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Bosch's own "Stanford"

A speech by Dr. Volkmar Denner,

Chairman of the Board of Management

of Robert Bosch GmbH,

at the inauguration of the Renningen research campus

on October 14, 2015.

Check against delivery.

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Madam Chancellor,
Mr. Minister-President,
Ladies and gentlemen,

As a CEO, today makes me proud. As a physicist, it makes me almost envious. Here in Renningen, we are inaugurating Bosch's new research center – a center we deliberately refer to as a campus. Just like at a university, it brings together many different faculties. It is a place where engineers and scientists of all disciplines can exchange ideas. It is, if you like, Bosch's own "Stanford."

I could also say that it will be a fine place to do research, and this is what makes my physicist heart skip a beat. I could imagine that this is a feeling you understand well, Madam Chancellor. After all, you too have had to forsake physics. That said, the two of us would perhaps give a lot to be young physicists again here on this research campus – not to gain insights into the inner workings of the world, but to look for new and meaningful solutions relating to driving, energy efficiency, or even digital connectivity. Here, at all events, the technological future is still open.

What very few people now remember is that Renningen has a history of paving the way for the future. If we go back 20 years, to a time when a campus was the last thing people were thinking of, we find our engineers using the adjoining airfield for driving trials. They were putting ESP through its paces – the electronic anti-skid program that was to hit the headlines a few years later, following the legendary elk test. In other words, Renningen was the site of the first trials for a system that would be such a blessing that it is now standard equipment in vehicles in many parts of the world. According to a study by the University of Cologne, this electronic guardian angel has prevented nearly 260,000 traffic accidents and saved some 8,500 lives in Europe alone. At Bosch, this is what we mean when we speak of "Invented for life" – a technology that gives our work so much meaning that it is an extra reward for our engineers.

Renningen is therefore a good place for pioneering technological achievements. For me, the story of ESP is an inspiration for the future – a future that will also see us further automating driving, and thus making it accident-free. And while not every Bosch innovation has such an immediate life-saving effect, our technological solutions can at least improve quality of life. For all our business interests, this is what motivates Bosch and its engineers. In the 20 years ahead, my expectation is that we will be seeing a lot of technology "Invented for life" emerging from Renningen.

At all events, we have invested more than 300 million euros in our new research campus on this prestigious site. After being spread over three locations in the greater Stuttgart area, 1,700 creative minds will now work together more closely and intensively than ever before. At the same time, Renningen will be the central hub of our global research and development network, with its 45,700 associates at 94 locations in 25 countries. This is on top of our 250 partnership arrangements with the world's best universities and research institutes. Both locally and globally, we are networking our research and development.

We are not solely concerned to improve connections among our brightest technological minds – we also want our technology itself to be connected. At Bosch, we regard the internet of things as an epoch-making development, on a par with the advent of electronics in the car 50 years ago. Vehicles, machines, household appliances, and energy systems will soon communicate automatically with each other. When they do, it will affect the industrial heart of the German economy. In an age of digital connectivity, how can Germany stay technologically on top of its game? It can do so above all by promoting the key competencies of sensor technology and software. However, IoT-related business also arises out of new services. And if we do not want to let others seize these opportunities, then we have to be even faster and less risk-averse than before. Or to put it another way: our engineers have to think like businesspeople – at an earlier stage than ever before.

To this end, large companies such as Bosch have to grant people creative freedom, beyond the classic organization. It is no coincidence, therefore, that we have set up our own start-up platform for new business fields. But we can only make the most of this creative freedom if we have associates who act like businesspeople. Wherever possible, we want young graduates to bring this dynamic mindset with them. I want to see German university education infused with a greater sense of entrepreneurship.

Many people seem to believe that Europe can become some kind of “silicon valley.” In reality, however, there are neither the opportunities nor the willingness to establish start-ups. This is not just about a lack of venture capital, therefore, but also a lack of boldness. It has to be a matter of concern for us that only 25 percent of Germans can imagine setting up a company, while the figure for the U.S. is 40 percent. To make matters worse, fear of failure is the reason cited by 80 percent of Germans, while in the U.S. this figure is only 30 percent. Especially among its young university graduates, this country needs more start-up spirit. In this respect, universities have to do more than prepare their students for exams in highly specialized fields. For example, a lot could be gained by university chairs that combine technological subjects with the development of business models. If the “silicon valley” model really is to be the way forward for Europe, we have to learn to take risks.

At a company like Bosch, at all events, the path from the campus to the market must be a short one. After all, we do not want technology for its own sake, but technology that is “Invented for life.” No less than the future of the company depends on this. This research campus is a promise that Bosch’s best minds will work together to come up with innovations of the caliber of ESP – innovations that leave a lasting mark on the world.

Press release

October 14, 2015
PI 8940 RB Zi/af

Technology and innovation location

Bosch officially opens new research campus in Renningen

Chancellor Merkel: “Research and innovation are the sources of our prosperity”

- Governor Winfried Kretschmann: “Impressive demonstration of faith in Baden-Württemberg as a location for innovation.”
- Bosch CEO Denner: “Renningen is Bosch’s own Stanford.”
- Applied industrial research for better quality of life
- Expansion of key competencies in microelectronics and software
- New work and office environment for innovators

Renningen, Germany – A completely new work environment for creative minds: with its Renningen research campus, Bosch wants to encourage interdisciplinary collaboration, and in this way further enhance its innovative strength. At the new center for research and advance engineering on the outskirts of Stuttgart, some 1,700 creative minds are doing applied industrial research. At a ceremony attended by Federal Chancellor Dr. Angela Merkel, Baden-Württemberg Governor Winfried Kretschmann, and many other guests from politics, business, and academia, the research campus has now been officially opened.

“With this research campus, Bosch is setting new standards,” said the Federal Chancellor Dr. Angela Merkel. She underscored the significance of applied industrial research: “Research and innovation are the sources of our prosperity.” She noted that Bosch has set itself the task of realizing ideas that nobody else has even had. “Bosch wants to stay one step ahead of developments,” the Chancellor said.

Governor Winfried Kretschmann said that the new research campus is “an impressive demonstration of faith in Baden-Württemberg as a location for innovation.”

“Like a university, our campus brings together many faculties. Here, we want our researchers to do more than just think about what the future could bring. We

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want them to be successful entrepreneurs as well. Renningen is Bosch's own Stanford. And at the same time, the center is an expression of our faith in Germany as a technology location," said Dr. Volkmar Denner, chairman of the Bosch board of management. The company has invested some 310 million euros in the new location. The research campus, whose motto is "Connected for millions of ideas," is the hub of Bosch's global research and development network. The supplier of technology and services also intends to strengthen the spirit of entrepreneurship there. It is precisely here that Denner sees Germany at a competitive disadvantage. "In Germany, there are neither the opportunities nor the willingness to establish companies. Especially among its young university graduates, we need more start-up spirit. In this respect, universities have to do more than prepare their students for exams in highly specialized fields."

Innovations for better quality of life

The hope for the future is that even more innovations will be created in Renningen that improve quality of life. The campus brings together many disciplines from science and technology. Whether electrical engineering, mechanical engineering, computer science, analytics, chemistry, physics, biology, or microsystems technology – in Renningen, a total of 1,200 associates in corporate research and advance engineering, plus 500 PhD students and interns, are now working on the technical challenges of the future. Up to now, these researchers were spread over three locations in the greater Stuttgart area. Chancellor Merkel was clearly impressed by the innovative research institute: "What you have managed to achieve here is the networking not only of research locations, but also of scientific disciplines." On a campus such as this, she said, it will be much easier to keep an eye on the big picture.

Governor Winfried Kretschmann wished the research campus a successful future: "Our hope for this campus is that it will create decisive stimuli for the development of automated driving, succeed in facilitating a breakthrough for electromobility, and drive forward ideas for connected industry. The research center wants to create the right conditions for such work – an environment in which creativity and productivity can thrive. Our wish is that this research campus will be the seedbed for many future innovations – innovations that are not just technically outstanding and economically successful, but also continue to live up to the company's sense of social and ecological responsibility."

Technological breadth in research and advance engineering

In the special campus atmosphere, Bosch's pioneering minds will work on both new products and innovative manufacturing methods. Their work will focus on areas such as software engineering, sensor technology, automation, driver assistance systems, and battery technology, as well as on improved automotive

powertrain systems. One area that is becoming increasingly significant is software expertise – particularly for IoT connectivity. “For Germany to stay technologically on top of its game in connectivity, it has to preserve and extend the key competencies of microelectronics and software. If it fails to do this, German industry will be left behind. We have no reason to fear competition with IT companies. But for our industrial enterprises, this competition will not be a walk in the park,” Denner said.

As for Bosch itself, Denner believes it is well prepared for the connectivity trend. For example, the company is not only the global market leader for micromechanical sensors, but has also been extending its software competence for some years now. The Bosch Group now employs more than 15,000 software engineers. Three thousand experts are working on the internet of things alone. Bosch especially sees huge business potential in the services that will arise as a result of connectivity. “If we do not want to let others seize these opportunities, then we have to be even faster and less risk-averse than before,” Denner said. “At an earlier stage than ever before, our engineers have to think like businesspeople. The things that are technically feasible should not only excite our researchers, but our future customers as well.”

Germany has to learn to be daring

Denner added that large enterprises such as Bosch have to create the space in which enterprise and entrepreneurship can flourish. Bosch is leading by example. The company has set up its own start-up platform for new business fields. Denner stressed that if the “Silicon Valley model” really is to be the way forward for Europe, “we have to learn to take risks.” Bosch Start-up GmbH helps Bosch researchers become successful businesspeople. For example, it takes care of things such as premises, financing, and other administrative tasks. In this way, new businesses can focus right from the start on their product and bringing it to market. The Bonirob agricultural robot is one of the first products to emerge in this way. The Bosch start-up Deepfield Robotics developed this robot, which is the size of a compact car, as an aid for plant breeding and crop farming.

The best working conditions for creative ideas

On the expansive research campus, there is plenty of space to test the agricultural robot. Apart from the main building, eleven laboratory and workshop buildings, and two buildings for site maintenance, there is also a modern proving ground for testing driver assistance systems. A networking matrix was used to determine who should occupy the individual buildings. It was based on analyses of how intensively individual disciplines exchange information with each other: The closer units work together, the shorter the physical distance between them on the new campus.

Quiet corners, collaboration zones

Bosch paid particular attention to working conditions in Renningen. Whether inside or out, the researchers will encounter a modern work environment. Essentially, the entire campus is a workplace. “Brainwaves in the fresh air, technology at the water’s edge – all this is possible here in Renningen,” Denner said. Wifi connections are available in every building and everywhere on the grounds. Laptops, tablet computers, and voice over internet mean that work can be done in every corner of the campus. Explaining the idea behind this, Denner said: “In Renningen, we offer our innovation team both quiet corners and zones for collaboration.” Office layouts have been designed on the basis of a comprehensive analysis of the innovation process. When they are exploring ideas, researchers need to have peace and quiet. Later on, exchange and collaboration with others take on more importance. These phases, as well as associates’ wishes, were considered when planning the complex. “Associates want more freedom to use their creativity in research and development – and fewer administrative duties. This is something the employee representatives actively supported,” says Alfred Löckle, chairman of the central and combined works councils. “The days when the design of workplaces was decided from above are over. Our associates spend a lot of time at their workplaces. It’s only right that they should also have a say in their design.”

The result of the joint consultation with everyone involved was a completely new office concept. Apart from individual workplaces, 270 meeting rooms of various sizes are the salient characteristic – meaning that there is sufficient room for both focused activity and teamwork. On average, each associate is just ten meters away from the nearest meeting room, and thus possibly also from the next innovative breakthrough.

Link to a fact sheet about the new research campus
Link to press releases about specific areas of research
Link to research and development at Bosch
Link to the Bosch Renningen website
Link to article about Renningen in the Bosch annual report

Press photos: 1-CR-21628, 1-CR-21637, 1-CR-21648, 1-CR-21651, 1-CR-21671, 1-CR-21672, 1-CR-21673, 1-CR-21674, 1-CR-21675, 1-CR-21676, 1-CR-21716, 1-PE-21680, 1-PE-21686

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The Bosch Group is a leading global supplier of technology and services. It employs roughly 360,000 associates worldwide (as per April 1, 2015). The company generated sales of 49 billion euros in 2014. Its operations are divided into four business sectors: Mobility Solutions, Industrial Technology, Consumer Goods, and Energy and Building Technology. The Bosch Group comprises Robert Bosch GmbH and its roughly 440 subsidiary and regional companies in some 60 countries. Including its sales and service partners, Bosch is represented in roughly 150 countries. This worldwide development, manufacturing, and sales network is the foundation for further growth. In 2014, Bosch applied for some 4,600 patents worldwide. The Bosch Group's strategic objective is to create solutions for a connected life. Bosch improves quality of life worldwide with products and services that are innovative and spark enthusiasm. In short, Bosch creates technology that is "Invented for life."*

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Press release
Bosch compact

Industry 4.0, data mining, metal 3D printing
Working on tomorrow's world: researchers at Bosch
Innovative products and new manufacturing processes

October 14, 2015
PI 9087 RB Res/af

Stuttgart and Renningen, Germany – Bosch has invested more than 300 million euros in its new research campus in Renningen, near Stuttgart, and created workplaces in a modern and inspiring environment for 1,700 people. Bosch is not only working on innovative products, however, but also on continuously refining manufacturing processes. These are just some of the scientists working there:

Dr. Lothar Baum: Data mining
The computer scientist Dr. Lothar Baum is an expert in data evaluation. Baum, who joined Bosch in 2006, works in corporate research and advance engineering. Together with colleagues in Renningen, Palo Alto, and Bangalore, he writes software that detects patterns in billions of data points. This includes data generated on production lines at more than 250 Bosch plants worldwide. Super-fast computers are used to analyze this data. If this analysis is done properly, quality can be assured and the process of monitoring workpieces speeded up – saving time and money. "The ability to generate new knowledge from big data is a key competence of the future," Baum says. In connected industry – also referred to as Industry 4.0 – this data also helps predict when machinery will need maintenance, which avoids downtimes.

Press photos: 1-CR-21636, 1-CR-21637, 1-CR-21638, 1-CR-21639, 1-CR-21640, 1-CR-21641, 1-CR-21642, 1-CR-21643

Torsten Reinhardt: Physical analytics, analysis of functional materials
Torsten Reinhardt has been with Bosch since 2000. One of his tasks in corporate research and advance engineering is to study the inner structure of materials. This means Reinhardt plays a part in ensuring the high quality of new Bosch developments right from the start. In the analytics department, one of his tasks is to make extremely thin cut marks in materials in order to study them under the electron microscope for possible weaknesses. He does this by directing a

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focused ion beam at the sample in order to ablate certain parts of it. In this way, structures in the sample can be exposed and analyzed at very high resolution. This kind of analysis is accurate to within nanometers (millionths of a millimeter).

Press photos: 1-CR-21695, 1-CR-21696, 1-CR-21697, 1-CR-21698

Dr. Witold Pieper: Metallic functional and composite materials
Dr. Witold Pieper's work involves exploring new materials for use throughout the Bosch Group. This means that he collaborates closely with many scientists and suppliers. As a physicist who specializes in materials science, his work also includes the analysis of various magnetic materials. "These include metals and ceramics, such as magnets that are based on rare earths," Pieper says. His team also tests whether it is possible to use new methods such as 3D printing to turn such materials into products with completely new characteristics. In addition, the department provides advice to Bosch colleagues around the world. The data gathered in Pieper's labs serve as the foundation for computer simulations of materials. Pieper has been with Bosch since 2011.

Press photos: 1-CR-21699, 1-CR-21700, 1-CR-21701

Joachim Frangen: Manufacturing automation, Industry 4.0
In Renningen, Joachim Frangen heads up work on the connected and flexible factories of the future. Collectively, these factories are also referred to as "Industry 4.0." By connecting people, machines, and materials, a virtual image of the manufacturing process can be generated on the computer – in real time. This combines several advantages. For instance, sensors are constantly gathering and transmitting data on the status of machinery. This data is analyzed by software to detect wear and tear, which means maintenance can be planned in good time. As a result, Bosch can prevent unexpected machine downtimes. Connectivity also facilitates the optimum use of resources such as energy and raw materials. One further advantage is that lines can be adjusted more quickly to new products. For Bosch, this means both improved customer focus and greater competitiveness. Frangen has been with Bosch since 1990.

Press photos: 1-CR-21702, 1-CR-21703, 1-CR-21704, 1-CR-21705

Dr. Martin Schöpf: Manufacturing technology for metals, metal 3D printing
One of the promising areas of Bosch research is metal 3D printing. This area is the responsibility of Dr. Martin Schöpf. Methods such as this open up many new possibilities: instead of keeping large, costly inventories of spare parts, metal parts can be printed as and where needed. In the future, 3D printing is also set to play a role in production processes. This will enable Bosch to bring new products

to market more quickly – a major advantage. “What is more, it means we can produce new shapes in metal that are simply not possible with existing processes,” says Schöpf, who has been with Bosch since 2003. Moreover, 3D printing can result in a single piece where once separate components were necessary – saving on joining times and sidestepping the need for seals.

Press photos: 1-CR-21706, 1-CR-21707

Dr. Andreas Michalowski: Laser materials processing

The focused energy of laser beams can work even the hardest materials – precisely and fast. This is Dr. Andreas Michalowski’s area of expertise. It includes controlling physical effects well enough to make the laser suitable for use in industry. Only then will it be possible to process any material precisely on a mass scale, and this in an economical way. One application for this at Bosch is in gasoline direct injection: using lasers, tiny holes can be drilled precisely into the metal of the nozzle. The result is ideal distribution of the injected fuel within the cylinder. Michalowski joined Bosch in 2011 and collaborates with an international network of experts from science and industry. With the number of possible applications for laser technology growing fast, there will be plenty for this passionate researcher to do for a long time to come. In 2013, Bosch, Trumpf, and the University of Jena won the German Federal President’s Future Prize for technology and innovation for this technology.

Presse photos: 1-CR-21708, 1-CR-21709, 1-CR-21710, 1-CR-21711

Dr. Thorsten Ochs: Battery technology

Bosch is researching batteries that will increase electric cars’ range while at the same time weighing a lot less and costing less than current batteries. In this way, Dr. Thorsten Ochs in Renningen is playing a crucial role in the breakthrough of electromobility. “To achieve widespread acceptance of electromobility, mid-sized vehicles need to have 50 kilowatt hours of usable energy,” says Ochs, who joined Bosch in 2000. With conventional lead batteries, this would mean increasing the weight of the battery to 1.9 metric tons, even without wiring and the holder. That is the same weight as a modern-day mid-sized sedan, including occupants and luggage. Weighing 19 kilograms, a conventional lead battery – as found today in nearly every car – stores a comparatively low 0.5 kilowatt hours. In contrast, Ochs is looking to store the necessary 50 kilowatt hours in a battery weighing just 190 kilograms.

Press photos: 1-CR-21622, 1-CR-21623, 1-CR-21624, 1-CR-21625-en, 1-CR-21625-o-Logo-en

Dr. Franz Lärmer: Microsystems (MEMS) technology

Tiny Bosch sensors are changing the way people interact with technology. In fitness wristbands, they measure physical activity and help people achieve better health and well-being. In cars, these microelectromechanical systems (MEMS) sensors identify dangerous situations and instantly alert the control electronics to keep the vehicle on the road. And because sensors measure the earth's gravity, smartphones can change their screen orientation to suit the user. Dr. Franz Lärmer has been with Bosch since 1990. He is one of the inventors of the method that makes it possible to create the microscopically fine structures found in MEMS sensors. Speaking about his objectives, Lärmer says: "One of the challenges in the ongoing development of our MEMS sensors is their energy consumption. For example, more intelligence in sensors makes it possible for us to reduce energy consumption." In 2008, Bosch won the German Federal President's Future Prize for technology and innovation for these smart sensors.

Press photos: 1-BST-20778, 1-BST-20779, 1-AE-20855, 1-AE-20856-e, 1-BST-20755, 1-CR-21650, 1-CR-21651, 1-CR-21652, 1-CR-21653, 1-CR-21654-en, 1-CR-21654_o_Logo-en

Jayalakshmi Kedarisetti: Power electronics

Electromobility is a major topic for Bosch, and thus occupies a prominent place on the new research campus in Renningen. Jayalakshmi Kedarisetti has been working in this field since 2012, developing the necessary new power electronics. These are a central element of electric cars. Power electronics convert the direct current provided by the battery into alternating current to drive the electric car's motor. They must also convert the alternating current that comes from a power socket into direct current to charge the battery. And all this needs to be done keeping power loss as low as possible. At the same time, these components have to cope with high operating voltages and strong currents while always satisfying high safety standards. Kedarisetti and his team are coming up with lots of new ideas for how to meet these requirements.

Press photos: 1-CR-21712, 1-CR-21713, 1-CR-21714, 1-CR-21715

Dr. Lutz Bürkle: Driver assistance systems

With their research in Renningen, Dr. Lutz Bürkle and his team help improve pedestrian safety. If braking alone is no longer enough to prevent a collision with a pedestrian who suddenly walks out in front of the car, the assistant developed by Bürkle's team instantaneously computes an evasive maneuver. As soon as the driver starts to steer, the system kicks in to support the lifesaving action.

The team's work focuses on developing the algorithms this requires. "According to our studies, the assistance system can help avoid a collision in 60 percent of cases, provided the driver reacts at least half a second beforehand," says Bürkle, who joined Bosch in 2002. Bosch plans to start production of the system in 2018.

Press photos: 1-CR-21644, 1-CR-21645, 1-CR-21646, 1-CR-21647, 1-CR-21648, 1-CR-21649-en, 1-CR-21649_o_Logo-en

Professor Dr. Amos Albert: Agricultural robotics

Professor Amos Albert teaches robots eco-friendly farming. "We use Bosch expertise in the fields of mechatronics and algorithms to help make sustainable use of natural resources," says Albert, who is CEO of Deepfield Robotics, a Bosch start-up that emerged from the company's research activities. "One thing our technologies do is enable the Bonirob agricultural robot to distinguish between crops and weeds," Albert says. On the basis of this knowledge, the robot uses a rod to ram unwanted weeds several centimeters into the ground. This obviates the need for herbicides. Thanks to GPS positioning, Bonirob can find its way around to the nearest centimeter. Albert has been with Bosch since 2002. His team is also working on solutions that will allow farmers to use connected sensor systems to gather information on plant growth in order to improve yield and quality.

Press photos: 1-CR-21626, 1-CR-21627, 1-CR-21628, 1-CR-21629, 1-CR-21630, 1-CR-21631, 1-CR-21632, 1-CR-21633, 1-CR-21634, 1-CR-21635-en, 1-CR-21635_o_Logo-en

Dr. Jürgen Kirschner: Executive vice president, applied research and production technology

Dr. Jürgen Kirschner is an executive vice president in corporate research and advance engineering at Bosch. His responsibilities range from battery technology and sensors to production engineering. In its more than 250 plants worldwide, Bosch often needs to use tools and methods that are not yet commercially available. "In those cases we develop them ourselves, which gives us a competitive edge," says Kirschner, who has held a number of positions at Bosch since 1989. One such novel tool is ultrashort pulse lasers, which can process even extremely hard metal with the greatest precision and at high speed. One of Kirschner's responsibilities, therefore, is to ensure that research provides Bosch with the processes and methods it will need for the reliable, high-quality mass production of its future innovative products.

Press photos: 1-PE-21661, 1-PE-21662

Dr. Michael Bolle: President, research and advance engineering, technology coordination

Dr. Michael Bolle is the president of corporate research and advance engineering at Bosch. His responsibilities include developing new ideas for future Bosch products. He also focuses on areas in which the company is as yet barely active, if at all; for example, using robots and sensor systems in agriculture. “For this purpose, we also want our researchers to develop a more entrepreneurial mind-set,” Bolle says. He joined Bosch in 1992 and has worked for the company ever since, apart from a four-year period spent getting a startup off the ground. “That experience is a really great advantage here in Renningen,” Bolle says. On the topic of the new research campus, he says: “We want to give our colleagues here the ideal working conditions they need to shape the future of Bosch and secure our innovation leadership.”

Press photos: 1-PE-21659, 1-PE-21660

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Press release

Inauguration of the Renningen research campus

New Bosch pedestrian protection system helps drivers brake and take evasive action

Technology computes imminent actions

October 13, 2015
PI 9032 RB Res/af

- The challenge: more safety for pedestrians in road traffic
- Aim of Bosch research: injury- and accident-free driving
- Bosch approach: development of new assistance systems to avoid collisions with pedestrians

Stuttgart and Renningen, Germany – Pedestrians are the most vulnerable road users. In 2014, 523 pedestrians died on German roads alone, accounting for 15.5 percent of all road deaths in Germany. Bosch is developing increasingly comprehensive driver assistance systems that protect pedestrians more effectively and help make the goal of injury- and accident-free driving a reality. At the company's new research campus in Renningen near Stuttgart, researchers are close to perfecting a system that helps drivers brake and take evasive action if there is the threat of a car-pedestrian collision. If braking alone is no longer enough to prevent a collision with a pedestrian who suddenly walks out in front of the car, the assistant instantaneously computes an evasive maneuver. As soon as drivers start taking evasive action, the system kicks in to support the steering maneuver. "According to our studies, provided the driver reacts at least half a second before a potential collision, the assistance system can help avoid it in 60 percent of cases," says the project manager Dr. Lutz Bürkle, who works in corporate research and advance engineering. Bosch plans to start production of the system in 2018.

Technology looks one second into the future

To test the technology, Bürkle and his interdisciplinary team have built a research vehicle. Its central component is a Bosch stereo video camera of the kind already used in production models. Mounted behind the windshield near the rear-view mirror, the camera provides a 3D image of the area to the front of the vehicle, and detects pedestrians and oncoming traffic as well as obstacles on the road ahead. A computer in the trunk of the research vehicle analyzes the information.

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If a pedestrian suddenly appears in the stereo video camera's field of vision, the system computes the likelihood of a collision as well as the route that must be taken to avoid it. All this happens at lightning speed – more than ten times a second. The correct interpretation of the images from the camera and the specific driving situation is particularly complex. "To plan the new trajectory as precisely as possible, we have to do things such as predict where the pedestrian is likely to be in a second's time," Bürkle explains. The team's work focuses on developing the algorithms this requires. Bosch's multi-faceted software expertise, which the company continues to expand, is vital in this process.

Key competence for automated driving

With their work on the analysis of camera images, the Bosch researchers are also making an important contribution to the development of automated driving. From 2020, it is expected that the Bosch highway pilot will enable highly automated freeway driving without the need for constant driver supervision. Among other things, this automation will be based on various sensors that provide a precise image of the vehicle's surroundings. Here, Bosch relies on its mid- and long-range radar sensors, on its stereo video camera, and on its image-processing expertise. Bosch's main goal in developing automated driving is greater safety on the roads. An estimated 1.3 million people worldwide are killed in road accidents each year. Ninety percent of these accidents are caused by human error. In difficult or confusing traffic situations, machine support can save lives.

The ultimate goal, therefore, is automated driving. In the meantime, Bosch will launch a whole range of useful driver assistance systems. Image analysis and the ability to compute new trajectories could also be used in an assistance system that guides vehicles through tight spaces. Roads are often clogged by cars parked on both sides, especially in cities. Things can get extremely tight if a van double-parks to make deliveries. The images from the stereo video camera can then provide crucial information. The computer analyzes it, and the assistant controls the power steering to enable the car to pass by without mishap, even when there is little room. "The examples show how Bosch is using sensors, software, and expertise in image processing to make mobility safer," says Dr. Michael Bolle, head of corporate research and advance engineering at Bosch.

A network spanning industry and academia

The emergency braking assistant, the evasive steering support for pedestrian protection, and the assistance system for tight spaces are being developed as part of the publicly funded UR:BAN project. UR:BAN brings together 31 partners

from the automotive, automotive-supply, electronics, communications, and software industries, as well as universities, research institutes, and municipal authorities. The aim of the partnership is to develop driver assistance and traffic management systems for the urban environment. Financial support for the project is being provided by the German Federal Ministry for Economic Affairs and Energy. Bosch knows that close cooperation between business and the academic world is conducive to innovation. This is why the company works with almost 250 universities and research institutes worldwide.

Internet:
Details about UR:BAN:
http://urban-online.org/de/urban.html
Details about driver assistance systems at Bosch:
http://bit.ly/1VlzMSl
http://bit.ly/1SYHw0T

Press photos: 1-CR-21644, 1-CR-21645, 1-CR-21646, 1-CR-21647, 1-CR-21648, 1-CR-21649-e, 1-CR-21649-e_n

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Press release

October 12, 2015
PI 9033 RB Res/af

Inauguration of the Renningen research campus
How Bosch is developing the battery of the future
400 million euros invested annually in electromobility

- More than twice the energy content and significantly lower costs by 2020
- Bosch approach: improving rechargeable lithium-ion batteries
- Technological breakthrough thanks to a Silicon Valley start-up

Stuttgart and Renningen, Germany – Bosch is researching batteries that will make it possible to drive longer distances without recharging, and will also cost less than current batteries. “Our battery experts are playing a key part in paving the way for electromobility,” says Dr. Michael Bolle, president of the corporate sector for research and advance engineering at Robert Bosch GmbH. As early as 2020, Bosch batteries should be capable of storing twice as much energy while costing significantly less. The market forecasts are correspondingly bullish: ten years from now, Bosch expects some 15 percent of all new vehicles worldwide to have an electrical powertrain. As a result, Bosch is investing 400 million euros a year in electromobility.

Current challenge: heavy weight, low energy density

Dr. Thorsten Ochs, head of battery technology R&D at the new Bosch research campus in Renningen, explains what will be necessary for progress in battery technology: “To achieve widespread acceptance of electromobility, mid-sized vehicles need to have 50 kilowatt hours of usable energy.” With conventional lead batteries, this would mean increasing the weight of the battery to 1.9 metric tons, even without wiring and the holder. That is the same weight as a modern-day mid-sized sedan, including occupants and luggage. At a weight of 19 kilograms, a conventional lead battery – as found today in nearly every car for powering their starters – stores a comparatively low 0.5 kilowatt hours.

The goal: a weight of just 190 kilograms, recharged in 15 minutes

Today’s lithium-ion batteries are superior in this respect. They store more than three times the amount of energy per kilogram. At a weight of 230 kilograms, the

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battery of a modern-day electric car provides approximately 18 to 30 kilowatt hours. But to achieve the desired 50 kilowatt hours, a battery weighing 380 to 600 kilograms would be necessary. With his colleagues around the world, Ochs is therefore working on energy storage media with even better performance. Their goal: to pack 50 kilowatt hours into 190 kilograms. In addition, the researchers are looking to significantly shorten the time a car needs to recharge. “Our new batteries should be capable of being loaded to 75 percent in less than 15 minutes,” Ochs says.

Ochs and his colleagues firmly believe that improved lithium technology will make it possible to achieve these goals. “There is still a long way to go when it comes to lithium,” Ochs says. To make progress in this area, his team in Renningen is working closely with Bosch experts in Shanghai and Palo Alto. And as a further measure to advance lithium-ion battery research, Bosch has established the Lithium Energy and Power GmbH & Co. KG joint venture with GS Yuasa and the Mitsubishi Corporation.

More space for electrical power – thanks to start-up technology from Silicon Valley

In theory, the solution sounds simple: “The more lithium ions you have in a battery, the more electrons – and thus the more energy – you can store in the same space,” Ochs says. But because researchers need to improve cells at the atomic and molecular level, putting this into practice is a challenge. One of the main keys to achieving this goal is to reduce the proportion of graphite in the anode (the positively charged part of the battery), or do without graphite altogether. Using lithium instead of graphite would make it possible to store up to three times as much energy in the same space. Ochs and his colleagues have already developed many approaches for removing the graphite and replacing it with other materials. The Bosch CEO Volkmar Denner recently presented a prototype solution at the IAA. Thanks to its purchase of Seeo Inc., a start-up based in Silicon Valley, Bosch has now acquired crucial practical expertise when it comes to making innovative solid-state batteries. Such batteries have one other decisive advantage: they can do without any liquid electrolyte. Such an electrolyte is to be found in conventional lithium-ion batteries, where, in certain circumstances, it can pose a safety risk.

Advantages in a number of areas

Improved lithium-ion batteries would benefit not only drivers, but also all other applications that employ this technology, such as smartphones, laptops, tablets, cordless household appliances and tools, and many more products.

Internet

Electromobility at Bosch:

http://bit.ly/1Q5vrRH

http://bit.ly/1OhmDd9

SEEO website:

http://seeo.com/

Press photos: 1-CR-21622, 1-CR-21623, 1-CR-21624, 1-CR-21625-en, 1-CR-21625-o_Logo-en

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Press release
Bosch Compact

Gasoline injection, ABS, ESP, sensors
Examples of outstanding Bosch innovations
Thirteen exceptional achievements from more than 100 years

October 9, 2015
PI 9036 RB Res/af

Stuttgart and Renningen, Germany – In mid-October, Bosch will be opening its new research campus in Renningen, near Stuttgart. The company has invested more than 300 million euros in the site, and created 1,700 jobs in a modern and inspiring environment. Bosch research and development is not only concerned with innovative products, however, but also with continuously refining manufacturing processes. In this way, the company has come up with many innovations since it was set up in 1886. A selection of some of them is presented here:

1902: high-voltage magneto ignition system with spark plug

In the summer of 1901, Robert Bosch gave his colleague Gottlob Honold the brief of designing a magneto ignition system without the breakdown-prone break-spark rodding generally in use at that time. After just a few months, Honold presented his high-voltage magneto ignition system, based on what was known as electric arc ignition. By means of two coils on the armature, it generated a high-voltage current. This was conducted to a spark plug via a simple cable connection. The spark jumped the gap between its electrodes. This historic invention has shaped automotive design to this very day. No spark-ignition engine would run without an ignition system. Over the course of the decades, Bosch has refined ignition systems. Its Gasoline Systems division now manufactures modern ignition systems for a global market. In this way, Bosch plays a significant role in meeting legal emissions limits and fuel-efficiency targets, thus protecting the climate.

1927: diesel injection system for commercial vehicles

Around 1920, experts were vaunting the diesel engine as the powertrain of the future. Bosch was quick to latch on to this trend: diesel engines did not require any electric ignition, which was Bosch's most important product at the time. This jeopardized the company's existence. In 1922, therefore, Bosch began developing injection pumps for diesel engines. The first diesel truck was rolled

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out in Germany in 1924, enabling engineers to test the new pumps under normal driving conditions. Bosch started production of in-line pumps and injection nozzles for trucks on November 30, 1927. Nowadays, modern diesel injection systems are indispensable in trucks. Nearly 100 percent of all trucks worldwide are powered by diesel. In the passenger car segment in Europe, this figure is some 50 percent of all newly registered vehicles. With its highly efficient common-rail systems, Bosch is one of the world's leading suppliers of diesel injection systems.

1932: Bosch hand motor and Bosch hammer drill with impact mechanism

In 1930, Bosch engineers began developing hand-held tools for use in manufacturing. Their design was based on a hair trimmer. Featuring an integrated motor, the Bosch power tools could be flexibly put to use in production processes. They proved to be particularly useful in the production of diesel injection pumps. The company recognized the tools' market potential, and from 1932 sold them to builders and tradespeople as well. The same year also saw the market launch of the Bosch hammer drill. The "Bosch hammer" was the forerunner of the company's heavy electric hammer drills used in the construction industry. Its impact mechanism, which the company developed and mass produced, proved its superiority over other designs in heavy continuous operation, and was soon in use worldwide. Today, the Bosch Group's Power Tools division is the global market leader for power tools, power-tool accessories, and measuring technology. And in 2015 as well, Power Tools will again launch more than 100 new products in its four areas of business: power tools, accessories, measuring technology, and garden tools.

1933: first refrigerator

In 1933, Bosch built the first refrigerator designed to be affordable for the general public. There were already electric refrigerators in the market, but they were so expensive that only wealthy people or businesses (e.g. grocery stores and restaurants) could afford them. The Bosch refrigerator cost 298 reichsmarks, which was far less expensive than the other popular models of the time. Today, Bosch is Europe's most popular household-appliance brand, and continues to set trends worldwide – for example, with a connected fridge featuring integrated cameras which allow shoppers to check online whether there are still tomatoes in the fridge.

1953: hydraulic plow lift

In Europe at the start of the 1950s, farming still involved a lot of manual work. Any technology consisted in replacing draught animals with tractors. It was here that Bosch focused its efforts: in what work processes could technology be used to reduce the burden on people? The first thing Bosch came up with was a plow

lift. It used a motor mounted on the tractor to assume the heavy work of lifting and lowering the plow. The basic idea was to connect a hydraulic system comprising pump, oil tank, control unit, cylinder, and pressure lines to the engine. Suddenly, what had been a strenuous task became child's play. A gentle pull on the control lever was enough. The pump used the power from the engine, transferring it to the work cylinder, which used the pressure lines to determine the position of the plow. Engine oil was used to transmit force in the pressure lines. The plow lift was the birth of mobile hydraulics at Bosch. In 2001, this area was pooled with the competence of the industrial technology company Rexroth. Today, Bosch Rexroth is one of the globally leading suppliers of drive and control technology, helping to move machinery and plant of all sizes.

1967: Jetronic electronic gasoline-injection system

In 1959, Bosch began developing an electronically controlled gasoline injection system. When this system, called Jetronic, was launched in 1967, it was the first mass-produced system of its kind in the world. Nowadays, efficient injection systems are indispensable for modern cars. Bosch's gasoline direct injection goes from strength to strength.

1978: ABS antilock braking system

The success story of ABS began in 1978 with the start of production of the first electronically controlled four-wheel antilock braking system for passenger cars. It was a development Bosch engineers had been working on for nine years. Their pioneering technical approach formed the basis of all modern braking control systems. If the wheels lock up, ABS reduces brake pressure then increases it again – up to 40 times a second. This keeps braking distances short, even on slippery surfaces, and the vehicle remains steerable. Today, all new cars in the EU are sold with ABS. For motorcycles, the EU has mandated the system for all new type approvals from 2016. Since 1978, more than 190 million ABS systems have been manufactured at Bosch.

1985: Junkers/Bosch combined heating and hot water boiler with condensing technology

The most important heating technology innovation of the 1980s was the introduction of the wall-mounted gas-fired condensing boiler in Germany. Hugo Junkers had described the principle behind this technology as early as 1894. The eponymous company he founded was the origin of today's Bosch Thermotechnology division. The technology reuses the waste heat in exhaust gas. This waste heat is fed back into the heating circuit, thus considerably increasing efficiency without increasing consumption.

Condensing technology has become established in many European countries, and will become the de facto standard in the EU from September 2015. Bosch innovations are further increasing the efficiency of heating technology. The "SolarInside" control unit, for example, optimizes the interplay of condensing boiler and solar thermal system. With sales revenue of more than 3 billion euros, Bosch Thermotechnology is a leading European manufacturer of energy-efficient heating products and hot-water solutions.

1995: micromechanical sensors (MEMS) in mass production

In the 1980s, Bosch worked on making sensors smaller, more reliable, and more energy-efficient – ever more sensor data was needed for increasingly sophisticated cars. The previous manufacturing process – called "wet etching" – was no longer suitable for these tiny sensors. A Bosch research team thus invented "plasma etching," which in the industry is now known as the "Bosch process." When it started mass production in 1995, Bosch laid the foundation stone for this modern technology. Its current portfolio includes acceleration, yaw, mass-flow, pressure, and environmental sensors, as well as microphones. The company took 13 years to manufacture its first billion MEMS sensors. Nowadays, at its modern wafer fab in Reutlingen, near Stuttgart, the Bosch Automotive Electronics division manufactures the same quantity in less than year. Today, more than four million sensors are manufactured every day. On average, these tiny helpers are between one and four millimeters thick. Bosch is the world's leading supplier of MEMS sensors.

1995: ESP electronic stability program

Using smart sensors, ESP compares 25 times per second whether the car is actually moving in the direction that the driver is steering it in. If an analysis of these data indicates that a dangerous – and uncontrollable – situation is imminent (e.g. skidding), ESP intervenes immediately. By reducing engine torque and deliberately braking each wheel individually, the system helps the driver stabilize the vehicle and prevent skidding accidents. Since being launched in 1995, ESP has prevented 190,000 accidents and saved more than 6,000 lives across Europe. In Europe, more than 80 percent of all new vehicles are now fitted with this safety system, while the worldwide figure is some 60 percent. Bosch is the world's leading supplier, and celebrates a milestone this year: it will soon have sold 150 million ESP systems since production began 20 years ago.

2008: ultrashort pulse lasers used in production

Using precisely controlled, ultrashort laser pulses, extremely hard materials can be very accurately machined. Bosch has been driving forward development in this area for many years, and together with several partners in industry and academia, succeeded in making this technology market-ready. Finally, Bosch

succeeded in achieving a world first – namely, operating the laser in the machines it developed in-house so precisely that reliable mass production was possible, with all the associated benefits. This technology was put to initial use in the manufacture of lambda sensors. Today, one of the ways Bosch uses ultrashort laser pulses is to drill the extremely fine nozzles in the injection valves of its gasoline direct injection system. This allows fuel to be distributed even better in the combustion chamber. The result is a fuel saving of as much as 20 percent in gasoline engines, and lower emissions.

2015: smart mowing 2.0 with the Indego 1 200 Connect

The unique, tried-and-tested "LogiCut" navigation system ensures that the Indego 1 200 Connect robotic lawnmower mows efficiently along parallel lines. This enables it to mow the same lawn area at least 30 percent faster than robotic lawnmowers that mow at random. Using a smartphone app, the lawnmower can be simply and conveniently operated from anywhere. The app computes the best time for the next cut. To do so, it uses a complex algorithm as well as information about environmental conditions such as temperature and precipitation. Using this web-based weather forecast, Indego Connect mows the lawn when the conditions are right: not too hot, not too wet, and not too cold.

Press photos: 1-CR-21448 to 1-CR-21464

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Press release

Inauguration of the Renningen research campus

Intelligence for the fields: Bosch robot gets rid of weeds automatically and without herbicides

New applications for sensor technology and algorithms

October 8, 2015
PI 9031 RB Res/af

- The challenge: increasing agricultural yield
- Aim of Bosch research: automation and simplification of plant breeding and weed control
- Bosch approach: development of an intelligent and flexible agricultural robot

Stuttgart and Renningen, Germany – Back in 1950, a farmer would have been able to grow around 2,500 kilograms of wheat per hectare of cropland. Today, that figure has more than tripled. Advances in plant breeding and technical innovations will continue to be necessary in order to feed the growing global population. This is where Bosch's "Bonirob" agricultural robot can play a part. "We are leveraging our expertise in sensor technology, algorithms, and image recognition to make a contribution to improving quality of life, even in areas that are new for Bosch," says Professor Amos Albert, a robotics expert and general manager of the Bosch start-up Deepfield Robotics. According to estimates, agricultural yields need to increase by three percent a year to keep up with population growth. Along with innovative agricultural technology and improved crop protection, more efficient plant breeding will play a particularly important role. In this area, Bonirob automates and speeds up analysis. The robot, which is approximately the size of a compact car, uses video- and lidar-based positioning as well as satellite navigation to find its way around the fields. It knows its position to the nearest centimeter. It also helps minimize the environmental impact of crop farming.

Environment sensors and image processing in plant breeding

Today's plant scientists are able to analyze the genetic makeup of new varieties in great detail – in the laboratory. However, it is only real field conditions that will show how well the plants actually grow: whether they are resistant to pests such as insects and viruses, and how much fertilizer and water they actually need. In painstaking manual work in the field, plant scientists examine and analyze thousands of plants, recording the size and color of their leaves, the

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size and shape of fruits, growth forms, insect infestation, and chlorophyll content. Based on these findings, they then decide which plant strains are worth pursuing further. The Bonirob is named after this plant appraisal process, which is known in German as *Bonitur*. Without this robot, it can take up to ten years before improved crops are ready for the market. The Bosch agricultural robot's automatic image recognition can help here. "Algorithms analyze the photos taken by scanners and cameras. This automatic screening saves a lot of time and effort," Albert says.

Weed control with minimum environmental impact

Plant breeding is not the only thing Bonirob is capable of speeding up. The agricultural robot also makes everyday work in the fields easier. On the basis of leaf shape, Bonirob can distinguish between crops and weeds. With the help of a rod, it gets rid of weeds mechanically, rather than with weed killer. Undesired plants are simply and swiftly rammed into the ground.

Increasing intelligence through machine learning

In light of the large number of different plants, Bonirob's automatic image recognition plays a key role. Albert describes the challenge: "The leaves of carrots and chamomile, for example, are very similar in their early stages." As a result, he has to teach Bonirob how to learn and recognize the shapes of leaves. How do you "explain" the shape of a carrot leaf to a robotic system? Albert and his team use what is known as machine learning. This involves a large number of image files in which the Bosch researchers highlight the weeds. "Over time, based on parameters such as leaf color, shape, and size, Bonirob learns how to differentiate more and more accurately between the plants we want and the plants we don't want," Albert says.

New business thanks to agile teams

Albert and his team are developing the agricultural robot at Deepfield Robotics, a Bosch-owned start-up company that emerged from the work of a corporate research team in 2014. Bonirob is the product of a public joint project funded by Germany's Federal Ministry of Food and Agriculture that saw experts from Bosch, Osnabrück University of Applied Sciences, and the agricultural machinery manufacturer Amazone join forces. Under the auspices of Robert Bosch Start-Up GmbH, Bosch has since taken over the task of further developing this high-tech tool. At the 2015 European Robotics Forum in Vienna last spring, Bonirob was singled out for a 2015 euRobotics Technology Transfer Award. In September, the German Federal Minister of Food and Agriculture Christian Schmidt presented the agricultural robot with an award for innovation in horticulture. It won the Deutscher Innovationspreis Gartenbau in the "technology" category.

Internet

Another agricultural project at Bosch:

http://bit.ly/1UGSLq4

Details about the EU's Flourish project:

http://bit.ly/1Kcd8Wg

Press photos: 1-CR-21626, 1-CR-21627, 1-CR-21628, 1-CR-21629, 1-CR-21630, 1-CR-21631, 1-CR-21632, 1-CR-21633, 1-CR-21634, 1-CR-21635-e, 1-CR-21635-e_n

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Press release

Inauguration of the Renningen research campus

Hidden heroes: How Bosch is teaching things to feel – and changing everyday life

MEMS sensors are a key technology for IoT

October 07, 2015
PI 9034 RB Res/af

- The challenge: powerful, energy-efficient, cost-effective sensors for new connected solutions
- Aim of Bosch research: more safety, more productivity, more convenience, and better quality of life
- Bosch approach: interplay of energy harvesting, intelligent software integration, and reduced size

Stuttgart and Renningen, Germany – Although they are only as small as a pin head, they are changing everyday life in many fields: tiny Bosch micromechanical sensors. In fitness wristbands, they measure physical activity and help people achieve better health and well-being. In cars, sensors identify dangerous situations and instantly alert the control electronics to keep the vehicle on the road. Because sensors detect the earth's gravity, smartphones can change their screen orientation to suit users' needs. Bosch is the world's leading manufacturer of MEMS sensors (micro-electromechanical systems). Since the start of production in 1995, the company has manufactured more than six billion of them. "The key challenge in the ongoing development of our MEMS sensors is their energy consumption. For example, more intelligence in sensors makes it possible for us to reduce energy consumption," says Dr. Franz Lärmer, a Bosch sensor expert. It is hard to put a number on the many potential applications of sensors. They are a key technology for the internet of things (IoT).

Three approaches for lower energy consumption

Users of mobile devices such as smart watches, augmented-reality glasses, or wearables often wish for longer battery runtimes, smaller designs, more affordable products, and more functions. Until now, the capacity of the batteries in such devices has often not been enough to keep the sensors and their analysis chips constantly supplied with power. Devices have to be recharged more frequently if the sensor-supported functions are constantly in use. Moreover, better battery

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performance also opens the door to a wider range of intelligent applications. With the aim of reducing sensors' energy consumption, Lärmer and his team in Renningen have joined forces with Bosch researchers in Palo Alto, California, to pursue three different approaches.

The first approach: energy can be harvested from changes in ambient pressure, vibration, or temperature. As part of the publicly funded joint project 9D-Sense, Bosch is working with partners to research this kind of energy harvesting. Tiny rechargeable batteries can store even the most minuscule amounts of energy gathered in this way to provide sensors with power over a long period of time, maintenance-free. The second approach: sensors can be programmed to gather and transmit their data only when absolutely necessary. If a smartphone is lying still on a table, for example, its sensors do not need to be active. The third approach: at its research center in Palo Alto, Bosch has developed the world's smallest and most energy-efficient sensor unit. The contents of the BMI160's tiny housing, which measures 2.5 x 3.0 x 0.8 millimeters, include an accelerometer and a yaw-rate sensor (gyroscope). In a smartphone, the sensor unit measures things such as position. It can also be found in tablet computers and smart watches. In full operational mode, the BMI160's typical power consumption amounts to a mere 950 microamperes, which is less than half the market standard, as well as a world record. This and other Bosch sensors can be found in three-quarters of all smartphones in the world today.

Every object capable of gathering information

"In the future, nearly all everyday objects are likely to be equipped with sensors. This is a revolutionary development that will allow almost every object to gather information about itself and its environment. As a result, the potential applications of these objects will increase tremendously," Lärmer says. "But other things are also playing an increasingly important role, such as the combination of several sensors and the integration of software intelligence." One example comes from the world of physical fitness. By measuring atmospheric pressure, one sensor can determine which floor of a building the wearer is located on, while another sensor registers every movement the wearer makes. Together with the data from a tiny heart-rate sensor, which is attached to the user's skin, the sensor automatically transmits a fitness profile containing information about things such as changes in heart frequency while climbing stairs. If desired, a smartphone app can transmit the profile to a trainer. Applications related to early screening and diagnosis are also conceivable. "Changes in how people move can be an early sign of conditions such as dementia or postural defects. They could be measured in a similar way using MEMS sensors. This would allow us to diagnose and treat

illnesses at the earliest possible stage," Lärmer says. "There is no end in sight to the wide range of possible applications for connected sensors. Our research examines these possibilities."

The latest technical equipment for sensitive sensors

At its new research center in Renningen near Stuttgart, Bosch is working on the big future of these tiny components. It wants to make them even smaller and more energy efficient, thus paving the way for new applications. The best possible conditions are needed to manufacture MEMS, and the same goes for research into new MEMS generations. Even the tiniest grains of dust can cause major problems in the development and production of MEMS structures. At its new research campus, therefore, Bosch has constructed a suite of clean rooms to the latest technical specifications. All air in the building is subject to thorough filtering, resulting in no more than 370 particles per cubic meter. By comparison, air in a typical urban environment contains some 35 million particles per cubic meter.

Tiny structures, extremely sensitive

Microscopically fine structures are etched into silicon during MEMS production. On the sensor, the teeth of tiny comb-like silicon structures intermesh. Less than one-quarter the thickness of a human hair, these comb-like structures are pushed up against each other during movement. The distance between the teeth changes, leading to a change in the electric current in the comb-like structures. This current can be measured and calculated as an electric signal that the sensor then transmits. MEMS sensors are extremely sensitive thanks to this technology, Lärmer explains. "In a laboratory, you can use them relatively easily to measure the earth's rotation." What is more, the fine silicon structures are already capable of measuring movements of just one femtometer. This is the unimaginably small distance of 0.000000000000001 meters (10^{-15} meters), and thus the same magnitude as the diameter of atomic nuclei.

Animation

How an acceleration sensor works:
http://bit.ly/1LnkuHv
How a pressure sensor works:
http://bit.ly/1L5I9Ao
How a MEMS gyroscope works:
http://bit.ly/1gdMvbV

Internet

Bosch Sensortec:

https://www.bosch-sensortec.com/

Information about Franz Lärmer:

http://bit.ly/1MfGmKL

Details about BMI160:

http://bit.ly/1z0AE6V

Five billion Bosch MEMS sensors:

http://bit.ly/1UG7TJH

Sensors – how technology maps the world around it:

http://bit.ly/1iaEgK5

Energy harvesting:

http://bit.ly/1lFc33b

9D-Sense research project:

http://bit.ly/1hHR89T

Press photos: 1-BST-20778, 1-BST-20779, 1-AE-20855, 1-AE-20856-e, 1-BST-20755, 1-CR-21650, 1-CR-21651, 1-CR-21652, 1-CR-21653, 1-CR-21654-e, 1-CR-21654-e_n

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Press release

Inauguration of the Renningen research campus

The technician only rings once: data mining benefits Bosch and its customers

"Data is the new oil of the global economy"

October 5, 2015
PI 9035 RB Res/af

- Challenge: automatically detecting the right patterns in big data
- Research aim: better customer service and optimized production
- Bosch approach: international team of experts uses and develops new algorithms for data analysis

Stuttgart and Renningen, Germany – A new raw material is driving the economy. But unlike steel, gold, or plastic, it is invisible and intangible. This raw material is the constantly growing stream of data from connected factories, connected cars, and connected products. Used correctly, it offers huge potential for better customer service and optimized production processes – and thus for greater competitiveness. "The ability to generate new knowledge from big data is a key competence of the future," the computer scientist Dr. Lothar Baum says. At the new Bosch research campus in Renningen, he heads a team of experts that are involved in the computational process of discovering patterns in large data sets, or data mining, as it is known. Among other things, Baum's research focuses on how data mining can be used to optimize connected industry.

Cents add up to millions of euros

"Data is the new oil of the global economy," Baum says. To give one specific example: by evaluating manufacturing data, Bosch has managed to cut the time taken to inspect hydraulic valves by 17.4 percent. Such huge savings are a major advance in modern manufacturing, and this despite the many considerable improvements that have already often been made there. With some 40,000 valves manufactured every year, this represents a saving of 14 days for the company. In this particular case, an analysis of the production data relating to 30,000 manufactured hydraulic valves showed that certain subsequent testing steps in the inspection process are unnecessary, provided the results of several earlier steps are positive. The outcome of those subsequent steps can be reliably predicted by analyzing the earlier steps. Pinpointing such correlations – which are generally

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much more complex than the example given here – saves time and money. "When the number of parts runs into the millions, even savings of just a few seconds can soon add up, turning a few cents into millions of euros," Baum says. Every second and cent saved strengthens the competitiveness, and thus the attractiveness, of the products manufactured.

Bosch operates several clusters

Technically, all this is extremely sophisticated. "While the algorithms this requires have essentially been known for many decades, it has so far been impossible to gather data to the extent now made possible by the internet of things. And a lack of computing power has meant that it has not been possible to apply the algorithms to several billions of data points," Baum says. Now, however, thanks to clusters made up of many interconnected servers, these huge computational tasks can be performed on thousands of processors working at the same time. Around the world, Bosch operates several such clusters. Humans play an essential role in this process: they have to program the computers so that they can process billions of data points efficiently and in parallel, instead of sequentially.

The technician only rings once

These capabilities are also in evidence in another example that shows the benefits of data mining. The utility company British Gas provides its customers with heating and hot water. Many of the Bosch boilers installed by British Gas are now web-enabled and transmit a wide range of data from their day-to-day operation to the utility company: When is the boiler in use and for how long? How much time does it take for the flame to light? How hot is the water? "When a boiler needs longer to ignite than it used to, analyzing this information can reveal the potential causes," Baum says. "Now service technicians can take the appropriate replacement part with them right away when they call on a customer. They already know where the fault lies. Up to now, technicians have usually had to visit twice: once to find out what's wrong, and a second time to make the repairs." Data analysis thus saves British Gas money, and customers benefit from faster, better service.

34 projects with an international presence

Bosch operates hundreds of production lines at around 250 plants worldwide. Many of them are already connected to the web. Sensors on these lines transmit data, while algorithms use that information to detect potential wear and tear and provide information for timely maintenance work. This avoids unplanned downtime, increasing productivity. At its new location in Renningen, Bosch is helping its researchers and engineers communicate with each other even better than before, so that they can develop such solutions. In addition, 34 data mining-related projects have already been started. A team of 40 experts from around the world

is working exclusively on such projects. In doing so, they are supporting manufacturing associates in putting such projects into practice. The data experts are based mainly in Palo Alto, California – in the heart of Silicon Valley – and in Bangalore, India. Bosch's global alliance partners in this field include Stanford University and the University of Pittsburgh.

Advantages thanks to a transparent production process

The big data component of the Bosch IoT Suite already makes it possible to explore and evaluate large volumes of data. The IoT (internet of things) Suite is a comprehensive software solution that can be used to develop, provide, and operate IoT applications.

New jobs for new experts

As the use of data mining increases, so does Bosch's need for qualified software experts. "Data scientists must be familiar with software and be able to write it themselves for special purposes. They must have an understanding of math, statistics, and machine learning. What's more, they have to have detailed knowledge of the products and how they are manufactured, so that they can correctly interpret the data generated," Baum says. This is another reason why Bosch plans to hire 12,000 university graduates this year. With software growing more important in all Bosch divisions, graduates with IT skills also have good prospects, as do engineers.

The next goal: faster service at the car workshop

Baum and his colleagues are currently working to provide a forecast stating which cars will be visiting a Bosch Car Service garage and when, and what will be wrong with them. Workshops can then prepare for the necessary repairs by ordering the required spare parts, for example. This will also allow them to optimize their inventories. "Because the spare parts are already in stock at the workshop and do not have to be ordered first, drivers will get a faster and better service. We already have the methods needed to evaluate the data. Now all we have to do is amass enough data to be able to use those methods to full effect," Baum says.

Internet

Details of the Bosch IoT Suite:
http://bit.ly/1O0BwkC

Press photos: 1-CR-21636, 1-CR-21637, 1-CR-21638, 1-CR-21639, 1-CR-21640, 1-CR-21641, 1-CR-21642, 1-CR-21643

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Press release

Cars that drive themselves
Highway pilot technically viable in five years

September 15, 2015
PI 9016 BBM joe/Na

- Automated driving requires extremely reliable technology
- Bosch technology paves the way for artificial intelligence in test vehicles
- More than 10,000 kilometers of test drives completed on public roads
- Legal framework must keep pace with technological developments
- Increasing automation will cut traffic accidents in Germany by up to a third

Frankfurt/Stuttgart, Germany – Drive or be driven? Bosch is just a few years away from premiering a technology that will give drivers the choice between the two. “Thanks to our highway pilots, from 2020 we could see highly automated cars driving themselves on the freeway,” says Dr. Dirk Hoheisel, member of the board of management of Robert Bosch GmbH. In highly automated driving, the vehicle temporarily assumes full responsibility for driving tasks. “The car becomes the chauffeur, and the driver the passenger,” Hoheisel says. This improves safety on the roads, but also places great demands on technical reliability. Moreover, it requires fundamental changes to vehicle architecture. “As far as developing the technology goes, Bosch is in a good position,” Hoheisel says. However, it is equally important for governments to establish the necessary legal framework for automated driving. “Legislation must keep pace with what is technically possible,” Hoheisel says.

Bosch test vehicles: artificial intelligence on four wheels

On the German A81 and U.S. I280 freeways, Bosch is demonstrating what is already technically possible. Since the beginning of 2013, engineers have been driving highly automated vehicles on public roads – at first in test vehicles based on the BMW 3 Series Touring and, since mid-2015, in the Tesla Model S. “Our engineers have now completed more than 10,000 kilometers of test drives without a hitch,” Hoheisel says. The vehicles guide themselves through traffic – accelerating, braking, and overtaking as necessary. They also decide for themselves, and depending on the traffic situation, when to activate the turn signal and change lanes. The basis for all this is sensors that provide a detailed picture of the vehicle’s surroundings. In addition, Bosch’s partner TomTom

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supplies highly detailed map data. A computer uses all this information to analyze and predict the behavior of other road users, and on that basis makes decisions about the highly automated vehicles' driving strategy. "Bosch technology is making cars smart," Hoheisel says.

Modifying the test vehicles: 1,400 hours of work and 1,300 meters of cable

Before the test vehicles could start driving themselves, a number of modifications were necessary. In the case of the Tesla, Bosch spent 1,400 hours installing 50 new components, such as a stereo video camera, and laying 1,300 meters of new cable. There is a good reason for all this work. Highly automated vehicles must be capable of operating safely even if a component fails. The only way to achieve such operational reliability is with a design strategy that includes redundancy in safety-critical systems such as braking and steering. For example, the Tesla test vehicles feature both the iBooster electromechanical brake booster and the ESP braking control system. These Bosch components can brake the car independently of each other, without any need for driver intervention. Back-up systems are also available for the power supply and vital ECUs.

At first glance, however, the Bosch test vehicles barely differ from production models. For Hoheisel, it is clear that "the interior is where we will see the biggest difference in comparison to today's production models." Highly automated driving will change the human-machine interface, and calls for modern concepts for communication between car and driver. The driver must be able to intuitively understand and use the system. With its innovative display instruments, Bosch is already offering promising solutions in this area as well: the TFT instrument cluster featured in the Audi TT, for instance, offers maximum flexibility in processing combined with brilliant clarity. And using head-up displays, Bosch puts information such as speed, navigation prompts, and warnings directly in the driver's field of view. This information is superimposed on the vehicle's surroundings in such a way that the two seem to blend seamlessly at a distance of around two meters ahead of the vehicle.

In-depth understanding of all vehicle systems the key to success

Automated driving impacts the entire car: its powertrain, brakes, steering, display instruments, navigation and sensors, as well as connectivity inside and outside the vehicle. The key to success is an in-depth understanding of all vehicle systems. Few automotive companies worldwide have as much knowledge in this area as Bosch –and the complete acquisition of the steering specialist ZF Lenksysteme GmbH, now known as Robert Bosch Automotive Steering GmbH, at the start of the year has reinforced this further. Driver assistance systems are the backbone of automated driving. Even today, they help drivers change lanes, stay in their lane, and brake or take evasive action

when encountering an obstacle. “As we move toward self-driving cars, we will be premiering many new assistance systems,” Hoheisel says. The insights that Bosch gains from these will feed directly into the development of automated driving, giving it a further boost. Bosch has 2,000 engineers worldwide working on driver assistance systems. They support the two teams – one in Abstatt, Germany, and one in Palo Alto in northern California’s Silicon Valley – that have been developing automated driving since 2011.

Automated driving is first and foremost about making road traffic safer. Each year, an estimated 1.3 million people around the world are killed in road accidents. In 90 percent of cases, the accident can be attributed to human error. “In critical traffic situations, the right support can save lives,” Hoheisel says. Bosch accident research predicts that increasing automation can lower accident rates even further – by up to a third in Germany alone. This is something that insurers are now beginning to recognize. In the U.K., for example, vehicle owners are granted a more favorable insurance status if their cars are fitted with certain driver assistance systems, such as an emergency braking function for urban driving (AEB city). And automated driving makes road traffic not only safer, but also more efficient. U.S. studies indicate that applying predictive driving strategies when on the freeway can result in fuel savings of up to 39 percent.

Legal requirements: governments and associations need to act

Highly automated driving cannot become a reality unless there are changes to the law. One current legal constraint is the 1968 Vienna Convention on Road Traffic, which dictates that drivers must retain control of their vehicle at all times. Up to now, this has ruled out highly automated driving. Nonetheless, there are signs of impending changes to the regulations that apply both in Germany and in many other countries. One possibility would allow automated driving so long as the driver is able to override or disable it. Discussions are underway on how to revise the regulations to permit this exception. Quite apart from regulatory law, vehicle licensing law presents another hurdle. Regulation R.79 of UNECE, the United Nations Economic Commission for Europe, only allows automatic intervention in steering up to a limit of 10 kph. Up to now, there have been only half-hearted attempts to change this. However, an informal UNECE working group is now working on the issue. “We have every confidence that governments and associations will make the right move soon,” Hoheisel says. Following that, the only remaining problem is validation: using current methods, a highway pilot has to complete several million kilometers’ worth of testing before it can be released for production. Bosch is now working on new approaches that rely more heavily on simulation.

Press photos: 1-BBM-21367; 1-BBM-21369; 1-BBM-21371; 1-UBK-20767; 1-UBK-20782

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Mobility Solutions is the largest Bosch Group business sector. In 2014, its sales came to 33.3 billion euros, or 68 percent of total group sales. This makes the Bosch Group one of the leading automotive suppliers. The Mobility Solutions business sector combines the group's expertise in three mobility domains – automation, electrification, and connectivity – and offers its customers integrated mobility solutions. Its main areas of activity are injection technology and powertrain peripherals for internal-combustion engines, diverse solutions for powertrain electrification, vehicle safety systems, driver-assistance and automated functions, technology for user-friendly infotainment as well as vehicle-to-vehicle and vehicle-to-infrastructure communication, repair-shop concepts, and technology and services for the automotive aftermarket. Bosch is synonymous with important automotive innovations, such as electronic engine management, the ESP anti-skid system, and common-rail diesel technology.

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Press release

Electromobility

Bosch has groundbreaking battery technology for electric vehicles

September 15, 2015
PI 9049 BBM FF/SL

- Acquisition in California: Seeo Inc. to be part of Bosch
- Pure lithium anodes: an innovative leap in cell construction
- More than twice the range possible with solid-state cells

Hayward/Stuttgart – Bosch is debuting a new battery technology for electric cars that could be production-ready in as little as five years. “Bosch is using its knowledge and considerable financial resources to achieve a breakthrough for electromobility,” said Dr. Volkmar Denner, the chairman of the board of management of Robert Bosch GmbH. The acquisition of the U.S. start-up Seeo Inc. (Hayward, CA near the Silicon Valley) will help make this possible. In addition to its own development in the area of battery technology, Bosch now has crucial know-how in innovative solid-state cells for lithium batteries as well as exclusive patents. “Solid-state cells could be a breakthrough technology,” Denner said. “Disruptive start-up technology is meeting the broad systems knowledge and financial resources of a multinational company.” Up to now, the declared industry target has been to double batteries’ energy density and halve their costs by the end of this decade. With the new solid-state cells, Bosch sees the potential to more than double energy density by 2020, and at the same time reduce the costs considerably further. A comparable electric car that has a driving range today of 150 kilometers would be able to travel more than 300 kilometers without recharging – and at a lower cost.

Strategic expansion of existing battery research

The acquisition of Seeo Inc. fits seamlessly into Bosch’s electromobility strategy. Bosch already offers a wide range of components for electromobility, from motors and power electronics to batteries. So far, Bosch has realized 30 production projects related to electromobility. At the same time, engineers are working on further refining the technology, and in doing so, making electromobility a more practical proposition. After all, by 2025, the company forecasts that roughly 15 percent of all new cars built worldwide to have at least a hybrid powertrain. In Eu-

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rope, more than a third of all new cars will be electrically powered – the majority as plug-in hybrids. To this end, in 2014 Bosch joined GS Yuasa and Mitsubishi Corporation in establishing the joint venture Lithium Energy and Power GmbH & Co. KG, whose objective is to develop a more powerful generation of lithium-ion batteries. Seeo Inc.'s technology complements the work done thus far with Bosch's Japanese partners. The result will be a combination of groundbreaking start-up technology with Bosch's systems and technology know-how, GS Yuasa's cell competence, and Mitsubishi Corporation's broad industrial base.

Bosch has first samples

For years, automakers and suppliers have been trying to create more powerful batteries. Cells are an important building block – the battery of an electric car consists of numerous interconnected cells. Cells are thus a substantial part of the value-added. The performance of an energy storage device can be improved with various methods. For example, in cell chemistry, the material that the positive and negative poles (cathode and anode) are made of plays a major role. In current lithium-ion batteries, one of the reasons energy capacity is limited is because the anode consists to a large degree of graphite. Using solid-state technology, Bosch can manufacture the anode out of pure lithium, which considerably increases storage capacity. In addition, the new cells function without ionic liquid, which means they are not flammable. "The pure lithium anode represents a huge innovative leap in battery cell construction," Denner said. Thanks to its acquisition of Seeo Inc., Bosch now possesses the first sample cells which have the potential to meet the high standards of the automotive industry where durability and safety are concerned.

Press photos: 1-BBM-21511-e, 1-BBM-21559, 1-BBM-21560

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Mobility Solutions is the largest Bosch Group business sector. In 2014, its sales came to 33.3 billion euros, or 68 percent of total group sales. This makes the Bosch Group one of the leading automotive suppliers. The Mobility Solutions business sector combines the group's expertise in three mobility domains – automation, electrification, and connectivity – and offers its customers integrated mobility solutions. Its main areas of activity are injection technology and powertrain peripherals for internal-combustion engines, diverse solutions for powertrain electrification, vehicle safety systems, driver-assistance and automated functions, technology for user-friendly infotainment as well as vehicle-to-vehicle and vehicle-to-infrastructure communication, repair-shop concepts, and technology and services for the automotive aftermarket. Bosch is synonymous with important automotive innovations, such as electronic engine management, the ESP anti-skid system, and common-rail diesel technology.

The Bosch Group is a leading global supplier of technology and services. It employs roughly 360,000 associates worldwide (as per April 1, 2015). The company generated sales of 49 billion euros in 2014. Its operations are divided into four business sectors: Mobility Solutions, Industrial Technology, Consumer Goods, and Energy and Building Technology. The Bosch Group comprises Robert Bosch GmbH and its roughly 440 subsidiary and regional companies in some 60 countries. Including its sales and service partners, Bosch is represented in roughly 150 countries. This worldwide development, manufacturing, and sales*

network is the foundation for further growth. In 2014, Bosch applied for some 4,600 patents worldwide. The Bosch Group's strategic objective is to create solutions for a connected life. Bosch improves quality of life worldwide with products and services that are innovative and spark enthusiasm. In short, Bosch creates technology that is "Invented for life."

Additional information is available online at www.bosch.com, www.bosch-press.com, http://twitter.com/BoschPresse

**The sales figure disclosed for 2014 does not include the former joint ventures BSH Bosch und Siemens Hausgeräte GmbH (now BSH Hausgeräte GmbH) and ZF Lenksysteme GmbH (now Robert Bosch Automotive Steering GmbH), which have since been taken over completely.*