying bone.
- Vision technologies and more advanced picture recognition techniques is mentioned here because there value for medical application where analysed and discussed in this project. The techniques is however not suitable where unpredicted picture information is foreseen, which usually is the case in reconstructive surgery.
- The surgeon has to do a lot of artistic precision shaping with primitive hand tools. Different kind of case-by-case tailored guides produced by tool less production is an emerging market. Especially dental drill guides is fast emrging on the market.
- Robot assisted surgery can combine the human skill of creative and intuitive thinking with the precision and speed of a robot.
- Distance surgery or rather distance assisted surgery can increase the skill of both the highly specialist "super" surgeon as the local surgeon. The skill from the highly specialist surgeon can help more patients.
- By laparascopic surgery can video information be taken from inside body without too big surgery wound.

Haptic

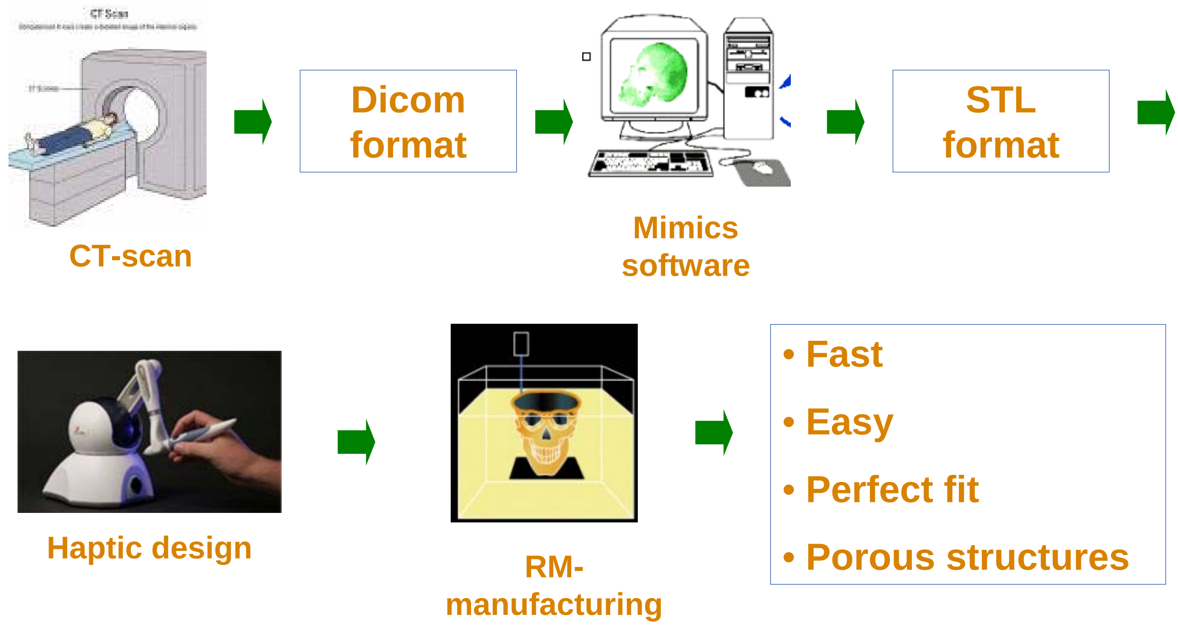
A haptic tool is an input device to a computer that makes it possible to not only see 2D or 3D pictures of the object, but also sence them. The technique is used to by surgeons to form an implant in digital clay. In the next step is it possible to produce these as physical implants by Rapid Manufacturing, a set of tool less production techniques direct from digital data.

In the general version is the patient holding a, usually, pen-like tool in his hand, which is the input device to the computer, but also the output device from the computer that makes the surgeon “feel” the objects.

The 3D pictures are generated at a computer screen and looked at through a special devise.



The surgeon is not a cad skilled designer and has earlier been limited to form simple geometries like this. In this special case the natural procedure is to first mirror the patients right hand side jaw in the computer with a special medical imaging programme and then adopt the form and joint areas by using the haptic tool to form a digital clay. The final digital implant is then produced by Rapid manufacturing a tool less, layer by layer automatic production method. The different steps in the procedure are shown in the next illustration.

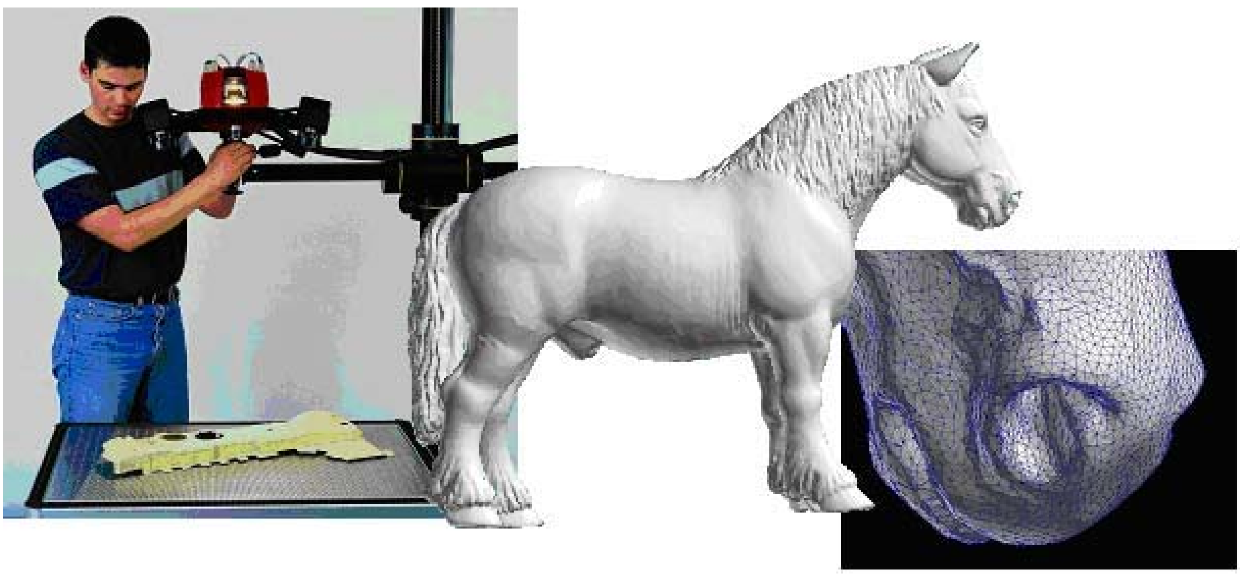


The technology to produce implants with the technique described above is not totally available yet, but will be very soon. The Nordic countries are well suited for the research and development. Together with US are we at the absolute front end within haptic techniques and together with England, germany and US in the front end of producing implants by rapid manufacturing.

The game producer can use haptics in two ways:

- To easily design game figures, crashed cars and more…
- To produce software like "art studios", where the user can produce 3D pictures by the natural way of forming digital clay.

When producing game figures is there an interesting possibility to combine it with 3D-scanning. There might also be medical applications of this:



Haptic is still not a well spread technology, but it can be expected that the technology will grow fast as costs is going down and there are free open source software available.

The company Novint has the target retail price of just $100 for this haptic input device.

Open source software is available to download at:

www.h3d.org.

Simulations

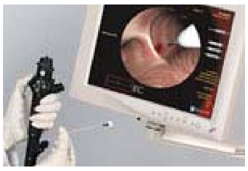
Simulations is an area where medical imaging and computer games may benefit from each other.

Medical simulations is usually a more specialized form of haptic techniques. While the general haptic techniques are mainly suitable for implant design, are simulations suitable for education of surgeons.

Surgeon education is very expensive and inefficient because you can not practice on the real object. Concepts difficult to explain and motor skills that otherwise may take years to acquire can be intuitively learned. An estimated 70 percent of procedural complications occur in a clinician´s first 30 cases. Simulators allow unlimited practice and a more reliable check point that the student have learned what he should.

The two main world companies within medical simulators are Immersion in the US and Mentice in Sweden. Immersion develop the physical user interface to be close related to the objects that the student will meet at the hospitals, while Mentice try to do slightly cheaper shortcuts which results in more realistic costs. As can be read under the chapters “The economic realities” and “Open market possibilities” do we recommend cost efficient solutions.

Vascular access



Endoscopy

Endovascular

Some Immersion simulation tools

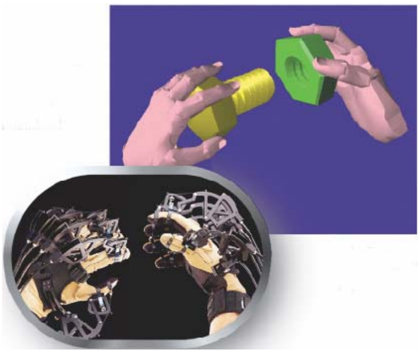
Hysteroscopy

Laparascopy

Mentice solution

Simulations within the game industry are usually not “real simulations”. The important issue is not to include true physical values in the driving, flight or war simulator, but to get a real feeling. It is more important that what your experience will logical than that it will be exact.

Immersion has several haptic game input devices on the market:



CyberGrasp

Gloves with separate force input for every finger

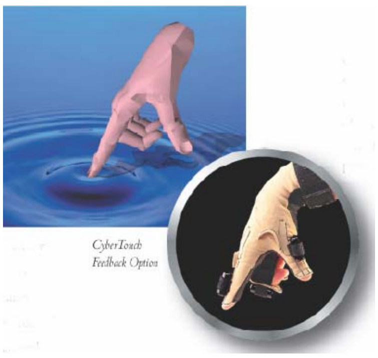
CyberForce

Adds hand and arm resistance and movements measurements in three dimensions

CyberGlove

CyberGlove is a more advanced version of CyberGrasp with 22 individual movements in your hand.

CyberTouch



The CyberGolve will be still more advanced by adding CyberTouch, which adds fingertip force feedback to CyberGlove.

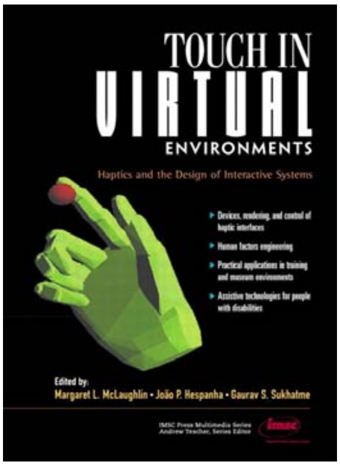
We have found 6 companies within haptic and medical simulations. 3 of those are based in the Nordic Countries and 3 in US.

Immersion	USA
Sensable	USA
Novint	USA
Reachin	Sweden
SenseGraphics	Sweden
Mentice	Sweden

Webbsites to visit:

www.haptic.org
www.hapticsymphosium.org
www.h3d.org
www.google.com

Litterature:



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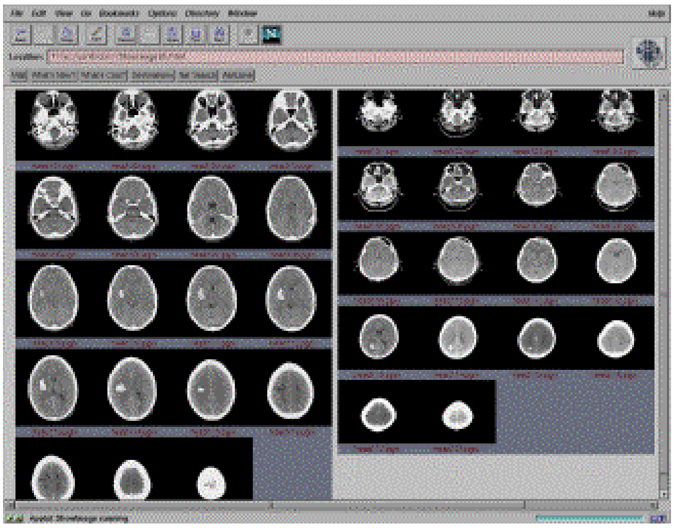
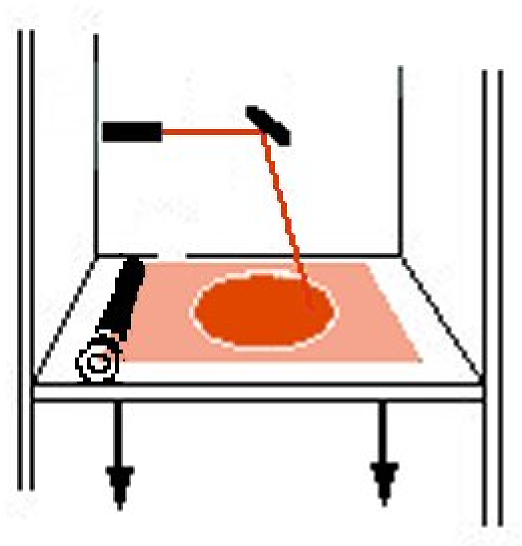
Physical models

A CT- or MR scanners produce slice by slice pictures of the body, usually with about 2 mm distance between the slices as can be seen in the picture below:



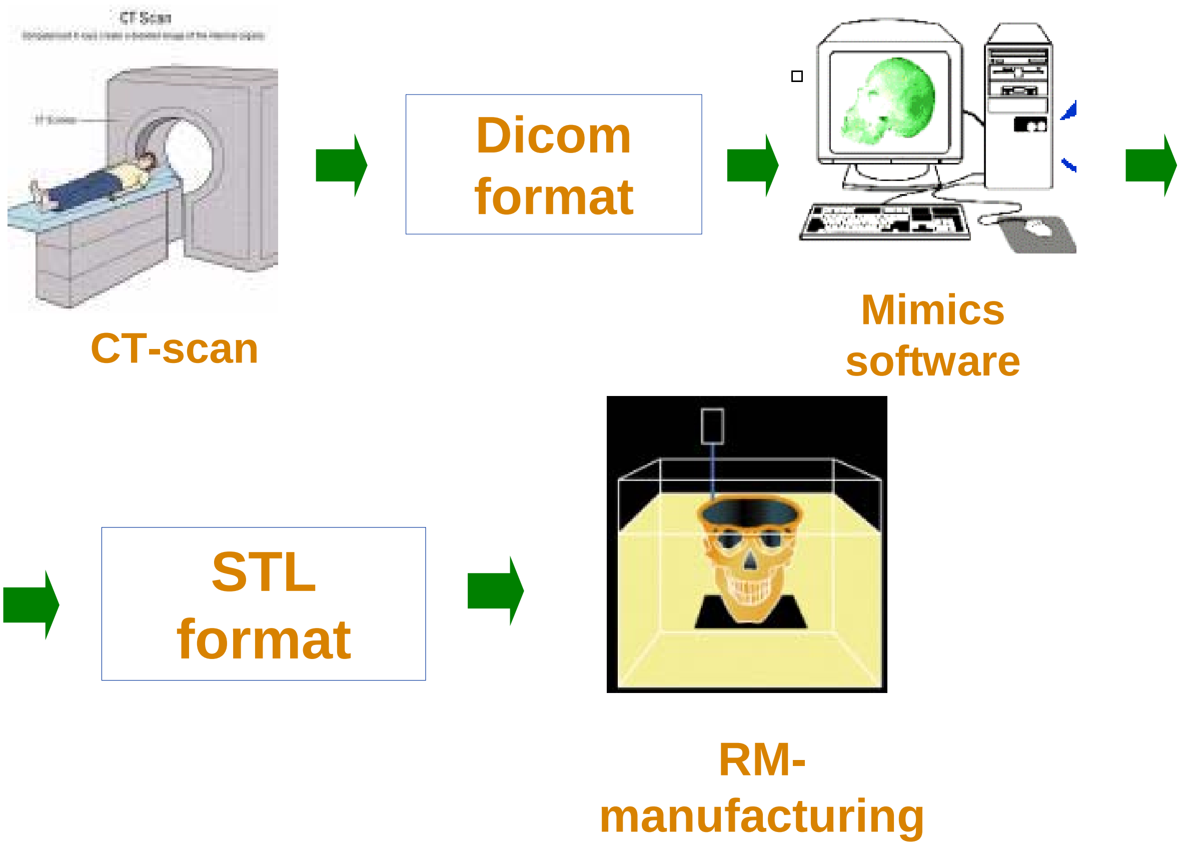
For decades has surgeons used these sliced pictures to build there own understanding of the patients anatomy. First since a very few years has 3d pictures and physical 3D models get reality.

3D models are produced by a set of technologies called Rapid Prototyping from their first application, prototypes in industry. There are many different Rapid prototyping techniques and building materials. As an example is Selective Laser Sintering described below:



In the laser sintering process, a fine powder of plastic, metal or casting sand is joined in the grain boundaries through heating with a high power laser.

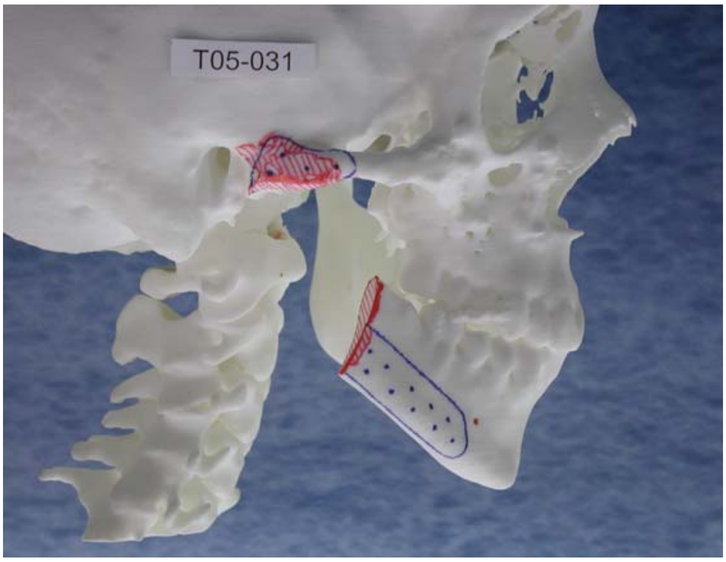
A thin layer of powder is rolled out over the build area. The laser keeps scanning the surface, and sinters (or melts) those sections that will form the part. A piston is lowered one layer thickness and a new layer of powder is rolled out. The procedure is repeated until the part is completed.



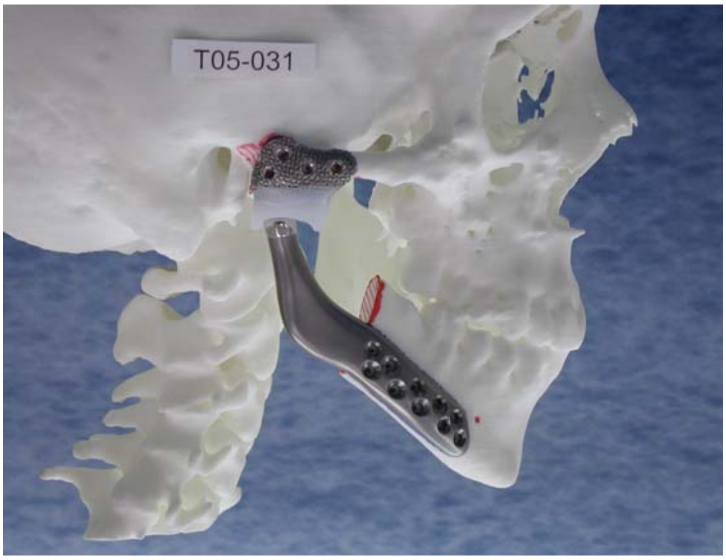
Physical models of anatomical structures have become an everyday luxury in many surgical disciplines working in areas where three-dimensional navigation is an everyday matter. There still are disciplines where the benefit of 3D modelling has not yet been identified, but these become sparser.

3D models today build up a gold standard for treatment planning, for communication and for follow up. 3Dmodels also, to a greater extent create a base for production of individually designed prostheses. There are basically two ways of fitting prostheses to bone. Either you have a standard prosthesis and adjust the bone with a jig to fit the prosthesis, or you use 3D technology to build individual prostheses to fit the bone. This is exemplified with two illustrations below.

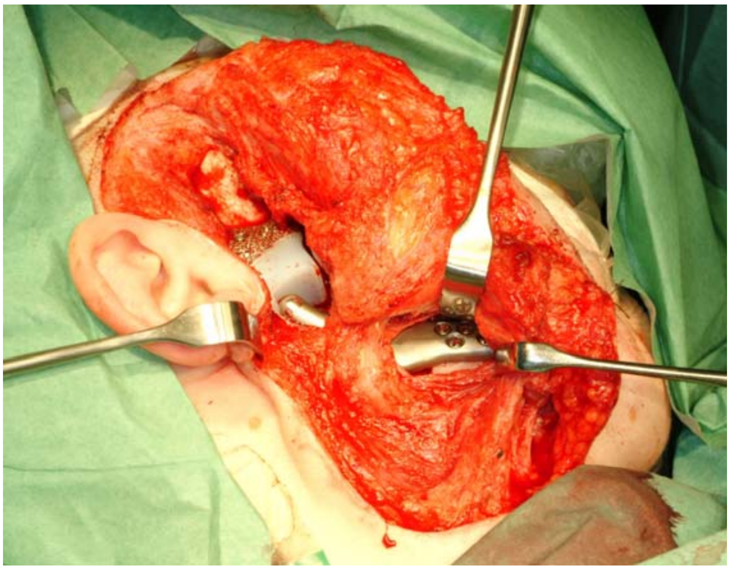
In tissue engineering, we will find that 3D models in terms of scaffolds, will play a major role up front, both as scaffolds as such and as scaffolds with biologically active functions. This will require intensive collaborations between molecular biologists, surgeons and technicians. It is an area where many brave brains may meet and test the limits of their respective specialties and only future can tell us the results.



3D model as a base for a temporomandibular joint prosthesis



The temporomandibular joint prostheis on the model



The temporomandibular joint prostheis installed.

Direct manufacturing of implants

The next logical step in evolution after physical models produced by Rapid manufacturing is to produce the implants itself by the same technology.

The market introduction of RM implants is very much a battle between the US and European enterprises, where Nordic companies has a good position with two RM machine manufactures Arcam and fCubic, where especially the first one are in the front end. The RM implant technologies are at a level where it is still not found on the open market, but it is obvious that it will come.

State of the art	Advance beyond state of the art with RM produced implants
Current methods of making customised implants are slow, complex, expensive and unreliable. Lead time of several weeks are commonplace	With RM implants can customised implants be produced in days, not weeks.
Many implants in reconstructive surgery are today designed and fabricated during the surgical procedure. This lengthens the duration of the operation whilst limiting the accuracy of the implant and quality of the corresponding reconstruction.	RM produced implants, designed prior to the operation from scan data of the patient and manufactured to precise and repeatable engineering tolerances. These implants will fit the patient exactly significantly reducing operating times.
To achieve a well functioning implant is it an important advantage to produce the implant with a porous structure allowing osseointegration. These porous structures are called scaffolds and the research are is called tissue engineering. Traditionally tissue engineering scaffold have been produced using relatively crude techniques, such as phase separation, salt leaching and gas induced foaming. These methods may not provide completely interconnected porosity, which in turn limits the bicontinuous nature of the implant as well as creating the possibility of “dead pockets” that can harbour infections.	RM implants can have precisely designed and manufactured internal structure for completely optimised osseointegration. There is also the possibility to produce functionally graded implants having a dense core or outer layer providing guided bone regeneration. This may also be used to prevent adverse soft tissue ingress.
Conventional implants have a limited life, eventually requiring replacement due to loosening or rejection. Often revision surgery is made more difficult due to bone loss during the original operation (making the patient fit the implant)	RM implants will be designed to match the patient (not the other way around) and they will have optimised biological performance.

Almost 1% of the Nordic citizens will require surgery involving the use of implants each year. This means that most of us, you and me, will require an implant during our life time. These operations could be performed with better results, less trauma, safer, faster and to lower cost.

What development is then needed to move this R&D area to a place on the medical market?

This is a multidisciplinary R&D area involving a lot of material science, bio-science, machine development, medical imaging and law approval strategies. The need on R&D in medical imaging is mainly in the development of haptic tools, as surgeons are not skilled in CAD-design and need easier digital methods to design their implants. The programmes associated to medical scanners must also allow more advanced, but still intuitive simple, imaging processing.

Vision Technologies

Can picture reorganisation be a useful tool for surgeons to better understand what they see in the patients wound or to automatic recognise cancer from a CT or MR scan?

This was evaluated in project. Without any distinct border between them, picture recognition can be of two kinds:

- Recognition of a complex pattern like a fingerprint
- Recognition of a simple pattern like: “Are there three or four screws mounted?” This is usually called vision technique and are mainly used in production control

In both cases are the patterns that should be recognised exact defined leaving very little to be judged by intuition. Such clear definition are difficult to achieve in the thought medical applications, why picture recognition would probably fail.

Medical scanners

The words medical imaging are sometimes used in the more limited sense of 3D-scanners for medical use. From an industrial economic point of view this is the by far biggest sector of medical imaging. Usual CT and MRI scanners works layer by layer. Still today most such scanners just show the surgeons a picture of each such layer at the time and the surgeon has to try to make his own 3D understanding in his own imagination.

The development within 3D-scanners includes better real 3D pictures shown to the surgeons. The competitive factors in development of new medical scanners are however other performance factors as described below, while about six software houses round the world has specialised in using the output data (in so called dicom format), translate them to illustrative 3D imagies and also allowing transformation to s.k. stl output format needed for production of physical models. See chapter about physical models.

The medical scanners industry are clearly dominate by two companies, Siemens and General Electric. Added to the are some other big companies like Philips, Toshiba and Hitachi. There are also a lot of small companies for nisches like mammography, bone density or bone loss measurements, radiations knifes and new technologies.

It is common that the new techniques that are developed in small R&D companies are later bought by the big companies.
The different medical scanner technologies are:

CT Computer Tomography	Used for the bone structure and also to define more exact coordinates together with other scanner technologies that are not suited for that.
PET Positron Emission Tomography	Shows where the biological activities are high. Good for identifying cancer and inflammations.

Combined CT/PET	Combines the possibility to identify biological activity by PET with the exact coordinates generated by CT. Still better for identifying cancer.
MRI Magnetic Resonance Imaging	Used for soft tissue
Ultra sound	A low cost imaging method
Multislice scanners	For bodies in motion, especially cardiac imaging. It also opens the market for economically realistic health controls by medical scanners.

Technology trends:
Singel slice CT scanners are replaced by multi-slice detectors. The development goes in steps of doubling the number of slices. The next generation is the 64 slice scanners. This enables the possibility to scan body parts in motion, specially the cardiac. Multi slice scanners can alternative be programmed to give a better resolution, which is useful in cancer detection.

More sensitive digital sensors and more advanced algorithms for current adjustment to patient attenuation results in lower radian levels

The combination of multi sliced scanners and lower radiation levels has made some hospitals in US to start to use the new multi slice scanners for routine whole body health controls. There are different opinions about the usefulness of this as some false indications on early problems sometimes are found, which cause both costs and anxiety.

A new type of scanners, Electron Beam, EBM, scanners are still faster and superior for cardiac motion. These scanners works like a TV-tube, with an electron beam that is steered by the electromagnetic field generated from coils to perform a scanning pattern.

The combined CT and PET scanners are shown to be superb for detecting cancer.

Dentistry applications

Drill Guides in Dentistry

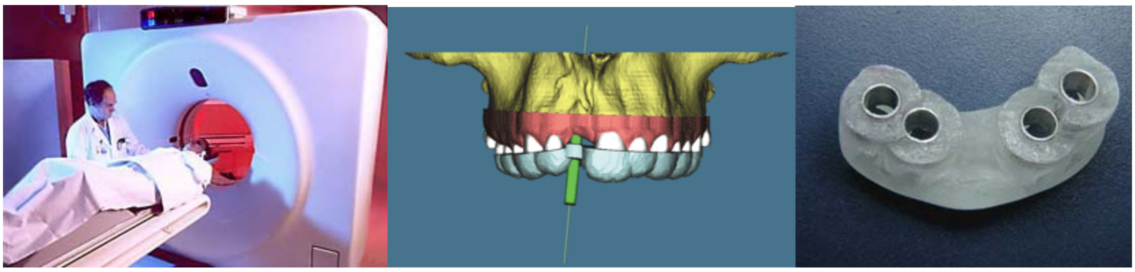
Installing implants can be very difficult and time consuming process. Surgeon, who is a professional, needs to make decisions how to install implants in right place, safely from patient point of view and also implants needs to last long. To help surgeon's work, drill guides are very good instruments to make operations more efficient and reliable, but also those can be used for pre-operational planning.

Drill guides function is to guide surgeon's drill to the planned implant location. This means exact dimensions; width, angle and depth. After surgeon has drilled the holes, he or she can install the implants safely and fast. Drill guides in dentistry purposes can be divided in three main categories; tooth-supported, bone-supported and mucosa-supported, others than these can be included in special implants.

Design, Manufacturing and Installing

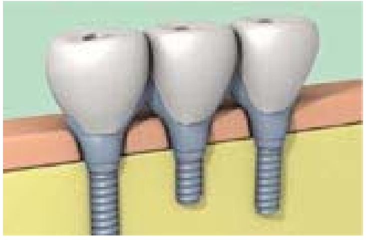
Before installing any implants, surgeon's needs to plan how to go through the whole operation. Drill guides can be designed by the help of state of the art 3D computer softwares. And guides can be manufactured by SLA (stereolithography which is a rapid manufacturing method, builds plastic parts or objects a layer at a time by tracing a laser beam on the surface of a vat of liquid photopolymer).

The whole (from designing to manufacturing) process can be divided in five stages. First stage is to take a CT-scan out of patient jaw, the case is that patient's jaw misses tooth. With the scanned image and computer, a 3D-model can be created out of that jaw. Surgeon immediately sees what is wrong and how it should be repaired. Second stage is to create a virtual model, of how the drill holes should be drilled for installing the implants in right position. Third stage is to create 3D-model and manufacture the actual drill guide. The physical drill guide can be manufactured by using SLA, to manufacture the guide one needs only 3D-model and a stl-file out of that model. The fourth stage is to assembly the guide to the patient for drilling the needed holes for implants. The fifth and final stage is to assembly the implants.



Process description: CT-scan, virtual 3D-modelling, rapid prototype by SLA

Assembly of drill guide, actual drilling, places where the implants will be installed.



Implants

What Makes a Game Successful?

Computer games can offer great possibilities to teach surgeons and students to practice different operations. A game is all about interaction between user interface and a player (or many players). A successful game is built up of a few important items:

- The **learning curve**. The user must have an easy time getting their hands on the “Play Game” button. So the installation must be a walk in the park. When the software is installed and successfully started, you need to captivate the viewer within the first few minutes. The difficulties should then increase as the gamer gets more skilled in the game If the learning curve is too steep however, many will quit before they get to master the software. The learning curve philosophy includes the presence of **goals**. It is VERY important that you **reward** the player according to the size or difficulty of the goal.
- It should be **interactive**. It is the strong feeling of interaction that makes computer and TV games so thrilling that the user can sit by hour together with his computer. The interaction is also perfect in surgical education as it allows for a control that the surgeon has got the skills he needs.
- It shall be **logical** and **natural**. It is more important that the game is logical than that it is realistic. The logical behaviour is important for learning, interaction and the thrilling enthusiasm of the gamer. It does not matter however if you are driving your car with a joystick instead of a steering wheel. The realism is less important.

The three factors above, learning curve, interaction and logical are necessary to achieve a successful game. The three items above should not only be kept in mind when creating a game, but also in all kind of education and many kinds of advertisements including lobbying. To be compatible the game producer must also reach the next set of demands:

- It must be built with **cutting edge graphics**. A lot of the competition between the game producer today deals about the quality of the graphic engines. Fornt line game producers has developed their own graphic engine and the quality of that is an important factor when trying to sell the concept to the publisher.

Number three on the priority list comes:

- The game should be built up on a **thrilling and unique story**. The story is the glue that binds all the other parts together. This is less important than the factors mentioned above, but still important. A good story can make a game famous over a few weeks.
- The game must include **competition**. The competitor can be another player or an artificial player generated by the game software.
- To keep the **target users in mind**. A real good game makes it difficult for the father to keep his hands away from the he bought to his 5 years old daughter. Adoption to the

target user is not the number one issue for creating a good game, but it still will have some importance.
- **Special effects** and qualities like surprises and mysteries.

The game like surgical educational software

What philosophies from last chapter should then be put into a medical educational software.

- First! Do not try to overdo it! The doctors will reply: “I have patients waiting! Is it really that important? And the students do not have the economy to pay the actual cost for the software. A game may cost 2 million euros to produce. Production of more content (ie. multiple surgical procedures) would increase the cost considerably.
- The three first items, **learning curve, interaction** and **logical** are the important items.
- You do not need the cutting edge graphics. There are numerous 3D engines available for leasing. Most software engineers with modest financial backing can program or get their hands on 3D software that is excellent for 3D modeling and 3D visualization.
- The story in surgical education is by nature thrilling. What could be added is clear goals and interactive effects like immune defence effects

In operations, which are operated by surgeons, the core idea is almost the same as in games. Surgeon’s work is to “communicate” to the patient through instruments which are needed during the operations. These instruments are real life “game controls” and in the gaming world the controllers will diffuse closer to real world applications.

With simple controllers and standard 3D graphics engines from the game industry, games-like educational packages could offer outstanding platforms for studying purposes and pre-operational planning. Combination of gaming technologies, state of the art medical imaging, advanced 3D technologies and haptic technologies possibility to find e.g. early phase tumors increases and that means the patient’s prognosis will be much better. This means that doctors and others could “play” the operations and do the examination forehand with actual 3D graphics of the patient. For educational purposes, games can offer very valuable information of how and why different kind of operations should be done.

3D-graphic cards are developing all the time towards more accurate and realistic graphics. When computers’ calculation speed increases there is a possibility to create games which are very close to the real life and real situations.

Other modern media

Complex information is easier to understand visually expressed. It creates strong, lasting impressions, and facilitates communication with speed and impact.

The interactive character of a computer game is very suited for education purposes where it is important to have some control over the skill achieved by the student. For a broader audience might short video films be more suitable. Visualized medical processes can demonstrate what happens in the organ at cell-level when a disease develops and the pharmacological effects of medicine. One advantage with the video film format is that it can easily be presented in many different ways like: In a powerpoint presentation, on the web, on TV and at the movie.

In Norway has the medical industry financed the development of a new type of pedagogic "action-video". The branch has together with medical experts used the film media to express a message. The scene is inside the human body where no camera can come. By combining film and 3D-animation can the target group visualise what is happening inside a blood vein where a blood clot is developing. The combining of 3D-video and film with actors result in a trustworthier message and an increased acceptance of the message.

Medical societies starts to realise the effectiveness in this media to supply messages for a wide audience. In one of the developed films you will meet a 25 years old female smoker. The lungs are made transparent, you see the healthy bronchi and the properly working mycosis and cilium. We follow the process inside one of the capillary veins on the surface to the millions of alveolus witch the lungs are built up by. We can study how the smoke gradually destroys the lunge functionality and meet the woman again when she is 40 with a developed chronic obstructive pulmonary disease, COPD. In Norway is it estimated that 250.000 individuals have developed this decease. The need for massive information to a broad group of people is thus big, which make a video suitable as message carrier.

More about action-videos can found at www.medxplore.com

A surgeons look on 3D imaging

The undersigned has been one of the active partners in the NI financed project on medical imaging.

As a maxillofacial surgeon concentrating on trauma and reconstructive surgery, I have found the development within three-dimensional 3D technology most rewarding for my specialty, as well as for specialties in neighbouring fields, such as plastic surgery, neurosurgery and ear-, nose- and throat surgery. Orthopedic surgery seems to have used 3D technology to a lesser extent so far, but would be an obvious field for the introduction of this technological innovation.

With the experience from 3D technology and the problems connected with teaching and obtaining surgical skill my participation in this NI project was to evaluate the possibility of joining knowledge from medicine, 3D technology and computer games into the creation of interactive teaching programs for anatomical studies as well as for surgical simulation.

Apparently, such a final outcome of our project year is not yet reachable. During one of my travels I visited a Boston based institution where computer based teaching materials have been produced for the US Army. These teaching devices are currently used in training sites in many parts of the world and have proven very beneficial in improving field doctor’s skill in emergency care. Even so, these devices mainly deal with rather “blunt” procedures, like installing chest drains et c. These procedures can then be added with computer-generated problems/decision making to solve medical problems all around.

Obviously, market rules. If there were a huge market for these programs, they would probably be around already. One day they will, no doubt, but not quite yet.

Meanwhile, we have found, that current technologies are most suitable for a wide array of situations within the medical field.

- There are excellent anatomical programs with interactive properties of many kinds. One of these programs have been solidly established by a company in the UK. Their anatomical education programs by now cover the whole body with subgroups for areas of certain interest.
- Other areas concern soft tissue prediction as results of underlying skeletal reconstruction or transformation. These programs are still undergoing major development and improve by the day.
- 3D technology today is used more and more for the production of individually designed prostheses and inlays and implants of all sorts. Apart from true prostheses, this technology can be blended with molecular biology in the field of tissue engineering. In this area we may over the next few years expect a rapid development. (See below.)
- Computer generated illustration technology has proven very beneficial in the information business. Within the project we have seen examples of very successful Nordic innovations in this field. The same technique that is used within internet-based advertisement can be used just as effectively to illustrate medical phenomenons. In this, as in many other areas of medicine, the fiscal realities are severe obstacles. Medical institutions rarely can afford to spend the money that major commercial companies put into their campains.

The recently finished NI financed project on medical imaging has merged people and companies with interest in the field. We have shared many thoughts that have developed our respective fields of activities. Some contacts have proven more valuable than others, and I am convinced that several interesting projects will emerge from the contacts established.

One such example is the use of advertising video techniques to illustrate medical processes et c. Once this is fully introduced into presentations of medical or surgical scientific reports, and the like, it will create a new gold standard in many fields. A preliminary project in this field currently is resting while we wait for appropriate funding.

One spin-off effect of the project is that we are negotiating about future collaboration between Helsinki and Stockholm on the development of 3D technology within reconstructive surgery. In May a group will meet to discuss these things further.

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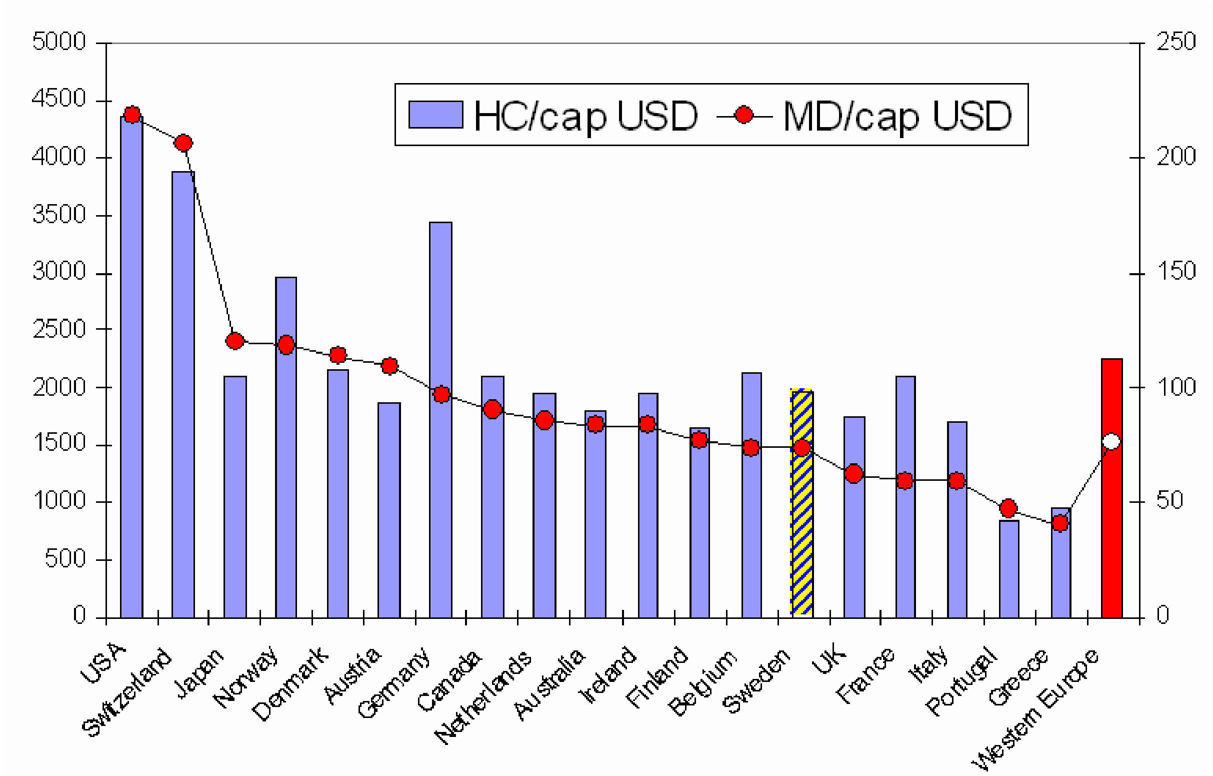
The economic reality

The main goal in this project was to investigate and search for possibilities to use the big serials scale effect of computer games to reduce costs and speed up development within the medical imaging sector. The project group focused specially on the challenge of efficient education of surgeons. Surgery and flying have a lot in common. The training is time consuming and expensive. Mistakes tend to become sad and expensive. Training cannot be done on the real hardware.
The future surgeon has to stand behind the experienced surgeon for a long time and this passive training cannot be planned as the patients come randomly. Neither can this passive training be focused on special difficulties on demand. Simulation tools for surgeons is as important as flight simulators.

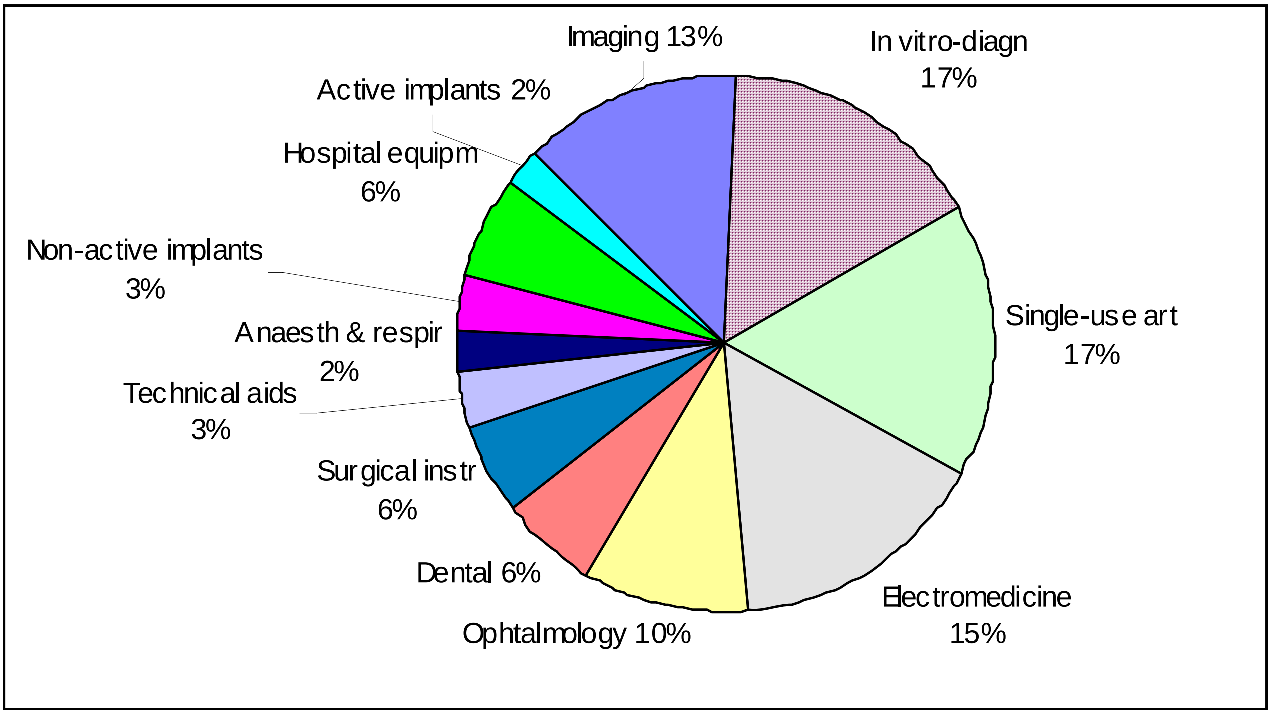
Medical scanners

The large economic industrial sector within medical imaging is the medical scanners.

- The US market for medical scanners including auxiliary products is $ 7.9 billions (2004)
- World market estimated from above: $ 20 billions
- The annual growth is 5.7%
- The fastest growing category is computer systems used for adjunts for disease detection. This sector has an annual growth of 21%
- The cost per scanner is
  - CT 0,3 – 1,1 million €
  - MR 0,9 – 2,2 million €
- Exchange frequency can vary between different countries, but are typically 7 – 9 years.
- US are the “leading” country in **h**ealth **c**are and **m**edical **d**evices cost per capita as shown in the diagram below:



The medical scanning market (in the figure below called Imaging) is 13% of the technical medical market

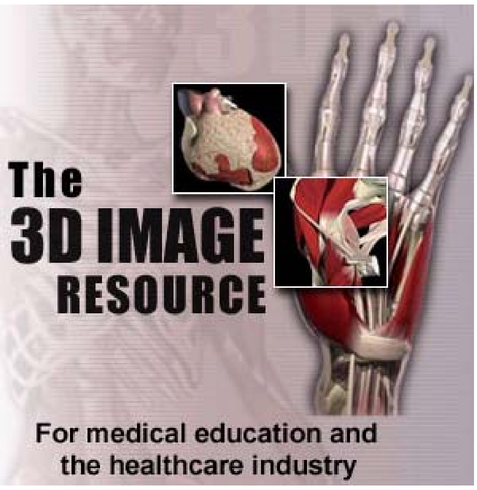


Two big companies Siemens and General Electric dominate the market. Other companies are Philips, Toshiba and Hitachi. Added to this are there many small companies in distinct niches like mammography, bone density measurements and radiation knifes.

Surgeon education
Surgeon education is expensive as the surgeons are not free to train on the real object. Examples of tools tat are wanted are:

- Advanced 3D imaging
- Simaulators
- Haptic

A success story within commercialising a useful 3D-imaging package is the company Primal pictures.



Primal Pictures has developed an advanced 3D image package of the human body. All parts of the bodie can be viewed in the cross section of your free choice and you are also free to look under the skin at the depth of your choice.
The basic development was founded by governmental research money. Primal pictures was established in 2001 and showed a turnover of 3.4 M€ 2003.
The product is sold in 44 different packages for different target groups like:
Hospitals, universities, students, sport injuri interests, hand therapists, chiropractors and short time licences.
The student price is 130e and the hospital full package

costs 930€.

Some important factors for the success of Primal Pictures are:

- That the product is a response on a real need and has a good quality
- The combination of governmental research money and commercial development
- That the product does not correspond to an incremental development step, but the opposite, by covering the whole body.

Estimate of the market size for surgeon education products:
Sweden educate 400 surgeons every year. We use to be 1% of the world in wellfare figures. This makes a World market 40.000 surgeon student pro year. With software products for 125€/student is the potential market 5 M€/year. The potential market to organisations might be in the same order.

The potential world market for surgeon pedagogic imaging educational product is estimated to 10 million euros pro year.

Computer and TV game industry

- Sales in Sweden 2004 170 Million €
- Annual increase (since 2003) 20 %
- From above estimated World market 10 – 15 Billion €
- Especially on line games 2003 1,9 Billion €
- On line games 2009 (estimated) 10 billion €
- Typical development cost for a game
  Yesterday 1 M€, today 4M€, tomorrow 10 m€

Economic summary

Medical scanners	$ 20 Billions
Growth: 5,7%	
Education	€ 10 Millions
Games	€ 10 – 15 Billions
Growth 20%	

Economic conclusion
As surgeon education has a market size of less than 1 per mille of the game sector and the game sector is very fast growing, can it not be expected that more than randomly the game sector will show economic interest in the surgeon education business. The education development will be much helped by the gigantic game sector, but mostly in an indirect manner.

Society economic effects

The real big advantage of a faster progress within the medical imaging areas are that human beings can be helped to a better life. In this chapter we will make rough estimates of the society economic effects for the Nordic countries, who together has 25 million inhabitants. The ambition has not been to develop scientific true values, but to get a rough feeling for the approximate size of the economic effects.

Save in surgeon education costs

The number of surgeons educated every year in the Nordic countries is estimated to 1.100 and the yearly cost of each for the university 8.000€. If an ambition programme with not just one, but a complete set of pedagogic tools can shorten the education with ½ year, the total saving will be **9 million euro**. It reasonable to believe that the pay-off time on the development costs will be in the order of 3 years.

Additional benefits will be

- Tax income from the surgeons that can start their carrier a ½ year earlier
- Sales of the education package outside the Nordic countries
- Increased quality check of the student skills
- Increased skills in advanced and rare treatments

Save by physical models

There are some studies done on the international arena in this area. The cost savings will come from:

- Time savings during operations
- Shorter hospital visit
- Lower mortality rate
- Lower number of re-operations
- Shorter recovery time to get back to job
- Higher number that will succeed to get back to work

Physical models are and should be used for complicated cases. As a rule of the thumb, the physical model will pay it’s cost for operation that last longer than 2½ hour, just by shortening the operation time. It is not un-common that complicated operations can take up to 18 hours. If we include the cost savings from shortened hospital visits because of a reduced trauma for the patient, the break through time will be reduced to 2 hours.

If physical models are used, and only used, for complicated cases, with operation times over 2 hours is the estimated cost savings within cranium, spine and maxillary surgery estimated to **40 – 50 million euro per year** in the Nordic countries.

If indications that show that mortality may be lowered by this quality increase in treatment are proved to be true, the society cost savings will be many times bigger.

Implant production

The technologies of producing advanced porous and patient tailored implant scaffolds are too mature to do an estimate of the society economic effects. The main savings will probably be outside the hospital by faster and better patient recovery. These characters of economic savings are usually summed up to much higher total values than savings within the hospitals.

Open market possibilities

This chapter focus on the market possibilities within image based pedagogic tools for surgeon education. As shown in earlier chapters is the market need for such products very high, but still is the market economy possibilities limited as the target group, the surgical student, is too small.

A lot of network discussion efforts have been put within the project into this area and two promising market concepts have been defined.

Concept 1

By studying successful and less successful companies in the area we believe in a product defined within these limitations:

- The development costs of the product should be shared between research finance organisations and one or two private companies. We believe that it is a realistic demand that this development should be research financed to some degree, as the main advantages will not be of business economic character.
- Keep it simple. It is easy, especially with research foundation, to have a high appetite on scientific and technology excellence, and there are no limitation in neither scientific or technology possibilities. To achieve a final product that can carry its own costs on the open market, do we believe that it must be kept simple.
- Rather than doing a single package for a single application we believe full multipurpose packages. The reason for this lies in the future marketing of the product. Full multipurpose packages don hardly not need marketing as they will show such a news value that the market will observe the product anyway. More narrow projects for single applications are however good pre-projects for later big scale achievements, maybe by an EU-project.

Concept 2

In some of the Nordic countries has lately “micro bribes” within the medical product markets been observed and focused. Where it very recently was standard that the market agent invited a number of surgeon to a nice dinner to show their new products is it now and sudden very much strict that nothing can be judged as small bribes.

For the time being is there a “hole” in the market strategies. One efficient method has been taken away and has not yet been replaced with anything else.

We believe that this hole can be filled with a real good web site. A web site that all surgeons around the world go to find many kinds of information. This web site can preferable be hosted by one of the big companies on the market like General Electric, Siemens or Astra. Hosting such a web site is efficient for their branding and gives them a first row position when marketing new products.
To be frequently visit the web site should mainly include stuff that is not directly connected to their brand, like educational video movies.

Research recommendations

Efforts within medical imaging will pay back in huge humanitarian benefits and society economic savings. The Nordic countries can reach a world front position in the area as we have an industrial frontier position within haptic technologies, computer games and Rapid Manufacturing technologies for individual human bone implant production.

We have recognised that most success stories come from a good cooperation between research projects and commercial interests.

We thus recommend that research programmes in the Nordic countries highlights the complete road from simulators in surgeon education, pre-operational planning, implant design and too implant manufacturing by Rapid Manufacturing. Three areas should be specially focused:

- Haptic design of implants
- Simulation
- Rapid Manufacturing of implants

The group do recommend the following research areas for the Nordic countries:

Educational packages
See chapter Open market possibilities above. Especially for the Nordic countries do we recommend smaller projects that can work as pre projects and entrance tickets for later EU-projects.

Wider spread of the use of physical models
Physical models are in weekly use by a few surgeons in a few hospitals. Sometimes even colleagues in the same hospital now about the usefulness of the technology or how to use it. The technology must also be developed for still more complex application like cardiac and combined scanner technologies (MR + CT or CT + PET).

Haptic and simulations
The Nordic countries are strong in these both areas. By adding research money we can be World leaders

Producing real implants by Rapid Manufacturing
As can be read in the chapter Direct manufacturing of implants, can Rapid Manufacturing give revolutionary advantages compared to today’s implants, as porous structures for optimal osseointegration and individual shapes.

The Nordic countries are strong within the area with the two companies Arcam and fCubic together with university and hospital expertise and network. The technology are expected to emerge to a new world industry sector with a fast annual growth.

Nordic Innovation Centre

Nordic Innovation Centre

The Nordic Innovation Centre initiates and finances activities that enhance innovation collaboration and develop and maintain a smoothly functioning market in the Nordic region.

The Centre works primarily with small and medium-sized companies (SMEs) in the Nordic countries. Other important partners are those most closely involved with innovation and market surveillance, such as industrial organisations and interest groups, research institutions and public authorities.

The Nordic Innovation Centre is an institution under the Nordic Council of Ministers. Its secretariat is in Oslo.

For more information: **www.nordicinnovation.net**

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