RESEARCH NEWS

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Phone: 089 1205-1302
presse@zv.fraunhofer.de
www.fraunhofer.de/presse

1 Titanium foams replace injured bones

Flexible yet rigid like a human bone, and immediately capable of bearing loads: A new kind of implant, made of titanium foam, resembles the inside of a bone in terms of its structural configuration. Not only does this make it less stiff than conventional massive implants. It also promotes ingrowth into surrounding bones.

2 Wheel in a corset

Are lightweight construction materials suitable for extremely stressed and safety-relevant components such as car wheel? Tests and calculations show that fiber-reinforced plastics are highly damage-tolerant and distinctly superior to aluminum in car wheels. Researchers have already produced a prototype lightweight wheel.

3 Image sensors for extreme temperatures

Image sensors which are used as electronic parking aids in cars or for quality control in production systems have to be able to withstand the often very high temperatures that prevail in these environments. Research scientists have produced a CMOS chip which functions even at a temperature of 115 degrees Celsius.

4 New luggage inspection methods identify liquid explosives

Liquid explosives are easy to produce. As a result, terrorists can use the chemicals for attacks – on aircraft, for instance. In the future, new detection systems at airport security checkpoints will help track down these dangerous substances. Researchers are currently testing equipment in their special laboratories.

5 Playing snooker with atoms

Scientists speak of sputtering when energy-rich ions hit a solid object and cause atoms to be released from its surface. The phenomenon can be exploited to apply microscopically thin coatings to glass surfaces. A research team has developed a special sputtering technique that greatly increases the efficiency of the coating process.

6 Vigilant camera eye

An innovatice camera system could in future enhance security in public areas and buildings. Smart Eyes works just like the human eye. The system analyzes the recorded data in real time and then immediately flags up salient features and unusual scenes.

The Fraunhofer-Gesellschaft is the leading organization for applied research in Europe. Its research activities are conducted by 59 Fraunhofer Institutes at over 40 different locations throughout Germany. The Fraunhofer-Gesellschaft employs a staff of around 17,150, who work with an annual research budget totaling 1.6 billion euros. Roughly two thirds of this sum is generated through contract research on behalf of industry and publicly funded research projects. Branches in the USA and Asia serve to promote international cooperation.

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Titanium foams replace injured bones

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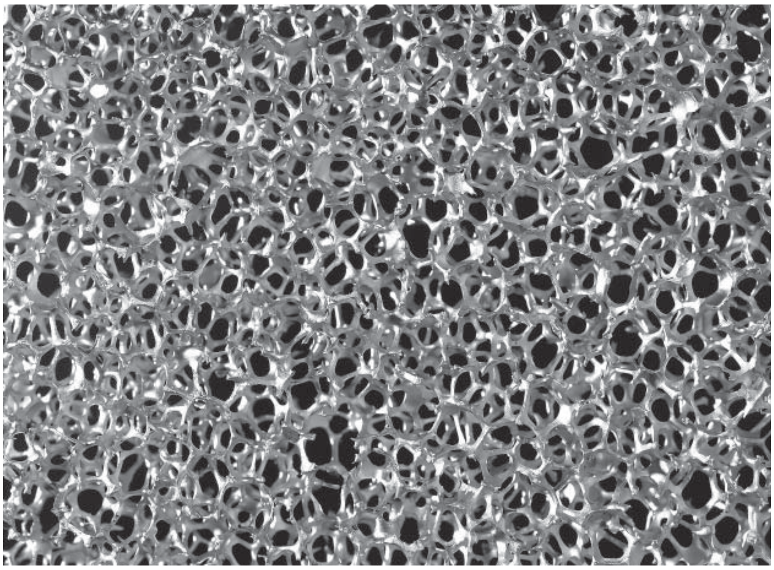
The greater one's responsibilities, the more a person grows. The same principle applies to the human bone: The greater the forces it bears, the thicker the tissue it develops. Those parts of the human skeleton subject to lesser strains tend to have lesser bone density. The force of stress stimulates the growth of the matrix. Medical professionals will soon be able to utilize this effect more efficiently, so that implants bond to their patients' bones on more sustained and stable basis. To do so, however, the bone replacement must be shaped in a manner that fosters ingrowth – featuring pores and channels into which blood vessels and bone cells can grow unimpeded. Among implants, the titanium alloy Ti6Al4V is the material of choice. It is durable, stable, resilient, and well tolerated by the body. But it is somewhat difficult to manufacture: titanium reacts with oxygen, nitrogen and carbon at high temperatures, for example. This makes it brittle and breakable. The range of production processes is equally limited.

There are still no established processes that can be used to produce complex internal structures. This is why massive titanium implants are primarily used for defects in load-bearing bones. Admittedly, many of these possess structured surfaces that provide bone cells with firm support. But the resulting bond remains delicate. Moreover, the traits of massive implants are different from those of the human skeleton: they are substantially stiffer, and, thus, carry higher loads. »The adjacent bone bears hardly any load any more, and even deteriorates in the worst case. Then the implant becomes loose and has to be replaced«, explains Dr.-Ing. Peter Quadbeck of the Fraunhofer Institute for Manufacturing and Advanced Materials IFAM in Dresden. Quadbeck coordinates the »TiFoam« Project, which yielded a titanium-based substance for a new generation of implants. The foam-like structure of the substance resembles the spongiosa found inside the bone.

The titanium foam is the result of a powder metallurgy-based molding process that has already proven its value in the industrial production of ceramic filters for aluminum casting. Open-cell polyurethane (PU) foams are saturated with a solution consisting of a binding medium and a fine titanium powder. The powder cleaves to the cellular structures of the foams. The PU and binding agents are then vaporized. What remains is a semblance of the foam structures, which is ultimately sintered. »The mechanical properties of titanium foams made this way closely approach those of the human bone«, reports Quadbeck. »This applies foremost to the balance between extreme durability and minimal rigidity.« The former is an important precondition for its use on bones, which have to sustain the forces of both weight and motion. Bone-like rigidity allows for stress forces to be transmitted; with the new formation of bone cells, it also fosters healing of the implant. Consequently, stress can and should be applied to the implant immediately after insertion.

In the »TiFoam« project, the research partners concentrated on demonstrating the viability of titanium foam for replacement of defective vertebral bodies. The foam is equally suitable for »repairing« other severely stressed bones. In addition to the materials scientists from the Fraunhofer institutes IFAM and IKTS – the Institute for Ceramic Technologies and Systems in Dresden – physicians from the medical center at the Technical University of Dresden and from several companies were involved in developing the titanium foam. Project partner InnoTERE already announced that it would soon develop and manufacture »TiFoam«-based bone implants.



The new titanium-based material features a foam-like structure. (© Fraunhofer IFAM)

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Fraunhofer Institute for Manufacturing and Advanced Materials IFAM
Winterbergstraße 28 | 01277 Dresden, Germany | www.ifam-dd.fraunhofer.de
Contact: Dr.-Ing. Peter Quadbeck | Phone +49 351 2537-372 | peter.quadbeck@ifam-dd.fraunhofer.de
Press: Cornelia Müller | Phone +49 351 2537-555 | cornelia.mueller@ifam-dd.fraunhofer.de

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Wheel in a corset

Just imagine your car suddenly comes to a halt on a quiet country road, and it's only four years old. This is not a pleasant thought. A breakdown is expensive. Not to mention the safety risk to the occupants – because the breakdown was caused by the extremely light plastic wheels so highly praised by the car salesman. One of them has broken. »Such a scenario must, of course, never happen in reality,« states Prof. Dr.-Ing. Andreas Büter from the Fraunhofer Institute for Structural Durability and System Reliability LBF in Darmstadt. The experts there specialize in operational strength testing of plastics in general and plastic wheels in particular.

To create the fundamentals for the production of lightweight and yet safe and reliable components they launched the High-Strength Plastic Structures project in cooperation with five other Fraunhofer institutes. »The aim was to provide the conditions and the tools for the operationally reliable design of extremely light safety parts made of SMC (sheet molding compound) material which could be produced on an ongoing basis in medium to large volumes. SMC is a fiber-reinforced composite material which mainly consists of inorganic constituents,« explains project manager Professor Büter. »Up to now SMC has only been used for secondary parts of the bodywork such as the bonnet or doors,« states Büter. »The purpose of our project was to clarify whether SMC is also suitable for safety-relevant primary parts.« SMC is superior to metal in several ways. It is not only lighter but also exhibits an excellent mass-to-strength ratio. What's more, it is cheap to produce in medium to large quantities.

But what are the material properties of SMC? How are the fibers oriented? What production methods are suitable for processing this material? Are there any air conclusions? What stresses and loadings can SMC car wheels withstand? The research scientists have looked into these and other questions. »On our test stands we have simulated for example how the wheels and suspension of a car behave on a rough road, in forward motion and reversing, and how long the components can endure these conditions,« states Andreas Büter, describing the tests conducted at the LBF. After three years of research work the scientists can now present the results. On conclusion of the project Büter highlighted an important finding: »If correctly processed, fiber-reinforced plastics are highly damage-tolerant and distinctly superior to aluminum wheels.«

And what happens now? In cooperation with the industry the researchers would like to create a wheel based on the developed prototype which can withstand high stresses and loadings. It would feature a local reinforcement of continuous fibers. »That would act like a supporting corset for the wheel,« the project manager adds, outlining his team's vision. A prototype of the lightweight wheel will be on display at the Composites Europe trade show from September 14 to 16 in Essen (Hall 12, Stand C33).

This wheel made of fiber-reinforced plastic is particularly light and exhibits high structural durability. (© Fraunhofer LBF)

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Fraunhofer Institute for Structural Durability and System Reliability LBF
Bartningstraße 47 | 64289 Darmstadt, Germany | www.lbf.fraunhofer.de
Contact: Prof. Dr.-Ing. Andreas Büter | Phone +49 6151 705-277 | andreas.bueter@lbf.fraunhofer.de
Press: Anke Zeidler-Finsel | Phone +49 6151 705-268 | anke.zeidler-finsel@lbf.fraunhofer.de

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Image sensors for extreme temperatures

More and more car manufacturers are equipping their vehicles with image sensors – e.g. to register the presence of pedestrians or vehicles in the blind spot or to detect obstacles when parking. The sensors must be able to function in extremely high temperatures and in blazing sunlight. If they are installed behind the rear view mirror or on the instrument panel, for example, they can get very hot. The Fraunhofer Institute for Microelectronic Circuits and Systems IMS in Duisburg has developed a CMOS (complementary metal oxide semiconductor) image sensor for an industrial customer which can withstand temperatures ranging from -40 to +115 degrees Celsius. The CCD (charged coupled device) image sensors available up to now fail when the temperature goes beyond about 60 degrees. »Our chip is not only heat-resistant, it even functions at arctic temperatures,« says Werner Brockherde, head of department at the IMS.

The research scientists have succeeded in developing pixels which exhibit an extremely low dark current. This reduction of residual current, which flows in complete darkness, makes it possible to capture very high-quality images even in extreme heat. »It was not easy to achieve a low dark current. An increase in temperature of just eight degrees doubles the dark current, resulting in image noise and reduced dynamics. Ghosting occurs in the form of artifacts or fuzziness and degrades the image,« explains Brockherde.

A further special feature of the sensor is its image size of 2.5 x 2.5 centimeters. This offers the advantage that for special applications with weak illumination or for capturing images in the infrared or UV range the sensor can be connected directly to an electronic image intensifier. The sensor has a resolution of 256 x 256 pixels. Its high dynamic range or exposure latitude of 90 decibels provides increased contrast and optimized detail accuracy both in shadow as well as in very bright areas. Nuances of light are precisely reproduced. Thanks to its efficient light absorption, the image sensor reacts with high sensitivity even in weak light conditions. It is therefore also suitable for night vision equipment. What's more, the chip supports cameras with synchronous as well as asynchronous shutters. The synchronous shutter prevents motion artifacts, for instance when recording rapid movements, reducing movement fuzziness. The rolling shutter permits a higher image frame rate and continuous image recording. The effect of this is to minimize image noise. »We produced the sensor in a standard process using 0.5 micrometer CMOS technology in our own semiconductor factory. We also produce special components here for industrial customers,« states the scientist, reflecting the expertise of the Institute. In addition to the automotive sector he can see further potential markets: »Our chip is suitable for deployment in chemical and steel production facilities, where it can be used for process and quality control. Very high temperatures prevail, for example, in rolling mills where sheet metal is produced.« The CMOS image sensor will be on show at the Vision trade fair from November 9 to 11, 2010, in Stuttgart (Stand 6 D12).

The CMOS sensor can be connected directly to an electronic image intensifier. (© Fraunhofer IMS)

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Fraunhofer Institute for Microelectronic Circuits and Systems IMS
Finkenstraße 61 | 47057 Duisburg, Germany | www.ims.fraunhofer.de
Contact: Werner Brockherde | Phone +49 203 3783-230 | werner.brockherde@ims.fraunhofer.de
Press: Martin van Ackeren | Phone +49 203 3783-130 | martin.van.ackeren@ims.fraunhofer.de

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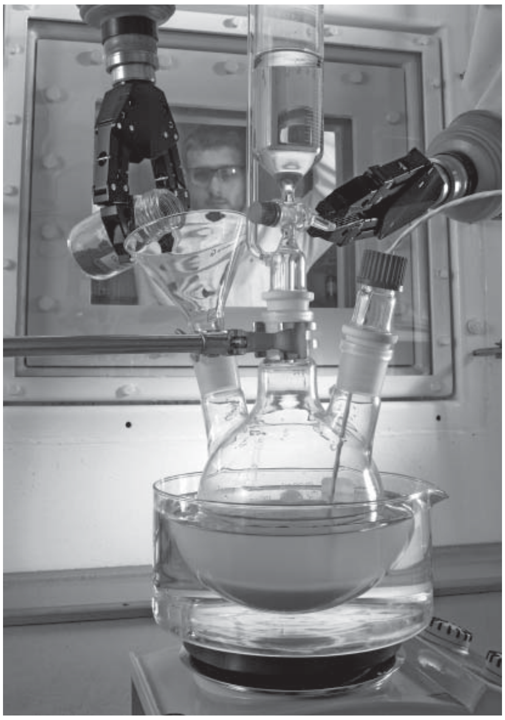
New luggage inspection methods identify liquid explosives

To most air travelers, it is an annoying fact of life: the prohibition of liquids in carry-on luggage. Under aviation security regulations introduced in Europe in November 2006, passengers who wish to take liquids such as creams, toothpaste or sunscreen on board must do so in containers no larger than 100 ml (roughly 3.4 fluid oz.). The EU provisions came in response to attempted attacks by terrorist suspects using liquid explosives on trans-Atlantic flights in August 2006. Now, travelers have a reason to hope to see the prohibition lifted. On November 19, 2009, the EU Regulatory Committee of the Member States passed a proposal to this effect issued by the EU Commission. Under the terms of the proposal, the prohibition of liquids will be lifted in two phases. First, beginning April 20 9, 2011, passengers in transit will be permitted to take liquids along with them. Under the second phase, beginning April 20 9, 2013, the limit on quantities of liquids will be lifted altogether. The EU Commission intends to introduce legislation to this effect this August. In the future, security checkpoints will feature equipment that can reliably distinguish between liquid explosives and harmless substances such as cola, perfume or shampoo.

This is also the intention of the European Civil Aviation Conference (ECAC), which lays down standardized detection procedures and inspection routines for liquid explosives. The explosives tests are being carried out by the Fraunhofer Institute for Chemical Technology ICT in Pfinztal. The German Federal Ministry of the Interior has officially designated the institute as a German Testing Center. The researchers there are working in cooperation with the German Federal Police. »In our safety laboratory, we can carry out the experiments under all of the safety conditions we would find in the field,« remarks Dr. Dirk Röseling, a researcher at ICT. »Either on their own or at the invitation of ECAC, the manufacturers bring their detection equipment to our lab, where they show us how to operate it and then leave. Then we begin with testing.«

But how do these experiments work? In their partially remote-controlled experimental facilities, first researchers at the safety laboratories manufacture explosives according to specifications provided by the ECAC. Security services provide the organization with lists of substances to use in manufacturing explosives. Then, the detection equipment must automatically identify the liquid explosive – as well as any harmless substances – as such. For instance, the equipment must not identify shampoo as an explosive and set off a false alarm. Depending on the scenario involved, individualized testing methods and systems are required: If open containers need to be inspected, for example, then the sensors detect the vapors given off. If luggage screeners need to scan unopened bottles in a tub, on the other hand, then x-ray equipment is used. The experts forward the findings of their tests either directly to the manufacturers of the equipment, or to the German Federal Police, which in turn passes the results along to the ECAC. The ECAC, in turn, notifies the companies of whether or not their equipment is suitable for certification. »In the past, luggage screening has only identified metals and solid explosives. The screening equipment of the future will also identify liquid explosives. Initial tests at the Frankfurt Airport have already successfully been completed,« Röseling summarizes. The researcher and his team will present details of the test scenarios and methods at the Future Security conference in Berlin, September 7 to 9, 2010.



Liquid explosives are manufactured in the safety laboratory. (© Fraunhofer ICT)

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Fraunhofer Institute for Chemical Technology ICT
Joseph-von-Fraunhofer-Straße 7 | 76327 Pfinztal, Germany | www.ict.fraunhofer.de
Contact: Dr. Dirk Röseling | Phone +49 721 4640-132 | dirk.roeseling@ict.fraunhofer.de
Press: Dr. Stefan Tröster | Phone +49 721 4640-392 | stefan.troester@ict.fraunhofer.de

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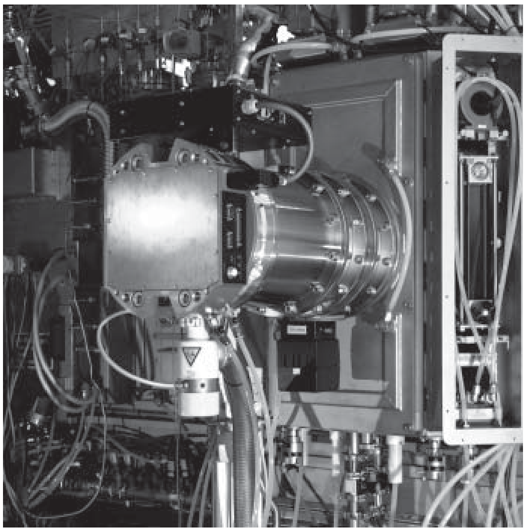
Playing snooker with atoms

Designed to be the most spectacular concert hall in Germany, the construction of the Elbe Philharmonic Hall in Hamburg is a controversial project, but it is already creating a sensation in the architectural world. Nobody has ever tried to build windows this high, each one five meters tall, of unique dimensions, and glazed with multifunctional insulating glass. The demands on the architectural glass used in modern structures like this are increasing all the time. Quite apart from their large surface area, they also have to offer outstanding optical characteristics and at the same time a high quality of thermal and sound insulation. These qualities depend to a large extent on their surface coating. And this has become a costly challenge.

Researchers at the Fraunhofer Institute for Thin Film and Surface Technology IST in Braunschweig have developed a new module for a sputtering plant that significantly increases the efficiency of the coating process. Sputtering is the preferred process for coating large surfaces. The process leads to an bombardment of a chosen material (target) and causes its constituent atoms to be ejected like billiard balls by the impact of the energy-rich ions – generally noble-gas ions. The latter subsequently condense on the surface of the glass or other substrate to form a thin film with specific properties depending on the characteristics of the starting material. Different designs are possible for the coating module. The version that consists of two rotating tubes containing strong magnets is referred to as a double magnetron. The magnets increase the sputtering rate, but severely limit the options available to the design engineers: »We can only sputter materials for which targets are available and can be produced,« explains IST department head Dr. Bernd Szyszka. »Moreover, the sputtering process we have been using up to now is inefficient, because only a fraction of the bombarding ions actually contribute to the sputtering effect. More than 95 percent of their energy is lost in the water-cooling system.«

The IST experts have overcome this obstacle by placing an additional flat target made of a heavy element such as bismuth behind each target tube. »This significantly increases the sputtering rate,« says Szyszka. The ionized noble gas causes bismuth atoms to be released from the flat solid body. These atoms are gradually »implanted«, as the experts say, in the tube target. As the researcher confirms, »The bismuth has enabled us, for example, to significantly improve the deposition of titanium dioxide.« The quantity of coating material removed from the target is increased. The IST researchers have meanwhile scaled up this effect to industrial level. »Using a simulation program, we were able to optimize the sputtering process in terms of material deposition on the flat and tube targets, even before we had built the new prototype model. We are now able to combine the target materials in any way we desire, without causing unwanted chemical reactions on the surface.«

The result is a higher deposition rate and a more homogenous surface coating based on new materials that previously could not be produced. It also takes less time to produce the coating, reducing the energy consumption. »The new coating technology has allowed us to replace three old magnetrons with two new ones. The system is much cheaper to operate and produces materials with improved properties,« says Szyszka. The researchers will be present at the Glasstec fair in Düsseldorf from September 28 to October 1, presenting a wide range of applications from panoramic car roofs that provide thermal insulation to photovoltaic cells with improved efficiency. »This is the start of a new revolution in large-area coatings,« promises the scientist.



The new coating module enables IST researchers to produce previously unattainable combinations of materials. (© Fraunhofer IST)

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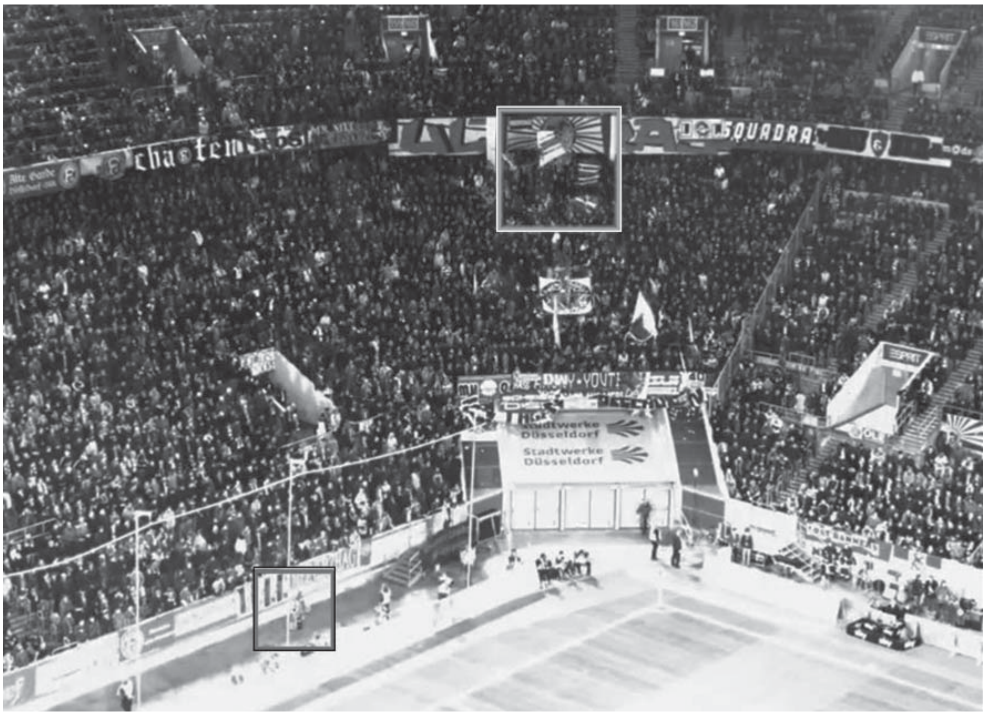
Fraunhofer Institute for Surface Engineering and Thin Films IST
Bienroder Weg 54 E | 38108 Braunschweig, Germany | www.ist.fraunhofer.de
Contact: Dr. Bernd Szyszka | Phone +49 531 2155-641 | bernd.szyszka@ist.fraunhofer.de
Press: Dr. Simone Kondruweit-Reinema | Phone +49 531 2155-535
simone.kondruweit-reinema@ist.fraunhofer.de

Vigilant camera eye

»Goal, goal, goal!« fans in the stadium are absolutely ecstatic, the uproar is enormous. So it's hardly surprising that the security personnel fail to spot a brawl going on between a few spectators. Separating jubilant fans from scuffling hooligans is virtually impossible in such a situation. Special surveillance cameras that immediately spot anything untoward and identify anything out of the ordinary could provide a solution. Researchers from the Fraunhofer Institute for Applied Information Technology FIT in Sankt Augustin have now developed such a device as part of the EU project »SEARISE – Smart Eyes: Attending and Recognizing Instances of Salient Events«. The automatic camera system is designed to replicate human-like capabilities in identifying and processing moving images.

Like the human eye, it can, for instance, distinguish objects when observing a scene, even if the objects are moving in front of a very turbulent background. The Smart Eyes system analyzes the video data in real time and immediately points out salient features. »That is invaluable for video surveillance of public buildings or places«, says Dr. Martina Kolesnik, research scientist at the FIT. »In certain circumstances the capabilities of a human observer are limited. Ask someone to keep an eye on a certain stand in a football stadium and they are bound to miss many details. That same person can only carefully monitor certain sections of the whole area and will quickly get tired. That's where Smart Eyes clearly comes into its own.«

The system hardware consists of a fixed surveillance camera which covers a certain area, and two ultra-active stereo cameras. Like human eyes, these can fix on and follow various points very quickly in succession – but also zoom in on details. At the heart of Smart Eyes is innovative software that automatically analyzes the image sequences. It replicates key strategies of the human eye and brain. Taking its lead from the flow of visual images in the brain, the software has a hierarchical, modular structure. It initially ascertains the degree of movement for each pixel, thus identifying the particular active areas in the scene. From this it learns motion patterns and stores them as typical models. On the basis of these models the system then identifies events and classifies them: for instance the software can distinguish between passive spectators and fans jumping up and down. Image patterns such as empty seats or steps are also identified. The application picks out salient events and focuses on these using the active stereo cameras. Depending on the priorities set by the security experts, various events are designated as salient. The program can, where necessary, filter out objects such as flags being waved to focus specifically on other salient events, for instance a person on the edge of the pitch. »Our image analysis software is compatible with camera systems produced by all vendors. It can be installed easily. The user doesn’t have to make any adjustments«, says the researcher. The Smart Eyes system will be on show at Security Essen 2010 from October 5-8, 2010.



The Smart Eyes camera records a stand during a soccer match. The software focuses on salient events such as a person on the edge of the pitch. (© Fraunhofer FIT)

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Fraunhofer Institute for Applied Information Technology FIT
Schloss Birlinghoven | 53754 Sankt Augustin, Germany | www.fit.fraunhofer.de
Contact: Dr. Marina Kolesnik | Phone +49 2241 14-3421 | marina.kolesnik@fit.fraunhofer.de
Press: Alex Deeg | Phone +49 2241 14-2208 | alex.deeg@fit.fraunhofer.de