
VIVE

Picture credit: Bauer

Beyond the Limits **of our Eyes**

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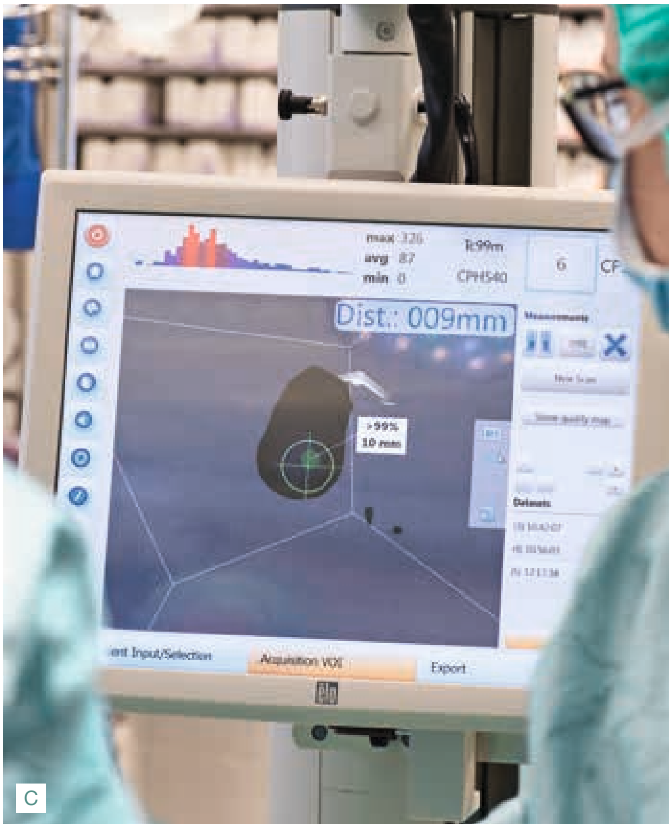
Nowadays, surgeons can access a wealth of information about their patients. X-rays, CT scans and MRI images reveal structures inside the body that are usually not visible to the naked eye. In the middle of an operation, however, physicians have to rely on their own senses. Prof. Nassir Navab wants to change this by bringing augmented reality into the operating theater.

The video image of the surgery is augmented with a 3D model of the radioisotope labeled sentinel lymph node.

Reference structure to determine the position of the patient in the camera image.

A gamma probe is used to map the sentinel lymph node by detecting radiation emitted by the injected radioisotope. This data is used for reconstruction and then visualized in real time in the video image on the computer screen.

Graphics: ediundsepp, Picture credit: Bauer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Sentinel lymph node
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Scanning the body area with a gamma probe (A) and tracking this action with a special camera and navigation system (B) allows augmentation of the video with a reconstructed 3D image. The surgeon can see which areas are already scanned (black). Based on the gamma data, a 3D model of the sentinel lymph node is calculated (C) and correctly superimposed on the body to guide the surgeon (D) for the surgical resection.

Claudia Doyle

Jenseits des Sichtbaren

Chirurgen haben heutzutage Zugriff auf eine Fülle von Informationen. Röntgenbilder, CT-Scans oder MRT-Aufnahmen machen Strukturen im Inneren des Körpers sichtbar, die menschlichen Augen normalerweise verborgen bleiben. Doch während einer Operation sind die Ärzte wieder allein auf ihre Sinne gestellt. Prof. Nassir Navab will das ändern, indem er Augmented Reality in den Operationssaal holt.

Die erste Anwendung von Augmented Reality, die routinemäßig von Ärzten eingesetzt wird, ist ein von Navab und den medizinischen Partnern der Nuklearmedizin und Frauenheilkunde am Klinikum rechts der Isar entwickeltes kleines Messgerät namens declipseSPECT. Es handelt sich um eine Miniaturausgabe einer Gammakamera, die der Chirurg während der Operation benutzen kann. Mit normalen Gammakameras ist das nicht möglich. Die mannsgroßen Maschinen sind meist in einem eigenen Raum installiert und nicht flexibel.

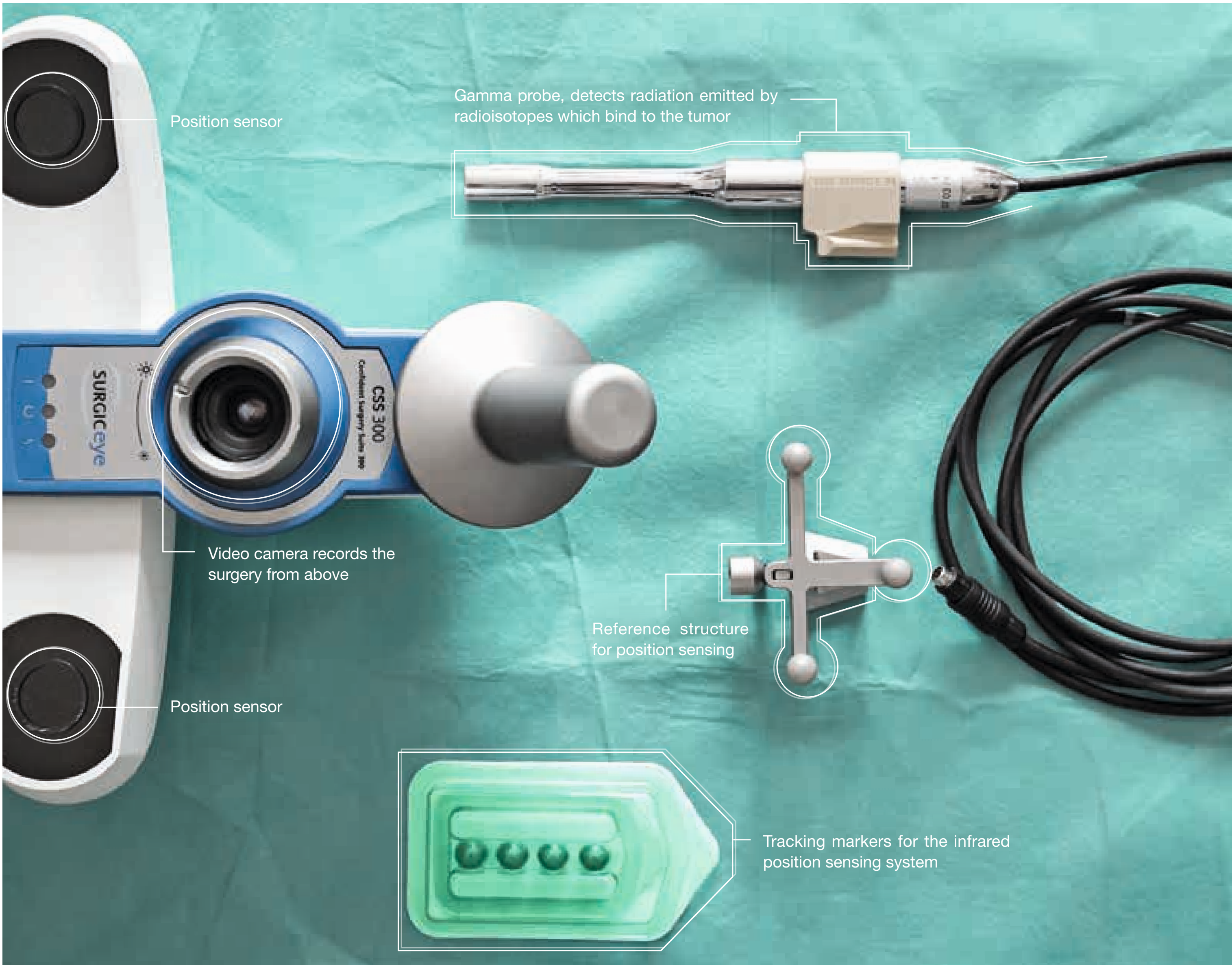
Zur Anwendung kommt declipseSPECT beispielsweise bei der Lymphknotenbiopsie. Hat ein Patient einen Tumor, dann prüfen Chirurgen mit Hilfe dieser Methode, ob der Krebs bereits metastasiert ist. Finden sich Krebszellen in dem Lymphknoten, der im direkten Lymphabfluss des Tumors ist, dann ist das wahrscheinlich.

Um genau den richtigen Lymphknoten chirurgisch minimalinvasiv entfernen zu können, spritzen die Mediziner dem Patienten eine sehr geringe Dosis eines radioaktiven Mittels. Dieses reichert sich im Wächterlymphknoten an und kann mit der Gammakamera detektiert werden.

Die Vorteile liegen in der kombinierten Darstellung der Daten. Zum einen ein Live-Videobild des Patienten, aufgenommen von einer über dem OP-Tisch installierten Kamera. Zum anderen die Lokalisierung der Lymphknoten, gemessen mit der Gammakamera. Der Chirurg weiß dann genau, wo er den richtigen Wächterlymphknoten findet.

Intensiv erforscht wird auch der mögliche Einsatz von sogenannten Head-Mounted-Displays. Diese in der Vergangenheit klobigen Brillen, ausgestattet mit Sensoren, Kameras und Bildschirmen, sind bisher vor allem aus der Unterhaltungselektronik bekannt. Doch auch ein Einsatz im Operationssaal ist denkbar. Die Chirurgen sollen dann den Patienten vor sich sehen und sich gleichzeitig je nach Bedarf Röntgenbilder, CT-Scans oder andere Informationen in ihr Blickfeld projizieren lassen. Möglich ist vieles. Aber die richtige Information zum richtigen Zeitpunkt anzuzeigen, das ist die große Herausforderung. □

Graphics: ediundsepp, Picture credits: Bauer



Nassir Navab invented declipseSPECT in collaboration with clinical partners specializing in nuclear medicine.

Graphics: ediundsepp, Picture credit: Bauer

With a steady hand, Dr. Stefan Paepke moves the finger-sized measuring instrument over the skin of his patient. The surgeon traces slow circular movements between the armpit and the breast. An image recorded by a camera can be viewed on a screen beside the operating table. Black spots that become steadily larger slowly start to appear. These are the areas that Paepke has already recorded with his measurement device.

Operating theater 3 in the gynecology department of Munich's Klinikum rechts der Isar looks no different to the facilities in many other hospitals. But there are a few important differences, such as a small device called declipseSPECT. This is a miniature version of a gamma camera – an instrument often used in nuclear medicine to detect cancer cells.

It takes Paepke around one minute to scan the entire area. A 3D image is reconstructed from gamma rays acquired from the area marked in black, wherein a green-colored region becomes visible. This is the sentinel lymph node, which lies in the direct drainage path of the primary tumor. If the tumor has formed metastases, the answer can be found in this lymph node. Paepke can use this image to pinpoint the exact location of the lymph node and determine its subcutaneous depth. He can then reach for his scalpel and extract the correct lymph node a short time later.

The working group led by Nassir Navab invented declipseSPECT in collaboration with clinical partners specializing in nuclear medicine. The system was designed, developed and tested from the outset in close collaboration with Stefan Paepke in the gynecology operating theater of Klinikum rechts der Isar. Since then, the device has been used in hundreds of operations at several different clinics. declipseSPECT thus holds the distinguished position of being one of the first medical applications of augmented reality which has already achieved market maturity and is in regular use in clinical settings. According to Navab, it will by no means be the last.

Nassir Navab has held the Chair of Computer-aided Medical Procedures and Augmented Reality at TUM since 2003. He stresses that he does not want to replace surgeons, but rather make their job as easy as possible. "Surgeons nowadays use only a small percentage of the information that is actually available to them," explains Navab.

One reason for this is the rapid rise over recent decades in the choice of medical measuring instruments available to clinicians. In earlier times, physicians could only take basic measurements like blood pressure, pulse rate or temperature. But now, technology in many different forms, including X-ray, ultrasound, CT scans, MRI, PET, SPECT and photoacoustic procedures, provide deep insights into what is happening inside patients' bodies. This means that specialists can, for example, visualize brain activity, see where cancer cells are growing and understand more about inflammations.

"Today's surgeons usually have too much, rather than too little, information at their disposal," affirms Dr. Jörg Traub. Since 2008, the former Ph.D. student of Nassir Navab has been managing director of the company SurgicEye, which has been overseeing the approval, market rollout and further development of the hand-held gamma camera. "These huge volumes of data have to be filtered and then presented at exactly the right time." This means that information should ideally be available immediately before or during the critical phases of an operation.

To achieve this, Navab's team miniaturized the SPECT acquisition setup. Normally, SPECT acquisition devices are man-sized imagers installed at a fixed location. The patient therefore has to be moved from the operating table to the gamma camera. The great benefit of declipseSPECT is the flexibility that comes with a tracked hand-held device. ▷

This RAMP Head Mounted Display (HMD) system was developed at Siemens Corporate Research at the end of 1990s.

Virtual reality becomes augmented reality when the VR set is combined with a camera, which records the real environment to be displayed inside the HMD. Additional tracking markers on the headset help determine the user's position more accurately.

Even though it is small and portable, declipseSPECT is very similar to fixed gamma cameras in terms of functionality. The patient is first injected with a radioactively labeled molecule. This is dispersed throughout the body and binds to certain tissue structures. The camera then detects the radiation emitted by this molecule.

In operating rooms without declipseSPECT, surgeons rely on acoustic signals from a type of Geiger counter, which emits peeps that go from fast to slow and from quiet to loud when it detects radioactivity. This does not tell the surgeon how deep the lymph node is located beneath the surface, however.

For patients, it is vitally important to have what is called the sentinel lymph node removed. As the closest lymph node to the tumor, it would be the first to be affected by a possible metastasis and has to be examined. The head and throat regions have a particularly high number of lymph nodes close to the tumor, and acoustic methods are of limited use when a tumor is being examined here. The problem is that it is not always clear whether the radioactivity is coming from the sentinel lymph node or from the injection point of the radioactive substance. declipseSPECT is able to throw light on this question. The surgeons at Klinikum rechts der Isar are extremely pleased with the new instrument, and welcomed the arrival of a computer scientist in their workplace with open arms.

When Nassir Navab moved to Munich in 2003, he immediately made it clear that his staff had to have direct contact with the surgical teams, preferably on a daily basis. Without further ado, he took over the empty basement rooms at the inner-city clinic of LMU Munich. He and his staff got to work straight away, continuously asking the surgeons what they need, what hampers their work, what could be improved and what they would like to add to their wishlist.

After six months, they were driven out of their underground vault. The hospital management had been won over by the work of Navab and his team in the meantime, however, and so they were offered a smart suite of offices right next to the operating theater in the new clinic building.

"I was delighted with the opportunity to set up my lab inside the hospital," affirms Navab. While working for his previous employers, there was much less interaction between engineers and clinicians. Just one meeting per year was organized to discuss surgeons' wishlists and identify the potential benefits of new technologies. "Twelve months later, we came back to the clinic and presented our inventions to the physicians, only to be told more often than not that it was not what they were looking for," relates Navab.

A short time later, Navab opened a second lab in TUM's Klinikum rechts der Isar, where he now works with physicians from fields as diverse as urology, surgery and nuclear medicine. They are all interested in finding out how augmented reality can make their work easier. The computer scientists and the clinicians are constantly discussing clinical needs and bouncing new ideas around for how to use advanced technology to satisfy them. ▷

Augmented reality optical see-through headsets have a transparent display and overlay the reality that the user views through the glasses with additional information.

Tests with a see-through augmented reality HMD: While cameras on the HMD allow for the augmentation of the patient view, infrared markers allow the HMD to be localized and co-registered with surgical instruments. Co-registration means that position and orientation of real and virtual objects match.

Graphics: ediundsepp, Picture credits: Bauer

“Surgeons nowadays use only a small percentage of the information that is actually available to them.”

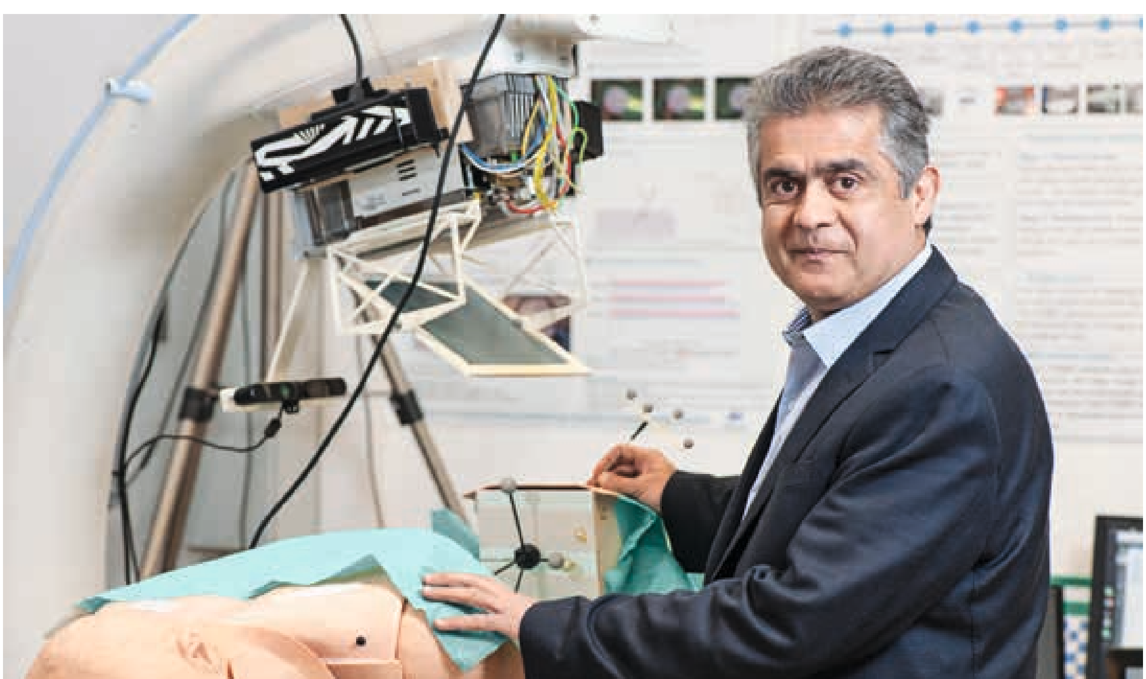
Nassir Navab

Try out AR yourself
Frieder Pankratz and David Plecher from Gudrun Klinker’s team designed an AR application for Faszination Forschung.
It runs on Android devices and can be downloaded using the QR code below. Once the app is installed, you can scan this article as well as the article about about Prof. Klinker with your smartphone or tablet computer. Some images trigger the app to show additional information, overlaid in 3D above the images.

Prof. Nassir Navab

A computer scientist embedded in the surgeon team

Nassir Navab was born in Iran and went to university in France. He initially studied mathematics and physics before moving on to computer science and system control. During his doctoral thesis, he performed research on a robot destined for a Mars discovery mission. After completing his doctorate, he went to work in the USA, first at Massachusetts Institute of Technology and then in the research department of Siemens in Princeton. In 2003, he relocated to Munich with his wife and two children, where he set up the Chair of Computer-aided Medical Procedures and Augmented Reality. One thing he regards as crucial to his work is close proximity to the physicians who will one day use the technology he is developing. “Without constant feedback from the operating theater, what we develop will not meet real-world requirements,” explains Navab.
Nassir Navab has been settled in Munich for 13 years now. He loves the city’s cosmopolitan and friendly vibe, relishing the fact that he can enjoy a Persian concert and then spend a chilled evening in a Bavarian beer garden – all in one day!



This interactive augmented 'magic mirror' allows everyone to get familiarized with their own anatomy. The left hand moves the AR local window into the anatomy and the right hand changes the level of details from bony structures, to organs and vascular system and finally the surrounding fat and muscles. The system can be used for anatomy education, patient information and rehabilitation.

"For me, it is not enough to have just one clinical partner," says Navab. Every surgeon has undergone different training and has a different way of thinking. It is therefore important to get feedback from as many people as possible since the ultimate objective is to get as many clinics as possible to use the new inventions. This is why Nassir Navab set up a second lab at Johns Hopkins University on the east coast of the USA around three years ago. He spends around one week per month stateside, asking questions, listening to feedback and developing new ideas.

One of the more long-term projects that he has been working on with his team focuses on a head-mounted display (HMD) for surgeons. These oversize spectacle frames equipped with cameras, screens and position sensors are a common sight in the world of entertainment. Just about every major player specializing in gaming consoles and video games has brought out its own version of an HMD by now.

There are two types of head-mounted displays. What are known as optical see-through HMDs have a transparent display, so what users see is their actual environment. Then there are video see-through HMDs with a non-transparent display, where two cameras film the user's surroundings and present this image to the wearer. It is possible to project additional information onto both types of display with AR technology.

At present, HMDs are mostly of interest as a training aid. The technology lets physicians practice certain procedures under realistic conditions so that they are better prepared when they have to perform them during an operation. HMDs also play an important role when it comes to planning operations. The scientists are currently working on ways to plan neurosurgical interventions like deep brain stimulation using HMDs. Bringing this technology to a live operating theater remains the Holy Grail, however. A surgeon wearing an HMD would not only be able to see the patient in front of them, but also be able to call up useful images like X-rays, MRT scans or ultrasounds on demand. "It is of course always possible to walk to a monitor and view the images there," says Ulrich Eck, head of the NARVIS working group, "but our vision involves projecting them directly onto the corresponding area of the patient's body."

The main challenges for the researchers at present involve processing and visualizing the data because of the massive computational tasks that have to run in the background. Feedback from physicians is crucial here because they can specify what information is important at which point during an operation.

"Augmented reality is often viewed as a gaming gimmick, and that is true in some ways," admits Jörg Traub. At the end of the day though, the technology is too useful to be limited to fun and games.

Claudia Doyle

Picture credit: Bauer