Research News

No. 11 – 2009

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1 History in 3D

Three-dimensional computer graphics is moving into museums. Works of art are being digitally archived in 3D, simplifying research into related artifacts and providing the public with fascinating three-dimensional displays.

2 Hybrid composite for root canal treatment

A dentist carrying out root canal treatment will need to use a variety of compounds. These do not always bond together properly and sometimes expensive follow-up treatment has to be performed. But a new class of material meets the requirements and solves the problem.

3 Lasers put a shine on metals

Polishing metal surfaces is a demanding but monotonous task, and it is difficult to find qualified young specialists. Polishing machines do not represent an adequate alternative because they cannot get to difficult parts of the surface. A new solution is provided by laser polishers.

4 Perfectly proportioned

The manufacture of parts by compaction and sintering involves filling a die with metal powder. Research scientists have simulated this process for the first time to achieve an evenly distributed powder density. This improves the cost-efficiency of sintering.

5 A delicate grip

Solar wafers for use in the production of photovoltaic systems are extremely sensitive. In a test and demonstration center research is being conducted on grippers to determine the best way of handling delicate wafers in order to optimize the production process.

6 Measuring distances in microseconds

Standard laser devices are fast enough for measuring the size of a room, but they need to be faster for outdoor mobile applications. Researchers have brought these scanners up to speed – they can measure ten times faster than usual scanners.

7 Zooming in on data

Companies of all sizes are struggling with the growing flood of data and information. Staff can quickly lose sight of impending risks or hidden opportunities. Now a new zoom software is helping users get their data under control again.

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Virtual archive for works of art from all over the world: Objects will be reproduced three-dimensionally.

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Topic 1

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History in 3D

If you don't have the time to travel to Florence, you can still see Michelangelo's statue of David on the Internet, revolving in true-to-life 3D around its own axis. This is a preview of what scientists are developing in the European joint project 3D-COFORM. The project aims to digitize the heritage in museums and provide a virtual archive for works of art from all over the world. Vases, ancient spears and even complete temples will be reproduced three-dimensionally. In a few years' time museum visitors will be able to revolve Roman amphorae through 360 degrees on screen, or take off on a virtual flight around a temple. The virtual collection will be especially useful to researchers seeking comparable works by the same artist, or related anthropological artifacts otherwise forgotten in some remote archive. The digital archive will be intelligent, searching for and linking objects stored in its database. For instance, a search for Greek vases from the sixth century BC with at least two handles will retrieve corresponding objects from collections all over the world.

3D documentation provides a major advance over the current printed catalogs containing pictures of objects, or written descriptions. A set of 3D data presents the object from all angles, providing information of value to conservators, such as the condition of the surface or a particular color. As the statue of David shows, impressive 3D animations of art objects already exist. "But we are still a long way from being able to sensibly correlate 3D data between different objects," says Dr. André Stork, Head of Department at the Fraunhofer Institute for Computer Graphics Research IGD in Darmstadt and a partner in the 3D-COFORM consortium.

Stork and his team are generating 3D models and processing them for the digital archive. "A 3D scan is basically a cloud of measured points. Further processing is required to map the object properly," Stork explains. Researchers are developing calculation specifications to derive the actual object from the measured data. The software must be able to identify specific structures, such as the arms on a statue or columns on a building, as well as recognizing recurring patterns on vases. A virtual presentation also needs to include a true visual image – a picture of a temple would not be realistic if the shadows cast by its columns were not properly depicted. The research group in Darmstadt is therefore combining various techniques to simulate light effects.

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A researcher produces laboratory samples based on the new material.

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Hybrid composite for root canal treatment

Unrelenting toothache means a visit to the dentist is inevitable, and if the tooth decay is really bad root canal treatment is often the only option. The dentist first removes the nerve completely and then closes the ensuing canal with a filler. This must be airtight to prevent bacteria from entering and causing renewed inflammation. On the other hand, the material must also be removable. If the natural crown is severely damaged, the dentist will anchor a root post in the previously filled canal using dental cement. The post provides an anchor for the composite material used to rebuild the remaining part of the tooth, the core, which serves as the base for the core build-up material and the prosthetik treatment e.g. a crown. In root canal procedures, therefore, various materials are combined, each fulfilling different requirements. The problem is that the materials are not always compatible with each other or do not bond properly with the hard dental tissue. As a result, the post may break, the core and the crown may not adhere to the post properly, and the expensive crown may need replacing. Such faults are not rare and generally occur in the single-digit percent range.

Researchers at the Fraunhofer Institute for Silicate Research ISC in Würzburg working in collaboration with their research partners at VOCO GmbH have now developed a material that can be used for all the components used in root canal treatment. "The basis of this material is provided by ORMOCER®s," explains Dr. Herbert Wolter, group manager at the ISC. "We have combined these ORMOCER®s with various nano- and microparticles to achieve the highly diverse properties needed." Materials used in filling the root canal, for instance, should not shrink as they harden, should form an airtight bond with the dental material and be visible in x-rays. The material used to rebuild the tooth, on the other hand, should have the same properties as the tooth itself. "Hybrid materials are well suited to these requirements. For instance, they only shrink by about 1.3 percent as they harden, while standard materials generally shrink by 2 to 4 percent. ORMOCER®s can also be adapted to adhere to the different parts of the tooth," says Wolter. VOCO GmbH is already producing dental preparations and product development is making good progress. Market launch could therefore be just a few years away.

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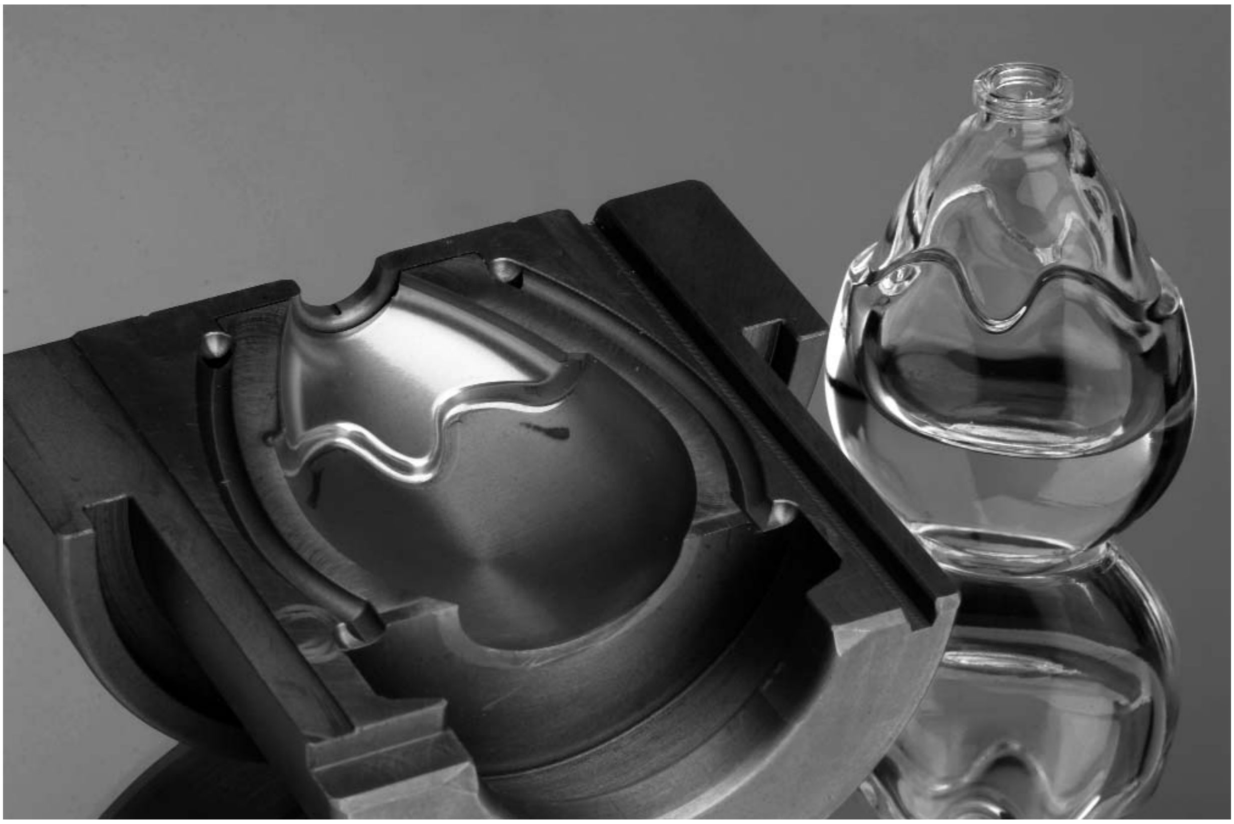

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Metal mold for glass manufacture: the lower part of the mold has been left unprocessed, the upper part has been laser-polished. On the right, the product that can be made using a mold of this type.

Picture in color and printing quality: www.fraunhofer.de/press

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Lasers put a shine on metals

Jobs are in short supply, and yet some sectors have difficulty in finding suitable trainees for specialist tasks, such as polishing injection molds. The work is time-consuming and monotonous but requires highest levels of concentration, because any blemish in the mold can render it useless. A skilled worker may often need a whole week to polish a single metal mold. Up to now it has not been possible to use machines for this dreary work because they cannot get into the curved shapes.

Researchers at the Fraunhofer Institute for Laser Technology ILT in Aachen have developed a way of automating the polishing work: "We do not polish the surface by hand with grinding and polishing media. Instead we use a laser," explains Dr.-Ing. Edgar Willenborg, group leader at the ILT. "The laser beam melts the surface to a depth of about 50 to 100 micrometers. Surface tension ensures that the liquid metal flows evenly and solidifies smoothly." Like in conventional grinding and polishing, the process is repeated with increasing degrees of fineness. In the first stage the researchers melt the surface to a depth of about 100 micrometers, in further steps they gradually reduce the depth. "We can set the melting depth by means of various parameters: the laser output, the speed at which the laser beam travels along the surface and the length of the laser pulses," states Willenborg. Laser polishing does not achieve the same surface smoothness as perfect hand polishing – hand polishers can achieve a roughness Ra of 5 nanometers, the laser at present can only manage 50 nanometers – but Willenborg still sees considerable market potential for the system. "We will concentrate on automating the medium grades: a roughness of 50 nanometers is adequate for many applications, including the molds used for making standard plastic parts." The high-end levels of smoothness will therefore remain the domain of skilled hand polishers.

The time gained by laser polishing and the cost saving achieved are enormous. Whereas a skilled polisher needs about 10 to 30 minutes for each square centimeter, the laser polishes the same area in about a minute. A prototype of the laser polishing machine developed by the scientists in cooperation with mechanical engineering firm Maschinenfabrik Arnold has already been built. Willenborg estimates that the system will be ready for industrial use in one to two years' time. At the Euromold trade show, to be held from December 2 to 5 in Frankfurt, the researchers will be presenting examples of three-dimensional surfaces polished by laser (Hall 8, Stand M114).

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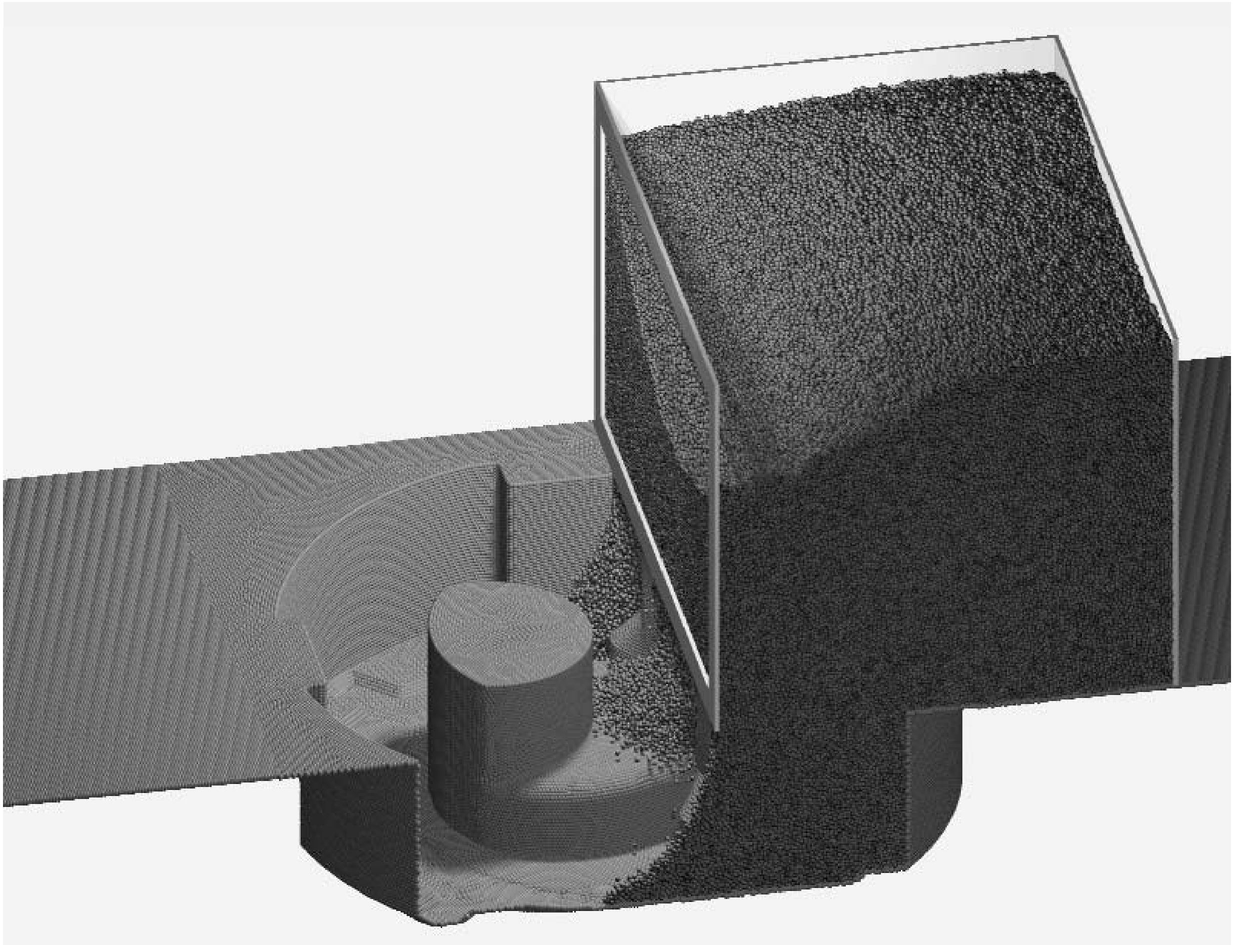

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A new simulation technique helps to improve the sintering process: it calculates the best method for achieving an even density of the powder in the mold.

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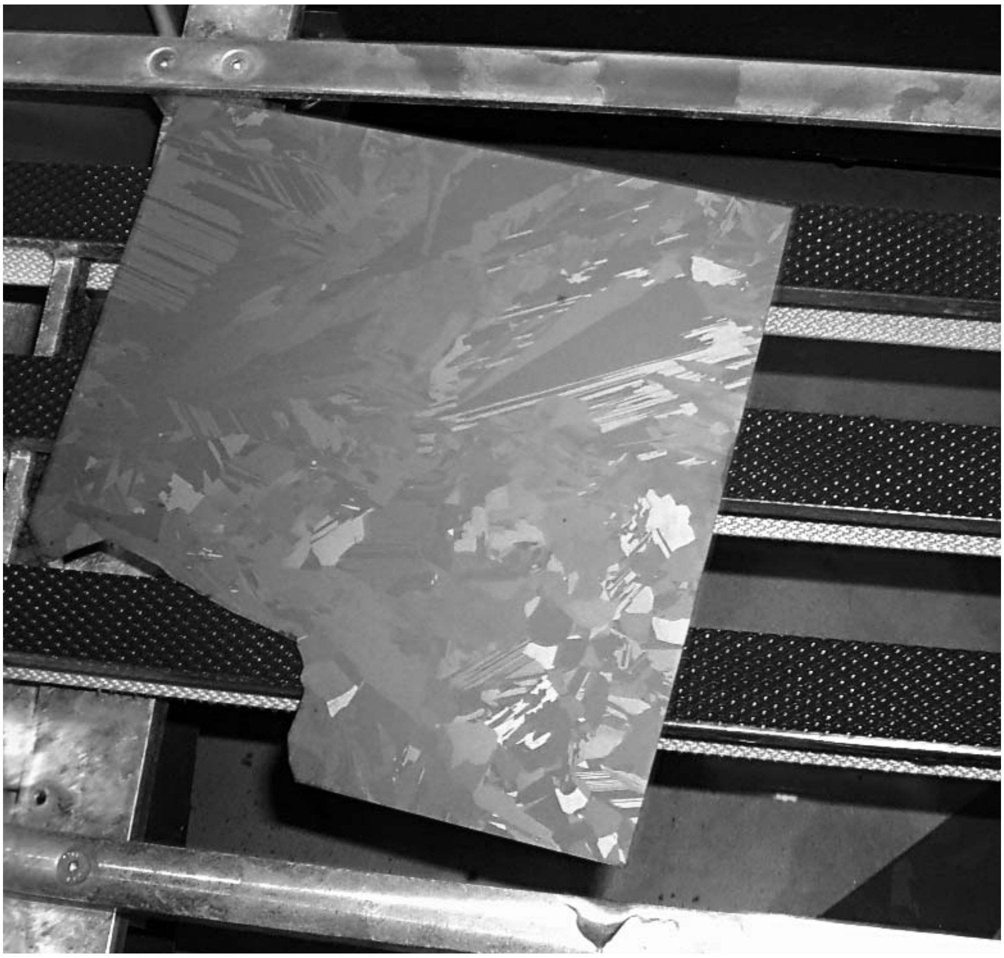
Perfectly proportioned

It all happens very quickly: the feed shoe, configured as an open-bottomed box, moves across a surface in which a recess forms the shape of the desired part. The fine-grained metal powder dropping from the feed shoe settles in the mold. Stamps then compact the loose powder grains at a pressure of several hundred megapascals to produce the "green body" – a preform in the shape of the finished part which now has to be sintered in a furnace at a temperature below the melting point of the material. This procedure ensures that the compacted grain structures become more compressed and harden.

Dry compaction and sintering are common processes in industry. They deliver precisely shaped parts that can withstand high mechanical loads. There is still potential for improvement, however, and Fraunhofer researchers aim to perfect the technique and avoid costly waste. "Filling the die is a critical step in dry compaction," states Dr. Claas Bierwisch from the Fraunhofer Institute for Mechanics of Materials IWM. "The metal powder is not distributed 100 percent evenly in the mold. These inhomogeneous distributions of density could cause the part to warp or even crack, affecting its loadability, precision and service life," the project manager explains. Up to now an expensive trial-and-error approach has had to be applied to obtain the best results, but this will no longer be necessary with a simulation technique developed by the research scientists for optimizing the filling process. "By describing the powder numerically we can attach values to virtually every grain," explains Bierwisch. The physical properties, size and shape of the grains as well as the shape of the mold are all taken into account. The research scientists then calculate how and where the powder grains flow into the mold and what the density distribution is like after filling. It is now possible for the first time to realistically simulate the production of three-dimensional parts such as toothed wheels in gear systems or washers in one-hand mixer taps for washbasins.

What's more, the researchers can draw conclusions about the filling process, including how high the speed of the feed shoe needs to be and how it should move. In some cases the shoe only needs to move forwards and backwards. For other parts the die has to oscillate as well. The scientists can simulate the sintering events through to completion of the finished part and can therefore replicate the entire process chain. They are currently optimizing the manufacture of magnetically soft coil cores for wheel hub motors, which could play an important future role in electric vehicles.



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Solar wafers are only 150 to 180 micrometers thick, which makes them extremely delicate and fragile.

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Topic 5

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A delicate grip

Accidents will happen: if you are washing a wine glass and apply just a little too much pressure it will break. A similar thing happens to technicians in the production of photovoltaic systems when they handle solar wafers. With a thickness of just 150 to 180 micrometers, the filigree substrates are extremely fragile. Various types of automatic gripper can be used to lift or transfer the wafers – mechanical grippers make direct contact with the object, while Bernoulli grippers create a vacuum to hold the wafer without actually touching it.

”The grippers must be able to work precisely and gently even at high speed, because they have to cause as little waste production as possible and yet handle a high throughput,” says Christian Fischmann, research scientist at the Fraunhofer Institute for Manufacturing Engineering and Automation IPA. He is currently evaluating different grippers and handling methods at the test and demonstration center being established by the Institute under an EU program. A key question is whether the robotic claw achieves the required level of precision. To the naked eye the movement looks ideal even when things are moving fast, but pictures taken with a high-speed camera show that there is actually a short time lag before the claw lets go of the object, which slows down the production cycle. Some steps in the production process require particularly gentle handling, for instance lifting a wafer from a stack. A method using jets of air separates the wafers gently: air is blown by nozzles into the stack, lifting the top wafer off the ones below so that it floats above the stack. Studies conducted by the Stuttgart group also show how production processes can be optimized using different gripper principles. Until now the general practice has been to employ only one type of claw along the entire production line, but the various handling methods are not equally well suited for every step in the process, Fischmann explains. “It all comes down to finding a balance between gentle handling, speed and operating cost.” Bernoulli grippers, for example, are relatively expensive to use because air has to be pumped through non-stop.

Even though the demonstration center is still in the development phase, several customers who want to have their gripper systems tested have already been acquired. The scientists now intend to expand their activities to include research on handling contaminated wafers and contamination caused by grippers.

In a measurement channel the laser radar (on the right) determines the distance of an object up to 80 meters away every two microseconds or faster.

Picture in color and printing quality: www.fraunhofer.de/press

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Topic 6

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Measuring distances in microseconds

Will the massive truck be able to pass under the bridge or should it take another route? Do the houses lining the street leave enough room for the oversized vehicle to pass through? Such questions are answered by sending out a car fitted with distance measuring equipment to check the route the heavy load will take. A laser mounted on the car scans bridges, buildings, signs and trees along the way. Working on the time-of-flight principle, the scanner sends out short laser pulses which are reflected by the obstacles they encounter. The time the light needs to travel to the obstacle and back to the integrated sensor provides the distance measurement. The results are coupled with the car's GPS position. Unfortunately, the car has to travel very slowly to pick up enough points on the objects for accurate measurements. Using scanners of this type in airplanes or helicopters to determine terrain elevations and objects on the ground is also problematic, as high plane speed means the resolution is low and the resulting image incomplete.

Researchers at the Fraunhofer Institute for Physical Measurement Techniques IPM in Freiburg have now substantially increased the speed of distance measurement, which is the key to more efficient laser scanning. "We can either measure ten times faster or retain the scanner speed but analyze ten times as many points of an object – for instance from an airplane," explains Dr. Ilia Bourovoi, project manager at the IPM. The laser measures the distance several million times per second. Dr. Bourovoi reveals how the researchers achieve this speed: "We have developed new electronic circuits and special software to process the data. In addition we have optimized the laser pulse rate." While conventional scanners need several pulses for one measurement, the new pulse laser radar can determine the distance on the basis of each individual transmitted pulse. Apart from higher measurement speed, this offers the further advantage that the measured values do not depend on the speed at which the scanner is moving – for instance when mounted on a car or airplane. Scanners requiring several laser pulses per point produce blurred images as the scanner has already moved when the next pulses are transmitted.

The new pulse laser radar device has already been built on a laboratory scale. In future, cars equipped with it will be able to travel at regular traffic speed as they record 3D data along roads. From aircraft too the pulse laser radar will deliver a high measurement point density.

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Topic 7

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Zooming in on data

The printer churns out page after page of data from the ERP system: a list of suppliers, unpaid accounts or empty stock. The user can't see the wood for the trees. Are the contact details needed for a bulk mail-shot by the marketing department still up to date? How complete and correct are the addresses? An error ratio of ten percent means that of one million letters sent 100,000 will fail to reach their intended recipients.

InfoZoom software can help. Developed by the Fraunhofer Institute for Applied Information Technology FIT in Sankt Augustin, it enables employees who have to deal with large volumes of data to recognize proportionalities, connections and relationships at a glance, without having studied information science. Just a few simple clicks are needed to ask sophisticated questions and generate professional ad hoc analyses without any knowledge of programming. The key factor is the way the data is presented clearly and readably on screen. The clever interface lets the user zoom in and out, making connections or correlations immediately evident. For example, a database containing complete details on company sales can be queried about individual products and sales areas, generating detailed answers in a matter of seconds. One click on "hand soap" provides details of all sales for this product. In addition to processing data input from spreadsheet applications such as Microsoft Excel, the software solution also has interfaces to databases such as Oracle or DB2 from IBM. InfoZoom is therefore used by large companies and organizations, including utilities and banks, to analyze their master data and by the police to compile criminal statistics. As prices start at levels comparable with Office applications, the software system is also affordable for smaller businesses. "The return on investment is usually very quick," confirms Ralph Gattinger, Managing Director of humanIT.

The program is being marketed by humanIT Software GmbH in Bonn, a spin-off from the research institute and now a wholly-owned subsidiary of proAlpha Software AG in Weilerbach. Further development work is being conducted in collaboration with the FIT.

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