Streamlining Research in Dynamic Innovation Networks

Cycles of innovation in information technology have become so short that the classic distinction between research and development is no longer valid. Today, the old model — in which basic research ultimately led to industrial implementation via a large number of development stages in various organizations — is considered for too time-consuming. This outdated production-line principle needs to be replaced with dynamic innovation networks that integrate publicly financed basic research, application development and product transfer in so-called Centers of Excellence.

It’s also a fact that specialized centers work faster and are therefore more successful in the competitive world of research. One good example of this is the German Research Center for Artificial Intelligence (DFKI), which is responsible for the entire innovation spectrum in this area. Since its foundation in 1988, it has been working closely with Corporate Technology at Siemens AG. To speed up the pace of innovation, DFKI runs simultaneous projects in the areas of basic research, applied R&D and product transfer — all under one roof. The projects are carried out by the same scientists working together in different teams. This approach is especially effective when it comes to developing, for example, the next Internet generation (see the article on the Thinking Web on page 41).

The DFKI Supervisory Board is dominated by stockholders from industry. In addition to ensuring DFKI’s adherence to lean management structures and cost-efficient research, Board Members also work with the company’s scientists to draw up roadmaps for future research. Here, a key criterion is the projected benefit to industry. Modern research centers such as the DFKI are organized as public-private partnerships and are closely linked with industrial research. Their work is strictly project-oriented, employee contracts are of limited duration, and management boards include representatives of both industry and the science community. Project work often produces industrial spin-offs. Furthermore, DFKI scientists are not expected to work solely as researchers until they retire; instead, research activity is regarded as simply the career phase that immediately follows a successful academic education. Young scientists are expected to do research in Centers of Excellence for a limited period of time in a business-friendly and project-oriented setting, and to follow this phase either by putting into practice modern concepts of education in universities or by implementing technology transfer in the world of business.

Public-private partnerships, project-oriented research, the establishment of Centers of Excellence, and bringing together the best thinkers from the worlds of science and business so that they can plan research roadmaps, scientific megatrends and strategic focuses in research — these are the key components of the dynamic innovation networks that will help participating companies to maintain and improve their leading positions in key areas of information technology.
In the kitchen, Mark uses voice input to access his electronic cookbook and calls up different types of organic and inorganic waste. He decides to make a salad, which requires cutting, washing, and cleaning. As he works, he observes how the waste is sorted into different compartments: one for green waste, another for paper and cardboard, and a third for metals and plastics. This system helps him to manage waste efficiently and reduces the amount of waste sent to landfills.

In the living room, Mark uses his voice-activated entertainment system to watch a movie. The system automatically selects the appropriate sound setting based on the genre of the movie and the preferences of the users. It also adjusts the lighting and temperature of the room to create a comfortable viewing environment.

In the bathroom, Mark uses his voice-activated shower to adjust the water temperature and pressure. The system also provides a variety of showers, from gentle rain to powerful jets. Mark also uses the voice-activated toilet to flush the toilet and adjust the water pressure.

In the garage, Mark uses his voice-activated garage door opener to open and close the garage door. The system also provides automated lighting and security features, such as an automated lock system and a security camera.
The Magic of Virtuality

Long before construction begins, future factories will function as virtual systems. Designers, engineers, suppliers and customers will be able to see the final product before production actually starts. This will accelerate processes, increase flexibility, prevent planning errors and lower costs.

Munich, Germany, October 2010. “So that’s what the new jacket will look like. That’s fantastic,” says Cynthia Brown, as she looks at the large screen. Cynthia is standing in the virtual reality (VR) lab of the Virtuplant planning office and studying the design of an “intelligent jacket” with integrated electronic components. VR software expert Arnold Goetz pushes his computer mouse across the Sense device! Cynthia nudges her colleague Oliver Bach. He has come to the presentation with her to see how the product from their biotechnology company, which monitors bodily functions and sends data to a family doctor, can be fitted into clothing. Virtuplant has digitized all of the data. Now Goetz will simulate and test the entire process — in other words, everything from production of table to turn the jacket. At the sleeve, a small PDA — personal digital assistant — with a roll-out display comes into view. Light-colored strips of conducting material run through the fabric. Elements made of a photovoltaic film are attached at the back, hardly visible. These economical solar cells are found on the shoulders too, and there are soft plastic rechargeable batteries inside the shoulder pads. As the mouse moves, the jacket takes up an ever greater portion of the screen, until finally the inside is visible. “That’s our Health-2010..."
the fabric to integration of special functions. “We’ll begin with the material,” says Goetz. “Then comes the PDA, then your HealthSense device, and finally we’ll run through the supply chain.” Suddenly the image of a factory appears on a large curved screen in the virtual reality room. “But I said we don’t want a blue floor in the hall,” blurts out Wolfgang Globas who heads upmind&drapery, a garment-making company. He steps over to the computer table and snaps at Goetz. “I want gray. We should have stayed with the conventional planning.”

“Now we’ll have it in a second,” murmurs Goetz. He calls up the palette, selects the right color with a mouse click andhands Globas a pair of 3D glasses without saying a word. “Ah!” Globas exclaims. “Hmm. But aren’t the machines too far apart? And the lengths of fabric are too wide?” “No problem,” says Goetz. “During virtual operational testing, we discovered that the previous design triggers unacceptable vibrations at certain running speeds.”

Goetz indicates a machine by pointing to it with a laser pointer and says: “We increased the distance here. Now nothing vibrates. I see,” mutters Globas. “That’s probably why the fabric used to tear now and then — but why are the lengths wider?” “Well, with this arrangement you have about 20 percent fewer rejects,” Goetz answers. “Now let’s get back to you,” he says, turning to Oliver and Cynthia. “Just a moment,” says Cynthia. “We still need a second to hook up with our colleague Markus Zoller.” She displays his number on her UMT’s cell phone. A moment later Zoller has established a connection from his office via the Internet. The Virtualplant software feeds him the image through “data glasses,” so it’s as if he were sitting in the VR lab with the others. Goetz continues. “The problem is that sometimes the HealthSense device disrupts data transmission in the jacket because of its frequency. So I designed a screen and fitted it into the virtual model.” Oliver and Cynthia are amazed. “You figured that out just by using our data?” says Oliver. “What did I tell you,” Zoller intones from the speaker. “The man’s a genius!”

“Could the jacket be ready to go to market this winter?” asks Cynthia. “That could work out,” says Goetz. “I’ll run through all the supplier logistics right away.” He turns toward his monitors. Then Globas approaches and says quietly. “Ah, Mr. Goetz, do you have a second?” he asks, wincing from his concentration. “Somewhat it looked more cheerful in blue, maybe we’d better go with that after all.”

Norbert Aschenbrenner

With innovation and design cycles getting shorter each year, companies are under pressure to become not only increasingly flexible, but also more productive and customer-focused. Digitalization and virtualization are helping them meet this challenge. In the future, production lines, machine tools, products, and even the entire logistics process will be modeled and tested in advance on computers. Shorter times to market and higher quality will be the result.

The Boston Consulting Group (BCG) believes that many of today’s factories are caught in a vicious circle. According to a BCG report on automobile production in the 21st century, manufacturing processes that have been established and perfected over decades all too often have no leeway when it comes to dealing with the flow and storage of materials in production areas. To prevent production slowdowns, inventories are kept at high levels, which drives up costs, compounds the shortage of storage space and creates an even more confusing factory environment.

To escape this situation, production lines must be designed in a modular way to allow rapid responses to changing market needs. "Of course it’s not like that in all companies,” says Dr. Bernhard Nottbeck, head of the Production Processes Department at Siemens Corporate Technology (CT) in Munich, Germany. “Nevertheless, nearly all companies must continue to optimize their production to remain competitive.” Ever-shorter innovation cycles will require companies to substantially increase their flexibility, he says.

In the auto industry, for example, it used to take five to seven years before a new model was ready for market. Today that cycle has been shortened to two or three years. To further accelerate this pace, experts — and not just those from automakers (see interview on page 13) and their suppliers, who have generally taken a pioneering role — are now counting on the digital factory.

Visualization of Virtual Data. “The digital factory gives planners and designers tools they can use to optimize production facilities or to subject a planned change to virtual trial runs,” explains Professor Engelbert Westkämper, Director of the Fraunhofer Institute for Manufacturing Engineering and Automation in Stuttgart, Germany (see interview on page 27). Today is still wishful thinking, but Nottbeck is convinced that by 2010 all the elements and processes of a factory could be represented in computer models. “We can already see the trend toward using computers to plan not just the products, but the entire production process,” says Uwe Bracht, Professor of Plant Engineering and Material Flow Logistics at the Technical University of Clausthal in Germany, and a specialist in factory planning. In a few years, a plant manager will be able to access all the data at the click of a mouse and display the information as images. In other words, it will be possible to visualize everything from machine utilization and the manufacturing status of production parts to the logistics environment and materials flow patterns.

The key is virtual reality. A number of researchers at Siemens CT are working on the visualization of virtual factories, processes and prototypes. Take Pável Gullmann, for instance. All it takes is a mouse click for him to...
Meeting at the video wall, planners and engineers can discuss digital drafts and incorporate improvements on the spot.

As with PCs, computing power has grown immensely in automation. Twenty years ago a SIMATIC controller had 24 kibytes (KB) of main memory. Today it has 16 megabytes (MB) plus a one gigabyte (GB) disk drive. In the past, mainframe computers were needed to control a production plant and its associated drive systems. Today, production units communicate with a central control via a bus system and are equipped with their own processors. The result: controls and drives function autonomously. Increasingly powerful processors make it possible to incorporate sensors in individual devices to support self-monitoring and on-the-spot diagnostics.

What’s more, systems are getting smaller and smaller. Soon sensors will have the computing power of today’s PCs — and greater computing power will provide enhanced flexibility. In the future, for instance, production processes may be significantly improved by incorporating imaging-processing sensors capable of distinguishing colors, scanning surfaces and measuring surface profiles.

Another important trend is the increasing level of embedded software. This makes individual components more flexible, because their functions can be easily updated. As a result, production can respond more swiftly to customer requirements, and factories can adapt to market needs with a greater level of flexibility.

The Road from Increasing Computing Power to Distributed Intelligence

As a whole, furthermore, design flaws are also detected much earlier. The time to production is thus much shorter — a feature that can cut costs by more than 20 percent in the planning phase. The system can also create virtual machine tools and their components, though Nottbeck stresses that “safety-related machines or components will always have a real-life prototype.”

Setting Standards. The reason why components, machines and production lines aren’t entirely simulated digitally is the lack of networking. “Dissimilar software tools are in use, and their interfaces are incompatible,” says Nottbeck. The result is costly programming that’s both time-consuming and labor-intensive. “We need to find a common language,” he adds. That’s still years away, but once standards have been established the entire industry will benefit.

The advantages of networking technologies that are already available are demonstrated by Siemens’ Totally Integrated Automation (TIA) concept. All products from A&D that can communicate — such as speed counters, circuit breakers and motors — function seamlessly with SIMATIC controllers. Totally Integrated Power (TIP) occupies the next level up in the network. In the SIMARIS software program, the Siemens A&D Power Transmission & Distribution and Building Technologies Group provide a tool that companies can use to plan the distribution of electrical power, both in buildings and processes, including climate control systems and information technology. The system determines the optimum ratings of required switches, conductors and power generating units. TIP’s potential benefits are huge, as the networked approach can cut energy distribution costs by up to 25 percent.

Networking enables the digital factory concept to provide even more extensive capabilities and services. As a case in point, Siemens Industrial Solutions and Services (I&S) has teamed up with neural networks experts from Corporate Technology to develop a process optimization solution for paper mills (see box on page 12). Another I&S project is aimed at medium-sized companies. In this case experts assume responsibility for
Siemens is conducting a pilot project in a factory. This approach enables the client company to achieve greater transparency and not only determine which of its products is profitable — but also how profitable. Specific customer questions regarding the feasibility and cost of manufacturing a component can be answered within an hour.

**Machine Tracking.** Transparency can also be enhanced by e-business. Thus, in addition to handling commodity flows, e-business can be used to remotely monitor and control machines. Siemens already provides a service to optimize machines via the Internet. Here, online dialog enables technicians to correct faults swiftly and simply.

Electronic monitoring can also be used to track the operational characteristics of machines over time so that signs of wear can be detected early. This approach allows maintenance to be performed on an “as-needed” basis. For instance, using a visualization system and data goggles, a non-specialized technician can perform various maintenance tasks (see article page 23), thus obviating many expensive visits by experts.

The Internet can also be used to enable virtual collaboration among product planners. One example is the development of the desktop charger for the Siemens SL45 cell phone. Engineers in Aachen and Munich, Germany, worked together on 3D models with production engineers in Taiwan on the project. Participants were able to view, rotate, cross-section and modify each model on their monitors. As a result, the coordination process was speeded up substantially, and the charger was completed in two-and-a-half months. The process normally takes four.

**New Challenges.** Virtual collaboration across cultural and language boundaries, virtual plant fly-throughs, machines and products visualized in 3D, remotely maintained and modular factories—these are just some of the revolutionary changes we can expect to see. Although humans will transfer more responsibility to intelligently controlled machines, they will also assume new responsibilities. When a multinational project team is studying a virtual model, for example, participants must be capable of reaching decisions swiftly and independently. This kind of teamwork calls for new skills. In addition to their own expertise, team members also need to understand interdisciplinary processes. “There’s no way an industry can get around digitizing and virtualizing its factories,” says Nottbeck. “But we still don’t really know how much these changes will impact our lives and the way we work.”

Norbert Aschenbrenner

**Fuzzy Logic Puts Industrial Processes on Autopilot**

Getting a new factory up and running flawlessly tends to take a long time. Professor Bernd Schürmann of the Neural Computation Department at Siemens Corporate Technology and his team are therefore working on a program that can automatically optimize plants — essentially putting the planning process on autopilot. In conjunction with Siemens Industrial Solutions and Services, these fuzzy-logic experts have, for instance, implemented the SIFLOT solution at Long Paper — a paper company based in Ettringen, Germany — to optimize the degree of whiteness of recycled paper. To do so, they fed all relevant values (raw material quality and fiber content — which can vary widely — as well as values regarding chemical usage and the amount of rejected material) into a neural network. The data was then used to train the network.

Recycled paper production. A SFLOAT neural network fine-tunes all relevant parameters. The system saves more than 1 million euros per plant per year.

The customer can now select a desired brightness level, and SIFLOT computes the correct values to achieve optimum quality at minimum cost. In the past, these values could be determined only by examining finished products in a time-consuming laboratory testing process. As a result, potential cost savings are enormous — over 1 million euros annually per plant. Applying methods similar to those used in paper mills, neural networks have also been used to control rail trains and optimize the smelting of scrap steel in arc furnaces. What’s more, once the data has been obtained, it can be used over and over again to create similar models. Schürmann and his coworkers are currently developing models for other process phases, with the object of using a combination of communicating neural networks to improve the production design of an entire factory.

What’s revolutionary about this concept? The key advantage is the close digital integration of product development and production planning. The digital factory is the logical extension of CAD applications in automotive product development. Thanks to this concept, decisions regarding hardware that used to require prototypes can be made on the spot. In the digital factory, production planning seamlessly extends the digital process. Its integrated data model forms the backbone that can support a range of functional modules, such as 3D simulation and conventional process time analysis.

What distinguishes the concept of the digital factory from Computer Integrated Manufacturing (CIM), which has been talked about for a long time but apparently never actually achieved? I don’t believe CIM has been a failure. It may well be that the initial euphoria was exaggerated and the expectations it created unrealistic. But I am convinced that with the digital factory we’ve taken a great step forward in the consistent use of data — which is the goal of CIM. Many important subsets of CIM are now taken for granted. And at the very least, the debate about CIM has taught us this much: Such a profound intervention in industrial processes and practices must never be considered merely from the perspective of information technology. It’s also crucial to consider organizational, technological and human aspects. But I have no doubt that we’ll succeed in realizing the digital factory. In a few years, it will be just as productive and will be just as productive and will have. One key element of this objective has already been implemented. Vehicle data at
DaimlerChrysler is now managed by means of a Product Data Management (PDM) system. But unlike product data, it hasn’t been possible until now to completely map process data, such as the robot programs used in production planning. The PDM concept must therefore be further developed until we’ve got an integrated data model—product development and production planning to actual production and, ultimately, sales and after-sales functions.

How would that work in a real-world setting?

Let me go back to the previous example. A digital vehicle moves through a digital factory. Today, in the assembly area, it looks like this. During digital mock-up (DMU) studies, the entire vehicle is virtually assembled. The idea is to check how and in what sequence individual components can be assembled. The assembly time and the associated tools can also be determined. It’s particularly important that design engineers and production planners work closely together to ensure that they can discuss improvements. For example, is there enough room for convenient access to a given assembly location, by hand or with a tool, to tighten a bolt? Such information provides the basis for configuring automatic assembly lines, designing factory layouts and, finally, planning the entire production facility in the digital world. And all of this happens long before the first real prototype is built.

Will it be possible to convert changes in virtual reality directly into design data? As you mentioned, incompatibility and the need for data conversion have been enormously time-consuming. Rapid planning and evaluation of alternative manufacturing and design concepts is a key objective of our digital factory initiative. When a production planner proposes improvements, a development engineer may have to make changes to the design data. In the past, the engineer would have been involved in a change order and would have had to make sure that all modifications and changes that are made in the corresponding data are automatically reflected in the planning of the entire factory, with its uniform database, enables manufacturing and design engineers to accomplish many changes directly in joint meetings, and therefore in a significantly faster manner. This approach increases flexibility and reduces investment risk, as changes can be made and evaluated long before any hardware is built. Of course, this works only if external partners, particularly-suppliers, are integrated into the process.

Will the digital factory concept save money?

Yes. With integration at the IT and process levels, we’ll be exploiting substantial opportunities—not only in terms of cost, but also in terms of quality and time. Our experience to date has shown that this approach can detect problems much earlier and resolve them at a lower cost. The results include substantially higher levels of maturity and, consequently, faster production ramp-ups, as well as fewer revisions in the entire process. Fewer revision loops not only mean faster time-to-market, but also more time for us to respond to customer requirements and product innovations.

Have you quantified the resulting benefits?

We’ve created a detailed business case for the implementation of our project. The initial effects we’re achieving today are showing us that our earlier assumptions are holding up well. But the digital factory is based not only on economic decisions, but also on strategic ones. No automaker can develop new products without using CAD anymore, and it will be exactly the same with the digital factory. Because of the great diversity of vehicle models, for instance, it is often the case that several different models are processed on the same assembly line. Such complex planning can only be managed with digital support. We’ve calculated that production planning time can be reduced by up to 40 percent, and that a simultaneous improvement in planning quality can be achieved. Furthermore, shorter development and production planning times result in lower overall costs.

What’s been implemented to date?

We’ve come a long way especially in factory planning, which has already been completely converted to 3D. We now plan factories like the Kölleda plant currently under construction in central Germany entirely in 3D. This new plant will be set up using the digital factory concept, with respect to both rapid planning and costs. In addition, we’re implementing initial workflows. For instance, digital methods were used extensively during the development of the new E-Class, which was planned long before there was a Digital Factory Project. Nevertheless, implementation is far from complete. This is due in part to shortfalls in software functionality and incomplete systems integration. However, it is also due to the continuing effort to further advance and adapt our planning processes and production sequences to the capabilities inherent in the digital factory concept.

When will your digital factory program be fully implemented?

During our rollout we’re focusing particularly on four priorities:

First, to base all our planning processes on standards and production principles that will subsequently be mapped into the software modules of the digital factory. This foundation will enable us to build entire production facilities, production lines and body-in-white plants from standardized modules.

Second, all relevant data about products, processes and resources will be entered into and administered by a data management system. The system will support a high degree of networking between development and planning. In this process, data will no longer be exchanged via interfaces. Instead, it will be managed in a common database accessible to all participants. As a result, changes in production planning will result in immediate feedback to development, and vice versa.

Third, we are networking all internal and external process participants through workflows in order to ensure they can accomplish their work by digital means.

And finally, routine planning tasks will be automated to give planners more creative freedom. This is because in digital planning, a lot of data can be generated automatically from existing data.

On the whole, implementation of the digital factory program is comparable to the introduction of CAD in product development. Implementation of the latter took ten to 15 years and in fact is still continuing. We are the beneficiaries of this process. I am therefore inclined to believe that implementation of the digital factory won’t take us that long, and that we will be using its key elements by 2005. By then, no manufacturing plant will be built without having first been completely simulated through its digital counterpart.

What are the limits of current technology?

In terms of digitizing production sequences and processes?

With today’s technology, virtual simulations won’t be able to completely replace a real test— at least not in the foreseeable future. When it comes to safety-relevant or critical issues—for either products or factories—real tests will be conducted in the future as well. But simulation, if used selectively, can certainly reduce the number of real tests dramatically. And that’s exactly what we are doing very successfully today.

When do you think the digital factory will become standard operating procedure in the auto industry and in other industries? At the earliest, the digital factory will become the state of the art by the middle or end of this decade. I would venture to say that virtually all automakers are now working on its implementation. However, they vary considerably in the way they are implemen- ting it. This is to some extent a philosophical issue, but it also has to do with their willingness to invest. System suppliers—those who supply assembly lines, for instance—as well as engineering services firms, are counting on this technology. Another key area is aerospace. Here the need is obvious, because when you’re building an airplane the first prototype has got to fly or at some point you’ll have a hard time finding willing test pilots.

What comes after the digital factory?

What’s going to be the fourth revolution in the auto industry?

That’s a little far off, like looking into a crystal ball. But I believe that electronics in particular will profoundly change the auto industry. That’s what planning and production people have to take into account well in advance. Other challenges will result from new materials, new approaches to active and passive safety— pedestrian safety, for example— and dealing with small production lots. The fact is that all of the automakers have been diversifying their models. As a result, more vehicles are built, even as production runs get smaller. This type of increased modular- ization requires both greater flexibility in production plants and lower costs for conversion. But that’s exactly where a digital factory will offer significant support.

Interview conducted by Sylvia Trage
The chemical industry is under pressure to become more flexible and to bring its products to market more quickly. But with huge plants, that’s simply not possible — which is why companies are interested in microreaction technology. Siemens is participating in a research project designed to explore the industrial suitability of tiny reactors.

On Dr. Arno Steckenborn’s fingertip is a square, glittering object that resembles a computer chip. The structures on its silicon surface are hardly recognizable. “What we have here,” says Steckenborn, a physicist with Siemens Corporate Technology in Berlin, “is a pressure and temperature sensor.” The modellike-looking device is a key component of a research project that could signify a radical change in chemical and pharmaceutical production. In the past, calculations were made according to a simple rule of thumb: the bigger the better. As a consequence, even large investments in technology represented a relatively small share of total costs. But this strategy is starting to show signs of strain. If product demand weakens or dries up, the manufacturer is left with an expensive, large-scale installation that is prohibitively expensive to convert. One solution is a miniplant that is easy to realize and can be augmented as needed by any number of additional mini-plants. Here, investment costs fall, and there is no need to spend time scaling up from laboratory to industrial production.

“Miniaturization would also have other advantages for the chemical industry,” says Inga Leipprand of Siemens Axiva, a company that specializes in plant construction and process engineering. Reactions on a miniature scale can be realized in modular units — in other words, very flexibly. Moreover, they take place continuously and without time-consuming overhauls or boiler cleaning — features that represent another cost benefit compared with today’s installations.

Many chemical reactions involve significant danger. However, it is the quantity of chemicals used that ultimately determines how much heat develops or whether a process could lead to an explosion. In contrast, the heat given off by a process can easily be dissipated in a reactor whose conduits are as narrow as threads. That’s because small volumes are associated with relatively large surfaces. Furthermore, the yield is often greater, and there are fewer by-products because conditions can be adjusted far more precisely in miniature. Poisonous materials can also be processed more safely on an extremely small scale.

Large-Scale Use of Microreactors. A change appears to be in the offing for the chemical industry. According to a study carried out by the Institute for Microtechnology in Mainz (IMM), Germany, all of the industry’s top 30 companies are interested in exploiting miniaturization technologies. In fact, many experts expect to see the large-scale use of microreactors in production processes from 2005 onward. Several companies have been investigating the new technology for some time, and some have already presented initial results in the area of industrial-scale use. Since August 1998, for example, Merck KGaA has been running several microreactors for the production of a fine chemical. For the Darmstadt, Germany-based company, flexible production is especially important. Merck sells more than 1,000 different chemicals, of which more than two-thirds are manufactured in quantities of less than ten kilograms per year. Similarly, at BASF in Ludwigshafen, Germany syntheses have been studied and the results used to optimize several processes.

There is, however, a drawback. The structures of the tiny reactors, whose conduits and supply lines are measured in micrometers (a millionth of a meter), do not allow reactions with solids, which would immediately block the paths. Nevertheless, experts think many basic chemicals and numerous fine chemicals, including pharmaceuticals, can be manufactured in microreactors. Nor is output volume expected to be a problem. In principle, with one another. Another drawback is that they cannot be operated fully automatically.

If microreactors are to succeed on an industrial scale, processes must become fully automated — which is where Siemens Automation and Drives (A&D) comes in. Together with Axiva, Merck and the Fraunhofer Institute for Chemical Technology (ICT) in Pforzheim near Karlsruhe, A&D is participating in a project sponsored by Germany’s Federal Ministry of Education and Research (BMBF) designed to develop a microreaction system for industrial use. In addition to containing modular microfluidic components to supply it with starting materials and process the product, the system will also be equipped with sensors, analytical elements and process control technology. The dimensions of the components are being chosen in accordance with the dictates of process development and the goal of continuous production on a kilogram scale. The project’s partners want to investigate a specific nitration. Nitration is one of the most important transformations in chemistry because the nitro (NO$_2$) groups attached to molecules can easily be transformed into other functional groups. As nitrications usually generate a great deal of heat and often result in many by-products, they are very suitable for testing microtechnology in an industrial context.
“The special thing is the integration of a fluidic bus system for chemicals and an electrical bus system for communication,” says Axiva’s Inga Leipprand. During the BMBF project, A&D will be responsible for the system, including the control system. Arno Steckborn and his colleagues at Siemens’ Micro-mechanics & Coating center will supply sensors for it. These are essential because the exact regulation of a chemical process requires detailed knowledge of the mixture’s pressure, temperature, mass flow and density—at every stage. “The main drawback of older pressure sensors for microreaction systems is that chemical residues get left over in their openings,” explains Steckborn.

Refining Microarchitectures. A membrane in the new pressure sensor, which is made of silicon, imparts the mixture’s pressure to a conductive structure by way of a stamp. The resistance of the structure changes and provides a signal proportional to the difference in pressure. A temperature sensor is located behind the membrane. The pressure sensor itself consists of two silicon elements that are bonded together. The “direct bonding” involved here relies on a type of cementing involved — too high, and metal atoms will migrate into the silicon layer, which reduces the sensitivity of the sensor. But Steckborn and his team have now refined the technique to the point that only 25°C Celsius is needed, which allows for even more complex components.

Steckborn has also succeeded in building what is probably the world’s smallest thermal conductivity detector. Its measuring chamber is one millimeter in length and contains a 0.3-micrometer-wide gold wire that is 0.5 Celsius hotter than surrounding gases. When their composition changes, the differences in the thermal conductivity of the gases results in a change of temperature at the wire and hence a change in its resistance, which is converted into a signal. This is nothing new. What is revolutionary, though, is the extreme miniaturization of the process.

Thinking Small. Miniaturization is also the centerpiece of another one of Steckborn’s components — a flow sensor that looks like a tiny antenna. The sensor is based on the principle of the Coriolis force, which appears in the context of rotating bodies and, for example, makes clouds in the northern hemisphere drift eastward. In the sensor, chemicals flow through a ring that is designed to vibrate. The Coriolis force causes extremely small displacements in the plane of vibration, from which the mass flow rate and therefore also the density can be calculated. Sensors based on this principle have been used for years in the chemical industry, but are up to 100 times larger. Steckborn looks at the tiny antenna in his hand and says: “Many people at Axiva and Siemens are used to thinking in the dimensions of conventional plant engineering. Naturally, for them, the trend toward miniaturization means a huge adjustment.”

Norbert Aschenbrenner

Microtransformers for fuel cells. The Institute for Microtechnology in Mainz is using these devices to convert methanol into hydrogen, which could in turn be used to power fuel cells.

They are the ultimate track-and-trace technology. They can hold loads of information and be attached to almost anything. Scientists just have to figure out how to manufacture them cheaply enough. When that happens, factories—and the robots that work in them—will be able to micro-manage every phase of production.

Even though automobiles are mass-produced, it’s hard to find two that are exactly alike. Indeed, the number of options is nearly limitless — a fact of life that enormously increases the cost of production planning for automobile manufacturers. Special customer preferences must be taken into account for each vehicle — often many thousands of times per day. Yet the business of tracking all these changes is not performed by a mainframe computer. Instead, manufacturers are now using transponders — tiny electronic tags that can transmit data signals through their antennas to provide vital feedback and help control complex manufacturing processes.

At General Motors’ Opel plant in Figueruelas, Spain, for instance, a supervising software system controls production. But, thanks to a data chip in its transponder, each vehicle knows what it needs to receive as it travels down the production line. Known as Moby 1, the system consists of a mailbox-sized transponder, a read/write device and a data communications module. Before the first piece of sheet metal for a car even begins its passage through the factory, the individual production data for the car will be part of is downloaded to a transponder mounted on the vehicle skid. As a result, each vehicle remains individually identifiable throughout the production process and can, for example, communicate whether leather or fabric seats are to be installed in it. At each station, the transponder communicates its on-board data to production robots.

The Moby 1 transponder uses RFID (radio frequency identification) to transmit data to the machines around it. This offers important advantages over barcode systems, since transponders can store much more information — and the data can be read without vi...
Chips on a Roll

In a few years it will be possible to use simple printing processes to manufacture electronic components from plastic materials. But before that can happen, scientists will have to come up with materials and production methods that will make it possible to manufacture plastic chips and transponders at an exceptionally low cost.

There’s no question that transponders are much more versatile than barcodes. They can store much greater volumes of data, are rewritable and can communicate information through their antennas. But they still have one critical drawback: They cost too much. Simple transponders now cost less than one euro — but a barcode merely needs to be printed on the product. And that’s exactly what researchers intend to do with transponders and the chip inside that makes them so smart. In the future, the intricate electronics will simply be printed on a substrate and incorporated into transponders that will cost only pennies.

Scientists have already succeeded in printing tiny transistors and simple electronic circuits using organic inks. What makes this technology possible was the discovery about 20 years ago that organic molecules can be conductive. Alan J. Heeger from the U.S., Alan G. MacDiarmid of New Zealand and Hideki Shirakawa of Japan discovered that certain organic molecules such as long-chain polymers not only have conductive, but also semiconductive properties similar to silicon. This discovery earned the three researchers the 2000 Nobel Prize for Chemistry. “These polymers can be dissolved in certain liquids just like pigments,” says Dr. Wolfgang Clemens of Siemens Corporate Technology in Erlangen, Germany. “We can process them just like ink in a printing process, which opens the door to fantastic new possibilities in the manufacture of electronics.” Unlike silicon chips, which must be produced in expensive clean-room processes, the polymer ink will make it possible to print electronic circuits in a manner similar to how newspapers are made. Another advantage is that polymers are flexible. Future polymer chips will be rolled up or applied to flexible surfaces such as fabrics. A transponder woven into a sweater could, for example, inform the washing machine of the water temperature it needs to provide. And in a supermarket, plastic chips could store not only the price of each product, but also its expiration date.

With these and other exciting applications in mind, several manufacturers and research institutions are collaborating in project PODOS, an initiative supported by the German Ministry of Research, to develop the first fully functional polymer chips. In the context of the project, Siemens and chemical giant Merck are jointly developing technologies for printing polymer chips. Merck is contributing its expertise in the field of various polymers. Clemens estimates that plastic transponders are rewritable. “That’s especially useful for logistics applications such as the ParcelCall system, which may be at a distance of about 15 centimeters from the transponder in the Moby I system. In the logistics chain, on the other hand, it’s especially important that Moby markers be readable over a distance of up to three meters. This capability enables transponder-equipped freight on trucks or loading docks to be identified in a matter of seconds.

Seamless Merchandise Tracking. Transponders have become important elements in today’s logistics chains. Many companies and research institutions are working to make these devices even smarter and are also trying to find new applications for them. One such endeavor was Project ParcelCall, which was completed in December 2001. Project participants included Siemens Dematic AG, the Technical University of Aachen, Germany, Philips and Ericsson EuroLab, among others. The project was designed to demonstrate the feasibility of using transponders to track product shipments and to determine which communication standards would be required. The idea is as follows: Trucks are equipped with readers capable of communicating with transponder-equipped freight items. The transponder information is then transmitted by radio to a central truck. The central truck is also equipped with a global positioning system (GPS), the addressers or the freight forwarder can use the Internet or a cell phone any time to determine the exact location of the merchandise.

“The transponders were also equipped with sensors capable of recording vibrations, temperature and humidity,” explains Hannro Wallschläger, a ParcelCall development engineer at Siemens Dematic. “This means that, for the first time, customers could check the condition of their ordered products online during shipment.” They could, for example, verify that a product had been continuously refrigerated.

Siemens experts designed the heart of the track-and-trace system — a server where the data was collected — as well as the user interface for the PC and the cell phone. A key advantage of the ParcelCall system is the fact that all information is communicated using XML, a uniform data format standard that is widely used on the Internet. This consistency is essential to ensure seamless shipment tracking. Most freight forwarders continue to use proprietary tracking systems with somewhat limited capabilities for tracking shipping information across different modalities in the logistics chain.

The final field trial in the project — tracking a truck from Sweden to England — was completed in December 2001. Project ParcelCall was designed to demonstrate the feasibility and the possibilities of seamless merchandise tracking. Many companies and research institutions are currently setting up demonstration laboratories for roll-to-roll technology. Here’s how production would work. The substrate material — such as a plastic film — is fed into a roll through a process sequence that varies with the application. Insulators, conductors and semiconductors must be printed in the sequence required to form the desired circuit. Finally, the substrate bearing printed polymer circuits is rolled up again — allowing chips to be sold by the yard. Also conceivable is a process that would allow chips to simply be printed on product packaging. But it’s still uncertain which materials could be used in large-scale production. In addition, even conventional printing techniques still need to be refined in order to print electronics with the necessary level of resolution. What’s more, these processes must approach a zero-defect level of quality and reliability. After all, while a tiny flaw doesn’t matter in a newspaper photo, it can make all the difference in the world in a transistor.
quickly transponders can move past a reader, and how many of the tags can be read simultaneously. This latter function is known as multitag capability and is a critical success factor for future transponder systems. At a supermarket check-out counter, for instance, transponder-tagged merchandise would be able to provide an instant and contactless tally of what was in a shopping cart.

The Faster the Better. A key factor in multitag capability is the data transmission rate from the transponder to the reader. That’s because the shorter the time required to transmit each data package, the less chance there is for transmissions from other transponders to interfere with each other.

Energy demand is also a key issue. Here, the lab has developed ultra-low power electronics that enable transponders to transmit across long distances.

The extra-high frequency transponders from Bulst’s lab are battery-operated and have an enormously long range — some can actually transmit over several kilometers. What’s more, it is now possible for the first time to measure the distance between reader and transponder to an accuracy of one centimeter. This makes it possible to precisely locate a given transponder by processing run-time data from several readers, which opens the door to entirely new fields of application. “Our transponders can bring order to even the most chaotic materials flow simultaneously,” explains Bulst. He envisions applications not to be limited to small local areas.

Transponders that can communicate across long distances.

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But transponders also have one further important characteristic. Under certain conditions, they can operate for many years on a battery.

While this in mind, Wolf-Eckhart Bulst and his team of Siemens scientists in Munich are developing transponders that transmit in the gigahertz range (between 2.5 and 24 GHz). Moby devices, by comparison, operate in the kilohertz or megahertz range.

According to the laws of physics (specifically, those governing bandwidth), the higher the frequency, the higher the data rate. Thus, using higher frequencies, a large number of transponders can be read in a shorter time. But processing such high-frequency signals requires new circuit designs in transponder chips — an area now being studied by Bulst’s team.

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Because many objects can be localized simultaneously,” explains Bulst. He envisions applications for the technology in the giant parking lots of auto plants, where several thousand cars must be moved around every day. A computer could easily be used to navigate transponder-equipped vehicles because each would be identifiable. And, Bulst adds, “There’s one advantage that makes extra-high frequency technology especially interesting. These transponders can be tracked even where GPS fails, inside buildings and in the canyons between tall buildings. And it can all be done with a very modest investment in technology.” — Tim Schneider

Hello, I’m Pump 235

Today, finding a malfunctioning piece of hardware — be it in an off-shore oil platform, chemical plant, refinery or manufacturing facility — can be as complicated as navigating the mythical Labyrinth at Knossus. Typically, a problem first becomes evident with a “ping” as a light starts blinking on an impressive array of monitors in a control room. Someone is then dispatched to track down the offending hardware and identify the problem. But neither task is simple. The process can eat up a significant amount of time, and many cell phone calls later, documentation must be retrieved and an order for a new part filled out.

A new technology called Speech-Enabled Augmented Reality (SEAR) developed by Siemens Corporate Research (SCR), in Princeton, New Jersey, holds the potential for a radical improvement of this entire process. Based on a system now being tested at SCR, here’s how SEAR would work in an industrial installation: A maintenance engineer working in a remote section of a chemical processing facility receives a message on his PDA, or on a wearable or mobile computer that a pump in section X is malfunctioning. The engineer’s movements are tracked by combining inputs from infrared beacons located in each area of the facility and a three degree-of-freedom inertia tracker in his Common Pocket PC. About twice a second each beacon transmits a unique ID, which is detected by the PDA’s IR port. This causes a VRML (Virtual Reality Modeling Language) browser to produce a VRML model (a realistic-looking 3D image) of the corresponding scenery file and viewpoint on the PDA’s screen. The engineer thus sees where he is standing in regard to his surroundings and an arrow indicates where he should go next.

Since the PDA has access to the facility’s geographically referenced and digitized database — the most important and complex part of installing SEAR — the engineer’s target object is known to the system. As a result, the PDA can use written or voice commands to direct the engineer to that object. Once in the area of the object, visual markers provide more precise location information.

Each marker has a unique combination of dots, making it look like two sets of tic-tac-toe boards. Held at the same angle as the engineer’s head, a camera in the PDA orients the mobile device based on any markers in its vicinity. “This solution allows us to calculate the exact position and orientation of the...” explains SCR’s Naor Navab, Ph.D., who led the development of the location detection technology. “Even if the object in question does not have a marker, the system can still identify it because it knows the user’s location and orientation and is constantly comparing it to a 3D model of the facility.”

Once the problem object is located, “the system starts downloading the associated information into the cache memory of the engineer’s mobile computer. The information appears on his mobile automatically, including the kinds of questions he can ask,” says Navab, adding, “if, for instance, he is standing in front of a pump, it knows which pump and displays questions about pressure, con-
tents, temperature and maintenance history." Depending on the underlying database, there is no limit to the number of questions that can be asked.

3D Voices: Once a question such as "What is your current pressure?" is asked, "SEAR uses Siemens’ Very Smart Recognizer voice recognition engine to process the information. The resulting data passes through a wireless access point to a database server. The server searches its database for the appropriate information, which is transmitted to the PDA. The PDA then generates a 3D voice into the user’s headset that sounds as if it is coming from the object in question," says SCR’s Dr. Stuart Goose, who developed the patented voice control system. "The ability to ask questions verbally and to receive spoken responses is important in situations in which the user needs to have both hands available," explains Goose.

Does SEAR technology require a major overhaul of a facility’s information infrastructure? Not necessarily. Many facilities already operate on SAP software that’s based on object inventory numbers and associated databases, and some power plants have 3D models that are connected to such a database. Furthermore, many factories already run WinCC, a Siemens automation program that controls programmable logic controllers. "The thing is," says Navab, "that today this information is shown in an abstract version on monitors. But the point is that the information exists, and that in such facilities, every object is already in the database. So in order to be efficient, our system has to talk to the WinCC and SAP systems.

And once that “talking” gets started, a lot can change, particularly in terms of maintenance and repair scenarios. Not only is each and every object in a SEAR facility in the database, but each could also have its own Internet address. As a result, information regarding each part could be harvested and compared with information from identical or competing parts in similar facilities. Maintenance and repair data could be compared and expert systems developed based on the resulting data. "By the time SEAR becomes commercially available in four or five years," says Navab, "it may be possible for an engineer confronted with a difficult problem on the factory floor to interrogate the part’s maintenance history, send a multimedia e-mail to the person who most recently serviced it, ask an expert system for an opinion, and, based on the responses, click the part’s Web address and order a replacement. It can all happen on the spot with zip lost time.

The applications for such a system are virtually limitless. They range from asking your PDA to direct you to the nearest flower shop on your way to a date, to complex and as yet unexplored scenarios in which multiple users, such as firefighters or security personnel, visualize each other’s movements as they move toward a common target. "This is a generic technology," says Navab. "All we can say now is that it is very likely to make many processes much more efficient.

Arthur F. Pease

Industry: Facts...

Industry: Facts...

World Market for Automation Technology by Sector

Table: Siemens

World Market for Automation Technology by Region

Table: Siemens

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Industry: Facts...

Information technologies are transforming the world of industry. Thanks to growing Web-based interconnectedness, processes within companies are moving faster and becoming increasingly automated. Advances in these areas are revolutionizing everything from online ordering and product tracking in the logistics chain to the digitalization of all the processes in development and production. Ultimately, we’re talking about the “convergence of office and production activities,” says Edgar Schüber, a Member of the Managing Board of the Software section of the German engineering industry association (VDMA).

Today, it is possible to simulate many design steps realistically on screen using powerful computers — without having to build elaborate and costly models or expensive test rigs. “Virtual simulations are now indispensable in automotive development,” says Human Ramanezi, who heads the Virtual Reality Center at the BMW Group.

In the past, it was necessary to make several prototypes. But that has changed. Today, planners, designers and test engineers work on the same digital model, which they optimize on screen using data communication. If necessary, they can even simultaneously modify the model from locations throughout the world,” adds Ramanezi. That reduces the costs and, above all, the development time. At BMW, this was one of the technical advances that made it possible to shorten the development time for a new model from six years to 30 months.

Robots on the March. In the future, more and more robots will be used in assembly, handling and packaging. The VDMA predicts that, on average, robotics and automation will experience double-digit growth rates in

➔
...and Forecasts

the next ten years. Intelligent sensor and image-processing technologies are making the robot a universal automation tool. Robots that give off-site service personnel a status report via their own homepage have already progressed from utopian dream to reality.

Industrial image-processing, familiar from surface inspection techniques and measurement technology, will find completely new fields of application. So far, only 15 to 20 percent of potential applications have been tapped. Germany’s West LB Bank estimates that sales in Europe will rise from 678 million euros in 2000 to 2.5 billion euros in 2006. Europe, which has a 25-percent share of the world market, can therefore still catch up with the U.S. (33 percent) and Japan (30 percent).

E-business as a New Opportunity. In their search for savings, companies are turning to the Internet. For instance, a study concerning cost reductions through e-business in the auto industry, conducted by Deutsche Bank and management consultants Roland Berger & Partner found that manufacturers could save up to five percent of total costs per vehicle through e-business. Purchasing via the Internet harbors enormous opportunities when combined with new business models such as desktop buying and marketplaces.

DaimlerChrysler procured a total purchase volume of approximately 10 billion euros worth of goods in 510 online bidding processes in 2001. At DaimlerChrysler, 43 percent of the total value of the parts in a planned production series was negotiated electronically. "The economic gains resulting from e-procurement in the first year of implementation have already convinced all parts of the company," says Dr. Rüdiger Grube, Deputy Member of the Board of Management responsible for corporate development at DaimlerChrysler. "Moreover," he adds, "this form of purchasing also has great potential for the future."

Data concerning the global market volume of B2B e-commerce — electronic commerce among companies — is, however, subject to large variations because of the different definitions and recording methods in use. Estimates range from $200 billion (Morgan Stanley) to $604 billion (Forrester Research). Forrester predicts that, by 2006, $7 trillion worth of transactions will be conducted online in the U.S. alone. Furthermore, it may not tell us if and when repairs are necessary because many experts participate in the process. They all want the latest information, and that’s what makes the job so difficult.

Is a lack of standards part of the challenge?

Some standards already exist. But so far they haven’t been consistent. What’s more, older equipment must also be integrated. But more of than not, the problem is that machine documentation isn’t available or doesn’t reflect the current status. For instance, it may not tell us if and when repairs or modifications have been made. Because of this it is difficult to tell how long it will take to assemble and store the missing data. This is one of the critical factors that will determine whether or not it will be possible to implement the digital factory within the next five years.

What can be done today to collect the missing data efficiently?

It won’t take long to create great 3D images. Present-generation CAD systems can handle that. We’re working on various scanner technologies that will enable us to scan factories with a laser. That will give us the ability to produce images from a distance of 50 to 80 meters. But sooner or later the machines or systems themselves will have to supply their information. At that point plug-and-play will...
have entered the industrial world. What’s more, we’ll be able to watch the action in the factory as it happens.

Wasn’t it possible to do this in the past? Well, yes, it was. But we didn’t have enough computing power to visualize the action at real-time speeds. Today we’re using virtual reality (VR). Virtual reality lets us visualize movements and processes — and move around in the factory. But the challenge isn’t to visualize fantasy worlds, it’s to see things as they really are in operation. And to do that we need appropriate models and programs.

Aren’t VR displays costly? No. VR displays can now be created on ordinary PCs. However, we would like to represent machine controllers — in other words, their programs — in these images as well. Only in this way will it be possible to subsequently interact with processes. Now that’s really a tall order, because the graphic representation alone is very complicated. After all, we’re dealing with situations in which vast volumes of data are changing very rapidly. But the greatest challenge is to represent an entire factory this way, complete with all its robots.

When do you expect this concept of the digital factory to become reality? In all probability, the digital factory in the form I’ve just described — including the technological models — won’t come into being before 2010. But there’s no doubt that it will be used across the board by all industrial companies — especially when the issue is planning, optimizing or resolving logistics issues. However, this new type of factory will also be capable of handling conversions and upgrades.

You mentioned plug-and-play. What would that require? First and foremost, consistent standards in information systems and in the way machines and systems communicate with each other. Penetration of electronic components into our factories still has a ways to go. Machines must therefore produce more rapidly and flexibly to remain competitive. The complete digitization of factory data will make a higher degree of automation and flexibility possible. The digital factory is a scalable geometric representation of the real thing. Its contents, configuration and processes can be depicted in moving, 3D realtime images. Planning can be conducted on a virtual level.

Simulations allow processes to be visualized and optimized. Everyone, including suppliers and customers, can gain detailed insights into factoring processes well before production begins. Time-consuming adjustments due to planning errors are thus eliminated — and often prototypes as well, which can lead to enormous savings.

Siemens is working on all aspects of the implementation of the digital factory. Software tools still need to be standardized to ensure comprehensible networking.

Machines or entire facilities can be controlled, optimized or serviced via the Internet. Siemens researchers in Princeton are developing a voicecontrolled system offering online maintenance assistance.

Increasing computing power makes it possible to outfit machines, sensors and actuators with ever more complex features. Together with embedded software, such decentralized intelligence increases production flexibility. Neural networks can optimize processes even further.

Transponders are a key element in production and logistics. Inside chips that store data used for controlling manufacturing lines. In the future, simple printing techniques will be used to produce extremely inexpensive plastic transponders.

The chemical industry is moving toward a “fab-on-a-chip” with the help of microreaction technology and automated control. Siemens is developing suitable sensors for such applications.

Interview conducted by Evdokia Tsakiridou

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Protecting Brands with Biomolecules

Genes make each person unique. Brand-protection technology from biotech company November AG works in a similar manner with products. The new technology aims to put a stop to brand piracy. Labels will carry a unique marker made of synthetic DNA, and a mobile reading device from Siemens Automation and Drives will check their authenticity.

Whether it’s software, processors or auto parts — hardly any consumer item is safe from piracy. According to the International Chamber of Commerce (ICC), counterfeit products result in approximately $300 billion in losses worldwide every year, or approximately five percent of total world trade. And that doesn’t include the losses and damages caused by extremely dangerous counterfeits, such as faked drugs or car parts.

In their fight against modern-day bootleggers, companies now have a tool that confronts counterfeiters with an impossible task. Biotech firm November AG in Erlangen, Germany, is using short synthetic DNA molecules for encryption purposes. Just like the natural biological code that served as a model, the system involves trillions of possible combinations, which makes the DNA-impregnated security labels just about as close to being unforgeable as you can get. Together with Siemens Automation and Drives, November has developed a system that can quickly and inexpensively check the authenticity of products that carry the DNA labels.

What’s more, the product, which will be launched under the name “brandprotection,” is scheduled to make its market debut by the end of 2002.

Presenting a label measuring 1.5 x 2 centimeters and incorporating a felt pad, Dr. Andre Josten, head of Development at November, explains how brand protection works. “The system includes self-adhesive labels, a pen with a special detection liquid and a hand-held reading device. The label contains DNA, which is hidden like a needle in a haystack. Suppose a customer in a store wants to check whether a product with the security label is genuine. First, the salesperson would run the reading device over it. If a yellow LED lights up, it means the label has not been tampered with.” After that, the salesperson activates the label with the pen and runs the reader over it again a few seconds later. A blue LED will light up if the label is genuine. A blinking LED indicates an error. If a retry leads to the same outcome, the label is definitely a fake.

November AG’s brandprotection technology is based on the ability of a DNA molecule to act as an information carrier. The DNA of living beings includes four constituents (bases) that are arranged like pearls on a string. Two of these single-strand molecules form a double-strand molecule. A guanine (G) is always joined with a cytosine (C), and an adenine (A) is always joined with a thymine (T). A sequence of G-A-C-G-T on one strand therefore corresponds to a C-T-G-C-A on the second strand. Researchers at November produce synthetic DNA strands of 20 to 30 bases as carriers of the encrypted information. The number of combinations this makes possible is equal to four raised to the power of x, whereby x is the number of bases. Thus, 20 bases corresponds to more than a trillion possibilities. A certain quantity of these single strands is applied to part of the felt pad in the label, the remainder serves as a reference field. The ink in a testing pen contains the counterpart strand that matches the encoding strand. This matching strand is designed in such a way that a fluorescent signal is produced when the strand from the ink and that in the label combine to form a double strand.

The reading device from Siemens Corporate Technology contains a laser that excites the fluorescent dye, causing it to glow. This signal is in turn detected by the reader. Only if the structure of the signal, including the reference field, is identified as correct does the user receive confirmation that the matching DNA strands are present and that the label is therefore genuine. The system is forgery-proof. The DNA strands are too short — and their concentration too low — for their sequence to be analyzed with available genetic techniques. The ink and the label also contain a large number of additional strands that counterfeiters cannot distinguish from the marker strand, thus ensuring that the latter is concealed.

In addition, it is impossible to outsmart the reading device with a label that already contains the fluorescent dye, since the reading process occurs in two stages and there must be a change in the signal detected during the two measurements. Customers also have the opportunity to receive their own special DNA sequence that can be easily exchanged right away if there is the slightest suspicion of tampering.

“One drawback of previous techniques based on biological markers is that an analysis could only be done in a lab,” Josten explains. “Our principle, on the other hand, works on site. It’s also very fault-tolerant, fast and easy to use.” With this system, Josten says, customers can be sure they’re buying the genuine article and not a pirate copy.

This development was made possible by the combination of November’s molecular-biological know-how and Siemens’ experience in the fields of electronics and optics. The key idea of using DNA as an unforgeable code came to November researcher Dr. Hans Kosak five years ago during a summer bicycle trip on the North Sea island of Langeoog. Contact with Siemens was established via Manfred Hüttlinger from Moby, a Fürth, Germany-based Siemens group that specializes in identification systems (see article on page 19). Hüttlinger, who was convinced of the potential of the technique as early as 1999, recalls that “At first, our electronics specialists and biologists didn’t have much to say to one another, and for a long time I fought on alone. But in the end, everyone was convinced that Siemens should invest.”

Even before November’s IPO, Siemens acquired a two-percent stake in the young company through Siemens Venture Capital GmbH (see article on page 76). November’s COO Dr. Thomas Schulze, who is also responsible for business development, considers the partnership with a global corporation an ideal arrangement. “Siemens is a door-opener for us,” he says. “What’s more, we haven’t had any of the problems one might expect with such a big company.”

Schulze believes that global companies with customers who demand a high level of brand loyalty stand to gain the most from the new brandprotection technology. The price of the system is to be kept as low as possible. The reading device built by Siemens will cost around 1,500 euros. The labels will be produced in batches of a million and more, which means they will sell for only a few cents apiece. “Right now, studies are being conducted with potential customers who are testing the system under real conditions,” says Schulze. Norbert Aschenbrenner
Being There

Once fiber optic lines reach our homes, life will change in fundamental ways. High definition video communication will not only be affordable, but ubiquitous – ditto computing. The result: A range of services such as online translations, intelligent agents that extrapolate information from the Web, and communication devices that automatically network their output. Here’s a look at what it might be like.

Good-bye rain. Hello sunny weather. We’re finally firming up our plans to leave London. Twenty-seven years after I moved here from Liverpool and founded IntrAcoustics — a company that sells wirelessly networked chip-based, diagnostic acoustical systems — it’s time to turn the business over to our daughters and head for the hills. Specifically, the hills around Siena, Italy. Just a year ago my wife Sally was asking her agent — a swarthy avatar she calls Mel — to do a search for potential construction sites in central Italy, and bingo, we found a whole hilltop. It had an abandoned brick-baking facility called “il Tegolato,” which was enough of an excuse to guarantee a construction permit for a “renovated” structure. Mel found the owner — it turned out to be an office of the Catholic Church that had only recently gone online — and helped us negotiate a contract that allows me to deduct the entire price as a charitable donation. Not bad for a guy who barely passed first semester Italian in college!

Naturally, even though we had already done so virtually, we physically visited the site a couple of times. But we’ve been able to handle just about all of the administrative- and construction-related business from up here. Luigi, our architect, loves high tech almost as much as Sally and I do. A couple of...
years ago he ordered a fiber optic connection for his home — which has since become his office — only a year after we got ours here in London.

Things have really changed since Opti-World hooked us up. Not many people who have fiber bother to go into an office any more. In fact, there’s a whole new market for converting office space into “homes in the sky.” Most of our friends have wall displays in their studies or living rooms, and the combination of nearly unlimited bandwidth and 3D optics gives them a feeling of being together that would have been unthinkable even five years ago. My retired friends tell me they love it because they can get together for games with acquaintances around the world, and kids who travel to ancient Rome or Aztec sites in Mexico on virtual class trips say that school is great.

Like everything around us, the displays — wall- or pocket-sized — are networked, which brings me back to my new pastime: wall- or pocket-sized — are networked, like everything around us. Researchers at Siemens are studying voice and video prioritization, failure detection and recovery techniques, and automated network administration functions in a simulated converged voice, video and data network.

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When and how the customer has requested. Are delivered affordably and exactly where, are instantly circumvented, and where goods are too small to be seen or perceived, too fast to comprehend, bits of information — once separate trickles of words on telephone lines and static images on monitors — are merging into a single, vast expressway. It is an expressway where there is no speed limit, where the number of lanes can swell or diminish automatically with varying levels of traffic, where each of countless trillions of weightless delivery vehicles has a unique license plate, where accidents are instantly circumvented, and where goods are delivered affordably and exactly where, when and how the customer has requested. Welcome to the Next Generation Network (NGN), the 21st century’s defining infrastructure project.

The NGN will change everything. In 15 years or less you will be working in a home, office, facility or vehicle in which virtually every object has its own Internet address. Everything from the LEDs that light your desk →

The NGN will change everything. In 15 years or less you will be working in a home, office, facility or vehicle in which virtually every object has its own Internet address. Everything from the LEDs that light your desk →
to the penny-sized piezoelectric mini-motors that slide your car’s windows will be accessible over the Internet. Manufacturers will be able to track their products, automate the compilation of maintenance information, harvest diagnostic nuggets, and provide their customers with software upgrades—all over the Internet.

In as little as three years, a PDA, voice ID or other biometric system will usher you into your personal Internet portal from any PC, TV or PDA. Depending on hardware and the services you have signed up for, you will be able to conduct a virtual teleconference—one in which an object, document or patient is the focus of the image—join an online game, participate in a video distance learning seminar, or simply download the movie, sports event, book, song or lecture of your choice in seconds.

Getting from Here to There. Most of the pieces of the NGN are either in development or are already being field-tested. Foremost among them is Siemens’ SURPASS architecture—a software tour-de-force designed to allow traditional digital voice communications to be metamorphosed into the “packets” characteristic of the IP (Internet Protocol) based data network. The result: Voice will be transmitted in the same way as data—a technology Internet insiders call voice over IP. “SURPASS has been developed to bring the phone and data networks together,” says Dr. Stefan Hink, who heads up product line management for SURPASS. “But before carriers will buy into it, they must be convinced that this convergence can provide 100 percent voice availability at the quality level their customers expect. Naturally, many aspects of SURPASS technology are still being refined. However, a number of customers are already using it commercially.”

The objective of achieving dedicated circuit quality in a packet world is no mean task. “The idea,” explains Hink “is to cut voice and video into packets, label each packet with a destination address and priority rating, use the packet switching network to transport them, reassemble them at the receiving end, and change them back into analog form for the user.” The problem is that today’s data network wasn’t designed to do that—at least not in real time. True to its original purpose—surviving a nuclear confrontation—the Web is extremely resilient. If a router goes down, other routers simply move traffic around it—but with one significant drawback: delay.

Figuring out how the NGN can offer real-time, high-quality voice and, by the same token, high-definition moving image transmission, is the objective of Project KING, the German acronym for Next Generation Internet Components. The three-year project, which is being funded by Siemens (50%) and Germany’s Ministry for Research and Education (also 50%), is concentrating on voice and video prioritization techniques, failure detection and reaction, and network admission control mechanisms.

When it comes to quality of service, prioritization is a top objective in the IP world. Today, when you pick up a phone, the signals terminate in a line card in a phone company “central office.” The line card provides a dial tone and sets up a circuit to the number you dial. Since the connection is dedicated—the equivalent of having your very own lane on a highway—quality, almost by definition, must be excellent.

Things are more complicated in an IP environment, where voice, video and data streams can share the same path. But if the line card is part of a SURPASS system, it can convert your analog voice signal into packets and label each packet as high priority. The stream then heads for a router, which recognizes the labels and zips them through the network in what specialists call a “virtual trunk”—a kind of express lane—ahead of competing data packets. “Nevertheless,” cautions Hink, “there are different approaches to the question of labeling, but none are completely mature. I think the entire industry is at a crossroads with regard to its understanding of how all of the new network components are going to work together.”

If a failure occurs anywhere along the path of a voice or video packet, it must be circumvented without causing any noticeable delay. “You can’t press a refresh button on your phone if a few of your partner’s words don’t arrive,” says Prof. Cornelis Hoogendoorn, who is in charge of Project KING. “If you’re playing a game before the miles reach your host, it will seem as if the game has stopped.”

With a view to meeting the needs of this exciting new market, Siemens has developed a technology that will, for the first time, allow subscribers to receive all their television programming over a phone line. Known as a DSL access multiplexer (DSLAM), the system offers the potential of sharply reducing the load on metropolitan area backbones. Here’s how: A subscriber equipped with a set-top box, a very high bit rate DSL (VDSL) modem (up to 32 Mbps), and a splitter pushes a button on her remote control for channel 75. Transmitted to a central office, the signal is multiplexed with those from, say, 1,000 other homes. The multiplexer compares the signals and finds that 97 homes have clicked the same channel. Rather than demanding 97 video streams from the data center where the carrier’s servers are located, it requests

TCP/IP: The Transmission Control Protocol (TCP) and the Internet Protocol (IP) are the two communications protocols on which data transmission within the Internet is based. TCP splits information up into small packets (up to 1,500 characters) and provides a header — a kind of label — at the beginning of each packet. The header contains information on the arrangement of the packets and a checksum, which can be used to determine if a packet has been corrupted or altered in the course of its journey. IP simply adds an address label containing the IP addresses of the sender and recipient to each packet.

IP Address: An IP address consists of four numbers separated from one another by periods, e.g. 204.171.64.2. Every computer connected to the Internet has such an address so that it can be unambiguously identified and packets can be sent to it. Users who log on via an Internet provider are assigned a temporary IP address for as long as they are online. Because these number sequences are so difficult to remember, domain names such as siemens.com, or worldbank.org are often assigned. The second part of an e-mail address (behind the @) is a domain name, which can be used to forward the e-mail to its destination network.

Router: Routers are the switching centers between the subnetworks of the Internet. They work like a railroad switch or an automatic letter-sorting system, reading the IP headers on the packets received and recognizing the packet’s destination network or router on the basis of a preprogrammed routing table. Modern routers can communicate with one another and constantly update their routing tables automatically.

IPv6: A new generation of the Internet Protocol. Compared to IPv4 — today’s most common standard — IPv6 offers specific advantages, including better support for real-time video and audio. The length of the IP address has also been increased—from 32 bits to 128 bits—meaning it will be possible to assign static Internet addresses to virtually unlimited number of devices.

Simulating a fiber optic connection between the U.S. East and West Coasts. Today’s fiber can already carry 160 wavelengths, each wavelength carrying 40 Gbs.
Meet the Organizations that Write the Internet's Standards

One of the most remarkable properties of the Internet is the absence of almost any form of control or limitation. However, even the Internet requires a number of organizations concerned with defining standards for the network. In keeping with its nature, these take the form of non-profit, private organizations rather than governmental authorities. The most important of these institutions is the Internet Corporation for Assigned Names and Numbers (ICANN). Representing a broad coalition of academics, technicians, Internet companies, and user groups, it is recognized by almost all governments. ICANN has taken on the task of ensuring the stability of the Internet. It issues all top-level domains worldwide (such as .org or .com), IP addresses and communications protocol parameters. The Internet Engineering Task Force (IETF) works closely with ICANN on the development of new communications protocols, while the Internet Architecture Board (IAB) concerns itself with the architecture of the Internet. The Internet Society (ISOC) has no direct powers of its own, but does represent an influential forum in which issues of decisive importance for the future of the Internet — topics such as taxation, copyright or censorship — are discussed.

Anatomy of an Information Exchange — in 2002 and 2015

Today (top) we have two digital networks: one for voice (telephony) and one for data (Internet), plus cable for television. Only the core benefits from optical fibers. Over the next few years, these networks will merge into what experts call the Next Generation Network (NGN). By 2015 (below), not only will this process of convergence be complete, but most urban networks (metro, local access exchanges, and many private homes) will also be able to benefit from optical connections, which offer virtually unlimited bandwidth. Unlike today’s telephony network, the NGN will be an intelligent, self-managing and self-healing system. Furthermore, it will be an all-optical system extending into most objects around us and permitting us to exchange information, services and applications in a personalized manner among information devices.
Getting More out of Fiber. Meanwhile, re-
searchers at Siemens’ Hoffmann Street cam-
pus in Munich are looking at every possible
way of coaxing more information through
existing fibers. Today, depending on the
number of lasers used — each of which pro-
duces a distinct frequency — there can be up
to 160 frequencies (also known as channels)
in a single fiber. Each frequency now carries
between 2.5 and 10 Gb/s. “But,” says Lankl,
40 Gb/s per wavelength is now technically
feasible. In fact, we recently demonstrated
this and set the world record of transmitting
7 terabits per second over a single fiber by
using 176 channels, each of which carried 40
Gb/s. Furthermore, we are exploring systems
that can operate at 160 to 320 Gb/s per
carrier.”

Never satisfied, Lankl and his team of re-
searchers are focusing on even more power-
ful systems. On the horizon is a technology
called Quadrature Phase Shift Keying (QPSK),
which is well known in broadca
ting, but has never been applied in an optical
environment. “It’s a subject of considerable interest
here in Munich,” says Lankl, who explains that,
by using gallium arsenide and lithium
niobate components to modulate the inten-
sity of laser light, the light can be horizontally
or vertically polarized in a fiber’s electrical
field. “If we could do this in addition to what we
can already do with optical frequency
modulators, we could quadruple the number of
bits transmitted per second. Concretely, that
means that by using 10 Gb/s equipment, we
could transmit 40 Gb/s instead of 10.”

Already, fiber is the norm throughout the
backbone and is growing throughout the
metro nets. The next step is the home. “The
last mile,” says Lankl, “is all that’s standing
between us and unlimited bandwidth. Once
that’s installed, it will withstand decades of
capacity increases.” Interestingly, the road
from the 20th century’s old circuit-switched
telephone system to the Next Generation
Network with its as-yet-unimaginable spec-
trum of services leads right into our living
rooms. Arthur F. Reese

Researchers have taken a step toward an all op-
tical net with the develop-
ment of a printed cir-
cuit board (cross-
section) that combines
electrical and optical
interconnections.

In the future, the Internet will cease to be a jumble of
unstructured knowledge.
Instead, it will provide
information tailored to each
user’s requirements.

The above conversation is, of course, ficti-
tious — but it’s not science fiction. Re-
searches around the world are working all
out on portals that understand and output
speech in a flexible manner, automatically
identify users and provide additional infor-
mation without being asked.

One such researcher is Dr. Hans-Ulrich
Block. Together with Dr. Dietrich Klakow
from the Philips Research Laboratory, Block, a lin-
guist from the Interactive Technologies de-
partment at Siemens Corporate Technology
(CT) in Munich, Germany, has developed a
concept that is expected to lead to a “super-
charged dialog system” within four years. It
already has a name: SInDia.

SInDia should solve the troublesome out-
of-domain problem of today’s dialog systems.
Such systems may know all the flights to
Athens, for example; but they stop working
when the caller leaves the “flight informa-
tion” domain and tries to book a hotel or ask
about striking taxi drivers. The goal of the
SInDia concept is to include a small talk man-
ager that actively slips interesting informa-
tion into the dialog in a conversational tone
— the weather forecast or tips on special
events in Athens, for example. At the begin-
ning, the applications will probably be limited
to predefined semantic relationships like
cities/weather or automobile/car rental fees.
“It doesn’t always have to be deadly serious,”
says Block. “It can be fun too.”

In terms of technical requirements, a sys-
tem of this kind is highly demanding. It must
be able to scan texts, tables and interactive
services like train schedules and price data-
bases on the Web at incredible speeds and
evaluate them on the basis of their meaning.
“So far, it has been very costly to develop
something as simple as a train-schedule ser-
vice manually,” says Klakow. “If we automate
that, we can help dialog systems get off the
ground and offer far more service.” This re-
quires that the computer “knows” what a cer-
tain piece of information means and in what
context it occurs, so that it can fit it into the
dialog appropriately later on.

In this connection, experts refer to a “se-
matic Web” — semantics being the theory
of the meaning of words and sentences. The

“Good morning, Ms. Brown — where will
you be traveling this time?” “To Athens, on
Tuesday,” answers Cynthia. “Okay,” says
the friendly voice on the handset, “I will
find a flight for you right away, but please
schedule more time, because the bus and
taxi drivers in Athens are on strike at the
moment.” Cynthia is grateful for the tip —
and surprised. She never would have
thought the automatic reservation system
could be so knowledgeable.

In the future, the Internet will have to be a semantic Web,
whose pages are characterized
according to meaning.
Today, searching for information on the Internet involves plowing through around a billion Web pages characterized by unstructured content (left). But in tomorrow’s Web, all pages will be tagged with elements that indicate their relevance. Software agents will automatically read and understand such tags, which are essential to the customer at any given moment.

During her flight to Athens, Cynthia Brown has to change planes in Frankfurt. She takes a walk through the shopping area at the airport. The PDA knows where she is and therefore displays information or special offers from the shops. Suddenly, Cynthia hears the last call for her flight to Athens. She looks down at her PDA, which now only displays arrows that point the way to her gate.

In the future, emotions and stress as well as information about shopping behavior, musical tastes or airplane seating preferences will be analyzed while a person surfs the Internet, and the ISP or even the user’s PDA. If the customer comes to an Internet portal or a voice response system, the content and/or the dialog will immediately be personalized. “After 20 years of research, we have now developed computer-based techniques for automatically defining personal user profiles,” says Wahlster.

Just as important for the mobile Internet of the future is the development of a new network structure. Despite faster transmission technologies, such as UMTS and wireless LAN, spectrum space is in short supply. One method that could be used to organize the Internet more efficiently is multicast. Thus far, data requested by a thousand users simultaneously has been sent out from the server a thousand times and distributed in a star-shaped pattern. Multicast, on the other hand, is more like a tree structure in which the data is sent only once and then duplicated en route at the appropriate nodes before being passed on to users.

Peer-to-peer techniques are another possibility. These have become well known mainly through the Napster music exchange platform. In this case, the data no longer comes from a server, but is exchanged directly among users.

“Peer-to-peer is becoming more and more important, because people don’t just want to consume; they also want to share text, music, images and their knowledge with others,” says Michael Finkenzeller of Siemens Corporate Technology (CT) in Munich. In the German research network, peer-to-peer applications already account for 60 percent of total data traffic.

Jochen Gimmlinger, who also works at CT, thinks children might set up “ad-hoc networks” in schoolyards and exchange melodies or logos directly from cell phone to cell phone without an expensive detour through the mobile phone network. This would take some of the load off networks. Furthermore, if reception were poor, data might be passed to other cell phones that offer better connections to the network. Gimmlinger has considered billing models for ensuring that no one is taken advantage of in “multihop” scenarios of this kind. Use of multihop could involve a fee. For instance, network operators could cover their costs by collecting fees for exchanging melodies in ad-hoc networks. On the other hand, those who open up their cell phones for others would collect bonus minutes of telephone time in return.

In the mean time, Cynthia Brown has arrived in Athens. She uses the digicam in her PDA to take a picture of the temple that towers over the city. Shortly thereafter, “Acropolis” appears on the display. The photo is superimposed on a picture that portrays the building as it may have looked 2,000 years ago. Arrows direct her to the top of the hill.

This is very much in the future for the Acropolis, but it is already partly a reality at C-Lab in Paderborn, Germany, where Siemens and university scientists are conducting joint research. The basic idea is a world encyclopedia in which images serve as the input for a search engine. In Paderborn, however, this futuristic PDA scenario is now being investigated by a home appliance manufacturer to present its high-quality products in sales showrooms. And indeed, the Paderborn researchers have come up with an appetizing solution. If the PDA with its digicam is pointed at a closed oven, the camera records a video of the oven and sends it to a computer in real time via a wireless radio network. The computer analyzes the video and uses the principle of augmented reality (see article on page 23) to generate additional image data that is superimposed on the right perspective. For example, on the display, the oven door then opens up, although it is still closed in the sales room. After a few moments, a virtual roasted chicken slowly emerges from the oven. The illusion is so perfect the customer’s mouth waters.

Bernd Müller
A few years ago, in an interview, Mark Weiser, the intellectual father of “ubiquitous” or “pervasive computing” — the omnipresent computer — said: “Why shouldn’t we obtain digital information from our environment, instead of us adjusting automatically? Today they are not. Today’s information highways lack intelligence. In the future, it is expected that the variety of terminals that are designed only for certain applications and have thus far been able to interact with one another to only a very limited degree. These range from sensors to cell phones, organizers and multimedia computers. It’s a matter of using the existing heterogeneous network technologies seamlessly,” says Joachim Sokol of Siemens Corporate Technology (CT) in Munich, Germany. He believes that “ubiquitous networking will become ubiquitous and invisible.”

The Internet as we know it is only the beginning. On the horizon is an all-inclusive network of communicating objects. Computing and communications will then become ubiquitous, indivisible and invisible.

Inside the All-Inclusive Network

The Internet we know is not the one we experience today. The Internet is also well on its way to becoming an all-inclusive communications medium. According to the TCP, IP, HTTP and HTML Internet standards, users are able to communicate with one another wherever they are.

But when it comes to a universal network, availability alone is not enough. Equally important is support for the various data streams across the boundaries of individual technologies and providers. Traffic congestion in individual network nodes and errors caused by wireless technology can lead to the loss of data or delays in service. For some applications — such as loading music files — this might be acceptable, for others, such as video telephony, it is not.

An example from telemedicine makes the problem clear. In the future, it is expected that a range of sensors in a “body area network” will record parameters such as blood pressure, respiration and heart rate. As researchers picture it, the data would first be stored in a hospital, retirement home or private home via radio, then processed and transmitted to a control station, doctor or provider through the fixed-line network or via satellite. But all of this presupposes reliable, real-time data transfers.

Too Many Terminals. An additional challenge is the variety of terminals that are designed only for certain applications and have thus far been able to interact with one another to only a very limited degree. These range from sensors to cell phones, organizers and multimedia computers. It’s a matter of using the existing heterogeneous network technologies seamlessly,” says Joachim Sokol of Siemens Corporate Technology (CT) in Munich, Germany. He believes that “ubiquitous networking will become ubiquitous and invisible.”

The Internet as we know it is only the beginning. On the horizon is an all-inclusive network of communicating objects. Computing and communications will then become ubiquitous, indivisible and invisible.

In tomorrow’s home, objects will communicate with one another. The refrigerator will “talk” with the notebook, the chair with the stereo, the sweater with the cleaning robot, and so on.

In the future, many small developments will lead us there.

Small but Smart. Microsystems technology can be used to integrate a high level of computing power, as well as sensors and actuators, into even the smallest objects. Full-fledged computers that fit on chips measuring only a few square millimeters and include a few kilobytes of memory — enough for a simple operating system — can now be manufactured at a very low cost. This technology is used for chip cards as well as for embedded systems; i.e. processors installed in all types of devices for control function applications. Such systems can be found in driver-assistance systems, digital telephone exchanges and industrial equipment. But in the future, they might also turn up in jewelry, household articles or clothing.

An example of ubiquitous computing is the intelligent toaster developed by Siemens researchers at Roke Manor Research in the UK. Equipped with a Web server with only a few kilobytes, it can be switched on and off via the Internet by means of a simple browser. Although some critics have dismissed the toaster as a pointless exercise, “it actually stands for something else,” explains Joachim Sokol of Siemens Corporate Technology (CT) in Munich, Germany. Jochen Sauter of Siemens Corporate Technology (CT) has visited several people to a presentation. The researcher from the Software and Systems Technology Department holds a PDA in his hand, welcomes guests and taps briefly on the display. Immediately, the blinds are lowered, the lights dimmed, and the display wall lights up. Sauter begins his talk, while his audience looks around in surprise. The furnishings of the room are perfectly conventional. However, participants appear to be on the receiving end of an object lesson in ubiquitous intelligence. Who turned the lights off and the air conditioning system on? Where is Sauter’s notebook? Where is his PowerPoint presentation stored? And where’s the projector?

A little later Sauter reveals his secret. “You are in our smart conference room,” he announces. With his PDA, which has an integrated radio module, he can control the presence server in the next room. He had saved his electronic documents on that server beforehand, along with a list containing participants’ e-mail addresses and other communications related data. By pressing a button, Sauter can therefore easily transfer all of the documents to the participants’ computers wirelessly. In addition, a presentation scenario (lights out, blinds down, display wall out and a discussion scenario (lights on) are stored on the server. The room itself is wired with an Instabus system. This data line for building services makes it possible to turn on the heat, operate the blinds, regulate the air conditioner, or create the appropriate lighting mood from a PDA. His conclusion: “Furnishing a room in this manner is already possible with today’s technology. In fact, it’s affordable even for a medium-sized company.”
Sokol. “Our colleagues at Reke Manor have demonstrated that you can make any everyday object Internet-compatible, no matter how small it is. All you need is an IP address.” This means that, for instance, a hot plate left on at home could be turned off from the office. But not every appliance needs to be supplied with an Internet address. It would be sufficient to have one for each house, apartment or housing cluster. Access to individual equipment could be managed through a gateway.

Common Language. All of this isn’t quite as easy as it sounds, however. “New standards are needed to define how devices communicate with one another,” points out Holger Küfner, an embedded systems expert with Siemens CT. Küfner is referring not only to household appliances, but also to the larger field of industry, where Siemens researchers have to slog through a maze of processors, memory chips, bus types and operating systems, many of which have their own software solutions. Furthermore, these components are subject to performance increases and expanded functions, all of which adds up to increased complexity. “The problem with all of this is that we don’t have a common embedded-systems language,” notes Küfner.

But that’s not all. Security questions will loom larger than ever as embedded components become part and parcel of our lives. After all, interlinked sensors and processors make it possible to record more and more information from the personal environment.

Ubiquitous computing would, in principle, make it possible to create detailed pictures of each person’s interests, affinities and weaknesses. Today, “IT monitoring” can provide only snapshots of what we do, where we go and what we buy. But in a world of ubiquitous computing, the picture could be far more complete. The distinction between online and offline would fade to insignificance. Could people opt out of the ubiquitous network? How can abuse be prevented? How can effective identification and authentication be achieved without compromising privacy? According to Sokol, providers, manufacturers and service companies will have to work together to overcome these challenges together over the next few years.

Evstafia Tsakiridou

No joke: This toaster has a built-in Web server.

Online at anytime. In the future, portable and wearable communication devices, computers and displays will ensure convenient mobile connections to our homes, offices and vehicles.

Ubiquitous Computing

The concept of “smart homes” has probably been taken farthest by Elite Care Oakfield Estates, a luxurious retirement facility in Milwaukie, Oregon. Here, the vision of the ubiquitous computer has become reality. According to Elite Care, the company “provides help for older people and an early warning system that can prevent accidents.” Each of 120 apartments is outfitted with memory chips and sensors. If a resident reaches for water, the action is registered by sensors on the glass. The time and the quantity of water taken are transmitted to a central office.

According to Robert Küfner, an embedded systems expert with Fraunhofer-Verbund Mikroelektronik, “provides help for older people and an early warning system that can prevent accidents.” Each of 120 apartments is outfitted with memory chips and sensors. If a resident reaches for water, the action is registered by sensors on the glass. The time and the quantity of water taken are transmitted to a central office.

Facts and Forecasts

Corporations may like to think they are part of a value chain, but in reality they are linked in a value web where collaboration with other companies—even competitors—is crucial to success. As a result, the corporate model of the 20th century—essentially hierarchical and isolated—is disintegrating. The 21st century enterprise is one embedded in a complex system of networks.

Value is no longer driven by how scarce a product, service or idea is, but rather by how many people can access it, observes Ice Forehand, CEO of Accenture, a leading global management consulting and technology services organization. The Internet is propelling enterprises toward a new open environment where success is achieved through alliances with partners, direct contact with customers and collaboration with competitors.

“Wealth and the growing importance of intangible assets are pushing companies toward new levels of collaboration, joint ventures, alliances, outsourcing and consolidation,” Forehand notes. “There is a new recognition that businesses are embedded in a complex system of networks. Many of these networks are underpinned by radical developments in information and communication technologies, though the implications of these changes for the corpor-
### Wireless vs Wired Connections

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Source: Ovum, London

### Potential for Ubiquitous Networking

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Source: Forrester Research, Inc.

### Envisioning Tomorrow's Teranet

**Dr. Raj Reddy** (65) is the Herbert A. Simon University Professor of Computer Science and Robotics in the School of Computer Science at Carnegie Mellon University, Pittsburgh, Pennsylvania. He served as the founding Director of the Robotics Institute from 1979 to 1991 and the Dean of the School of Computer Science from 1991 to 1999. He is a member of the National Academy of Engineering and the American Academy of Arts and Sciences, was President of the American Association for Artificial Intelligence from 1987 to 1989, and served as Co-Chair of the President's Information Technology Advisory Committee from 1999 to 2001.

**Interview**

What's your vision of the Next Generation Internet?

My vision is of an Internet you can bet your life on. It will be everything the current Internet is not — quick, reliable, inexpensive, robust and scalable. I believe these goals can be met. But probably the best solution is to start over. When the U.S. government decided to build the Interstate Highway System, it left the old roads in place, while adding an entirely new set of highways.

In your opinion, will the Next Generation Internet be ubiquitous?

Yes. That is, every person on the planet will have access to a computer. In addition, every device on the planet will be able to interact communicate. It is entirely possible that within ten years information and computing power will be as ubiquitous and inexpensive as electricity is today.

How do you manage such a system and keep it from failing?

The Next Generation Internet must be able to monitor, diagnose and repair itself. IBM, for instance, recently introduced an application called "Autoimmune Systems" that is geared to developing Internet software that can regulate itself in the same way our nervous systems regulate heart beat and hormones.

What benefits do you foresee?

There will be so much bandwidth that we will be able to replace broadcasting with unicasting. Anyone will be able to have an entire information product they want at any time. But that changes the old business model for music, books, movies, software and every other information product. The current markets will disappear for all the information products that can be converted to bits. That is a threat to many powerful lobbies.

**What would a new Internet cost?**

The price tag is surprisingly low. When you build an interstate road system, every mile costs around $30 million. But a mile of fiber-optic line costs less than $500,000, and as little as $50,000 if you can feed it into an existing conduit. Furthermore, that kind of high-bandwidth connection could eliminate half of the traffic on our physical roads. But the problem is not creating the global wide area backbone infrastructure, it’s the economics of getting that high bandwidth connection into every home and office — the so-called last mile problem.

Is any organization equipped to do that?

The existing incumbents have no desire to spend any more money because they are all in financial trouble. That leaves the government. The U.S. government should build the Next Generation Internet as it did the Interstate Highways; but in this case — because no one wants to have the government manage the Internet — it should hand over the results of its work to the private sector and then collect a fee, say, ten percent of the revenues on the resulting value-added services.

What benefits do you foresee?

There will be so much bandwidth that we will be able to replace broadcasting with unicasting. Anyone will be able to have an entire information product they want at any time. But that changes the old business model for music, books, movies, software and every other information product. The current markets will disappear for all the information products that can be converted to bits. That is a threat to many powerful lobbies.
Is this a Catch-22? Not really, because we’ll get there anyway. It’s a revolution that cannot be stopped. But it can be slowed. That is, if we don’t do anything, it will still happen over the next 25 to 30 years. But if we work proactively, we might have it in ten years.

You were the Co-Chair of the President’s Information Technology Advisory Committee from 1999 to 2001. Does Washington have a vision of tomorrow’s Internet? I believe there is a vision. But the problem is that no one has been authorized to put the question of the next generation, secure, self-healing Internet on the front burner.

Specifically, what needs to be done to fulfill the promise of the Next Generation Internet? We have to light up the fiber that’s already in the ground. Take Qwest. They’ve installed about 20,000 route miles of fiber in the U.S., each mile of which has about 100 fibers. But they’ve only lit up one fiber per mile. Why? Because the cost of lighting up one fiber—depending on the size of the network it serves—may be anywhere from $250 million to $500 million.

Is part of the solution to this what Siemens is doing—in other words to increase the bandwidth of a single fiber? Absolutely. We already have commercial systems that can carry 3.2 terabits per second on a single fiber. That’s 3,200 gigabits per second. And systems have been tested in labs that can carry 10 or 20 terabits per second. That’s an opportunity and a problem because, at that level, a single fiber can carry all the world’s phone calls. So now you have this huge investment in installed fiber but no use for it—until you create applications that economically put it to use.

What applications do you foresee? In six months we will have a fiber to our campus here in Pittsburgh and the future that you and I have been discussing will be here. We want to build the killer apps—video conferencing, video phones, video e-mail, video on demand. You name it. All of that can be done yesterday.

How do you get the ball rolling? The most important thing the phone and equipment companies can do is to turn all their lobbying efforts toward convincing governments to invest in this technology. And then, just as with the highway system, other industries will be created. They will be tomorrow’s equivalent of the motel and gas station chains of the last century.

And the price tag? About $100 billion for the U.S. And I estimate that as little as $10 billion would give us 90 percent of the impact. That would jump-start the entire communications industry and put entirely new business areas on the map.

Interview conducted by Arthur F. Pease

The Digital Divides

It is the age-old story of the haves and the have-nots. Those fortunate enough to be on the have side of the tracks seemingly have it all: food, shelter, clothing, and many of life’s amenities, such as automobiles, televisions, telephones, and, most recently, computers and Internet access. But for the have-nots, the recent advent of information technology (IT) just adds to the list of things they do not have. The chasm between the digital haves and have-nots has come to be known as the digital divide. First coined in the mid-1990s, the term originally described the gap between men in the U.S., who were the predominant users of the Internet, and their spouses, many of whom felt like Internet widows thanks to the amount of time their husbands spent online.

Since then, the online gender gap has been closed in the U.S., but the situation is quite different in other parts of the world. Urban planner Lisa Servon, author of a recent book on the digital divide, notes that women account for just 25 percent of Internet users in Brazil, 17 percent in Japan and South Africa, and 16 percent in Russia. Yet the gender divide is only one part of a complex picture, which is why Servon says, “I like to talk about digital divides, plural, because they are multiple.”

On a global basis there is the digital divide between developed and developing nations. Ninety percent of Internet host computers reside in the highest income nations. These same nations are home to only sixteen percent of the world’s population, notes Servon, whose book, Bridging the Digital Divide: Technology, Community and Public Policy, was released in August 2002.

Representing one end of the spectrum in the global community are the Scandinavian countries, particularly Finland. But in poorer countries the picture is not so bright. “The average Internet user in South Africa has an income seven times the national average,” notes Servon, while the average Bangladeshi would have to spend more than eight years’ income to buy a computer, compared with just one month’s salary for the average American. In addition to the divide between nations, digital divides exist between the educated and uneducated, the wealthy and poor, the old and the young, between Blacks and Latinos, and Caucasians; and between people in rural areas and inner cities, and those in urban and suburban areas. Of all of the divides, the greatest is between Blacks and Latinos, and Caucasians and Asians. Though that gap is closing, “There are still about 18 percentage points between Whites and either Blacks or Latinos in the U.S.,” says Servon, who is Associate Professor at the Milano Graduate School of Management and Urban Policy at New School University, Manhattan.

Efforts to address the digital divide in the U.S. began in 1995, when the first of a series of U.S. Department of Commerce reports called “Falling Through the Net,” pointed out the disparity between the digitally active and those who had no access to IT. The immediate result was the creation of a federal pro-

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Pardon 50

Pardon 51
gram that successfully subsidized the con-
nection of most of the nation’s schools and
libraries to the Internet. It opened an array of
follow-up programs intended to provide
support for other organizations, such as com-
umunity technology centers to help address
the digital divide. Similar organizations
sprouted up in other countries.

Access Isn’t Enough. The success of these
programs is evidenced by the fact that “we
have seen a huge increase in the num-
ber of people who have Internet access,”
notes Servon. Yet despite these successes,
the digital divide continues to grow on a
worldwide basis. Compounding the problem
is the fact that gaining access to the Internet
is just the first step in closing the gap. Ob-
taining appropriate training, and being able
to locate relevant information are equally im-
portant. Yet “policy makers have not really
recognized that a problem exists beyond ac-
cess,” says Servon. Hence, it is in these areas
that she sees the greatest challenges for the
future.

Understanding this point is studies of how
school children use the Web. “We’re find-
ing that kids in low-income districts do
more things like rote math and spelling drills,
which don’t use technology’s potential all
that much, while kids in wealthier districts
are doing much more creative thinking and
problem solving and communicating with
kids in other countries,” says Servon.

Regarding content, Servon points out
“English is used in almost 80 percent of Web
sites, yet less than one in ten people in
the world speaks the language. When I think
about the ramifications for the future, I think
about people who are part of the persistent
poor not being able to get out,” says Servon.

One way technology can help is by im-
porting power. Access and training enables
people to create their own content, and with
content they can organize. Internet access
also enables participation in e-commerce,
both as customers and entrepreneurs. Ser-
von, who works with low-income, small busi-
ness owners, tells of “many who are in re-
mote rural areas or inner cities, yet can
market their goods over the Internet.”

Established businesses can help bring
their upcoming counterparts into the fold by
forming and permitting programs that nar-
row the digital divide. “The business
community really needs to embrace this as an
issue in terms of contributing to efforts,
whether it be in school systems or through
their own training programs,” says Servon.
For instance, working with a number of
African countries, Siemens Belgium has devel-
opped “Euclides,” a project to train technicians
and engineers via the Internet.

With the help of government and indus-
try, recent innovations may well allow poorer
nations to leapfrog into 21st century tech-
ology. “Because of wireless technology it is
not necessary for these countries to go
through the progression of first getting wired
telephone service, and then moving on to
digital and wireless technology,” says Servon.
Instead, they may go straight to wireless in-
ternet connections.

Servon sees the Internet as having great
potential for increasing prosperity, for those
in less-developed countries, by giving them
access to the global marketplace. “In order
to benefit from globalization, however, people
need to be able to control the tools that en-
abled global markets to develop in the first
place,” she says. When it comes to world
peace, the future is less clear. “It certainly cre-
ates a lot more opportunity for communi-
cation, which is one of the prerequisites for un-
derstanding and, therefore, peace. But,” says
Servon, “we’ve also seen lots of destruc-
tive uses of technology and communication that
hinder peace efforts.” Which way the Internet
will take us remains to be seen, but if only
part of the world moves in that direction, we
will never get there. Victor Chase

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<tr>
<th>Household with Computers</th>
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<td>Individuals with Internet (Values for USA, Nov. 2001)</td>
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<td>General Population</td>
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<td>Male</td>
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<td>Under $15,000</td>
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<th>Cost Comparison Internet connections as a percentage of monthly income</th>
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Within 15 years, a “Next Generation Network” (NGN) will deliver a spectrum of services based on high-bandwidth (overwhelmingly optical) communica-
tion systems that will be as ubiquitous and inexpensive as electricity is today.

The NGN will allow speech and mov-
ing images to be transmitted affordably
and flexibly in real time and with a level of
quality currently possible only with dedicated lines. The technology will
work by transmitting these real-time-
dependent services as prioritized data
packets. The NGN will automatically
manage itself as well as its data traffic.
Siemens is developing technologies in
each of these areas.

Video over DSL (digital subscriber line) is widely expected to be the next
killer application. The technology will
allow users to obtain television pro-
grams over a telephone line, in addi-
tion to Internet, videophone and fax
services.

Siemens set the current world record of
over 7,000 gigabits per second (Gbps)
over a single fiber. This was achieved
by using 176 channels, each of which car-
rried 40 Gbps. If an all-optical system
could be completed, fiber links to the
home, there would be virtually no
limit to what could be transmitted.

In the future, nearly every object will
have its own Internet address and will
therefore be capable of communication.
To accomplish this, new standards will
be necessary. IP Version 6, for instance,
envisions something like 100 million ad-
dresses per capita worldwide.

Changes in Web programming will usher
in a “semantic Web.” Search functions will
find information based on meaning.
With the help of software agents, the user’s experience with the
Web will become increasingly personal-
ized. Phones, computers and other
appliances will recognize users and au-
tomatically connect them to their own
databases. Internet service provider
interfaces will reflect the individual
preferences and interests of users and
will automatically expand or contract
bands with depending on the service(s)
the user needs.
The Automatic Freight Car

Driverless freight cars could help shift traffic from congested roads to integrated rail networks. The first demonstration vehicle of this sort, the CargoMover, is being jointly developed and tested by several Siemens Groups together with external partners.

CargoMover is ready to roll. A horn sounds and the freight car, which is driven by a powerful diesel engine, sets off on its own accord, accelerates to a speed of some 90 kilometers per hour and disappears into the woods. A little later, the CargoMover approaches the loading ramp that Maierhöfer entered as its destination and decelerates. Suddenly, its horn emits a shrill blast as its sensors detect an obstacle (left) and the freight car comes to a stop at a safe distance from it. Only after an employee has removed the obstacle does the car set off again, heading for the loading ramp, where a truck is waiting to hoist a container onto the CargoMover. “Driverless freight cars could one day make a significant contribution toward shifting traffic from the road back to the rail network,” says Maierhöfer, explaining the aims of the CargoMover development project. “Today, he continues, “the trend is completely in the opposite direction.”

According to estimates from the German Federal Ministry of Transport and the 2002 Prognos European Transport Reports, freight transport in the European Union (EU) and other European countries that have applied for membership is expected to increase by 40 to 50 percent by 2015. That corresponds to an increase in the volume of goods being transported from 500 billion ton-kilometers in 2002 to 700 billion in 2015. But at the same time, the market share of rail-based freight transport is sinking rapidly. When compared with road, ship and pipeline, rail-based freight transport’s share of the market has fallen in the EU from 32.6 percent in 1970 to 14.1 percent in 1998. This downward trend is set to continue as a growing number of unprofitable lines are either dismantled or scheduled for reduced maintenance. But the consequences of these events add up to major problems for motorists and the environment. Even more trucks are likely to congest roads, causing billions of dollars’ worth of delays.

“The details are revealing,” says Maierhöfer. “In Germany, 80 percent of all goods are transported locally or regionally. In other words, they travel a maximum of 200 kilometers. In view of this, the CargoMover would be an ideal alternative to the truck in this sector.” CargoMover needs no driver, makes the most of gaps in the regular timetable, can carry as much cargo as at least two trucks (up to 60 tons, depending on design), is available around the clock and holds the potential of making secondary lines economically once again. In short, “With governmental support, the CargoMover concept would prove worthwhile for both the economy in general and for shippers.”

From a technical point of view, CargoMover has moved forward without a hitch. Less than two years after the project was launched by Prof. Fritz Freiherr of the Technical University of Rheinland-Westfalia (RWTH) in Aachen, Germany and Hans M. Schabert, a Member of the Siemens TS Board, a demo freight car was operational. The technology is an outstanding example of automotive freight car technology at the front of the vehicle. He taps in a password to activate a control panel on a large display at the most distant tracks has aroused even their curiosity: the CargoMover, the first fully automatic freight car.

Franz Maierhöfer, a Siemens engineer and Director of Cargo Logistics at TS, uses a key to activate a control panel on a large display at the front of the vehicle. He taps in a destination, steps aside, and within seconds...
If you’ve always wished you could get reliable and affordable household help, you’ve got something to look forward to. In a few years, service robots will perform a wide variety of tasks. They’ll clean windows, serve beverages, empty the dishwasher and more. And they’ll enable older people to live at home longer.

Eltville, Germany, fall 2020. The swift little robots rustle the leaves as they hurry up and down the rows of vines, carefully picking clusters of ripe grapes. The rush is on now with the grape harvest, because a long rainy spell is forecast to start tomorrow. The vintners can’t run the risk of letting the grapes get moldy, because they’re sure that 2020 will be a superb vintage! The stock price of the Rheingau Wine Investment Fund is already soaring to a record high.

“There you are at last!” Christine Dost hugs her son Peter and his young family. “I apologize, mom, but the sales rep for the new Multi-Rob stopped by. You know, that’s a great gadget! A robot for everything! Cleaning windows, mopping floors, vacuuming carpets, serving beverages. There are all sorts of accessories too, anything you could ask for. Just what you always wanted, right?” But Peter’s mom isn’t impressed. “I’ve already got so many of those little helpers in the house. I don’t need another one,” she says. Peter grins a little at this. It’s always the same with his parents — at their age you get a little set in your ways. But he’s sure that when Multi-Rob...
rings the doobell at Christmas, wearing a winning smile plus a ribbon and bow around its metallic midriff, they'll be thrilled.

A transporter robot glides past them with the family’s suitcases on its way into the house. “I want one of those!” exclaims little Elizabeth Dost, pointing at a Robo-Doggy another young girl is proudly walking on a leash nearby. “Why don’t you all come in,” Christine says. “Grandpa will be down in a minute to join us.” upstairs, Marcus Dost is just getting out of the bath, assisted by an intelligent wheelchair. He’s been having a lot of problems using his legs. Without help, Christine wouldn’t be able to take care of Marcus any more. But it’s been working out well so far, thanks to the little robot helpers. The wheelchair transports Markus to the living room downstairs — smoothly, gently, and automatically. It has effortlessly memorized the route during its initial orientation tour.

As the visitors enter the living room, a Siromob emerges from the kitchen — one of those almost humanoid robots with a rounded head and very agile arms. Because of its noiseless piezo motors, the Dosts didn’t immediately notice this electronic assistant despite its height of almost five feet. But there has never been an accident, since this very smart robot with its sensors and neurocognitive appraisal appraises any situation in an instant. If Christine or anyone else should approach it too closely, it will announce its presence with visual signals or verbally and immediately notice this electronic assistant. “You’ve always been good at getting out of the bath, assisted by an intelligent robot,” Christine says. “Grandpa will be down in a minute to go and freshen up a bit. That mechanical jock is pleased to answer. Only near the end of the game does it tend to get a little vague, because, after several “tastings,” the guests are beginning to speak less than distinctly. “We’ve got a surprise for you. Look who’s here!” announces Christine. It’s Melanie Dost, Peter’s sister, and she looks pretty exhausted. She has tried for the umpteenth time to beat her opponent at tennis. “Hi everybody! I’ll just go and freshen up a bit. That mechanical jock has beat me again.” Next time I’ll select level 4. At level 5 and against two rackets I just can’t win.” Her tennis partner doesn’t need a break. It’s a sports robot equipped with a special fuel-cell system that ensures it’s always ready for the next game.

“Siromob, would you please bring me a glass of water?” Melanie is back and flops onto the couch. In a minute the robot returns, handing her the glass. “You know, I can’t imagine how people ever got along without robots.” “Big deal,” Peter teases her. “You’ve always been good at getting out of doing housework.” “Here we go again!” laughs Christine. Siromob runs into a problem when it’s supposed to get orange juice for the twins. None is left. It looks sad as it tells the kids about it. Karen puts her coffee down and gets up: “I’ll run down to the gas station and get some juice. I need to refill the car’s fuel cell anyway.” And she’s out the door.

They have any questions — in any language — they want to know about viticulture. If they have any questions — in any language — their guide generally understands them and is pleased to answer. Only near the end of such tours does it tend to get a little vague, because, after several “tastings,” the guests are beginning to speak less than distinctly. “We’ve got a surprise for you. Look who’s here!” announces Christine. It’s Melanie Dost, Peter’s sister, and she looks pretty exhausted. She has tried for the umpteenth time to beat her opponent at tennis. “Hi everybody! I’ll just go and freshen up a bit. That mechanical jock has beat me again.” Next time I’ll select level 4. At level 5 and against two rackets I just can’t win.” Her tennis partner doesn’t need a break. It’s a sports robot equipped with a special fuel-cell system that ensures it’s always ready for the next game.

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The robots are piloted by Sinas, the world’s most advanced robotic navigation system. At Siemens, researchers are now working on systems that will allow these machines to work together as teams.

Mr. Clean

The vacuum cleaner robots that have recently entered the market must feel as lost as a captain without a compass. Tiresly focused on cleaning carpets, they wander about aimlessly in private households. After about an hour’s work, they head for their recharging stations; then, after a short interlude, these fully automatic helpers are set for action again. Unfortunately, they don’t have a clue about which areas they have already cleaned and which ones still need to be cleaned.

But not all robots are created equal. When it comes to the ST82 R, which is guided by a Sinas navigation system, things are very different. Shoppers at the Albert Heijn B.V. chain of supermarkets in the Netherlands are more than a little surprised when a big floorbot asks them politely to step aside, saying something like: “Excuse me, but I’d like to clean the floor here.” The robot has been navigating the supermarket’s aisles on its own, polishing the floors to a gleaming sparkle since the fall of 1999. The ST82 R was developed jointly by Hefar Cleantech and Siemens. “It has taken years of development work to perfect the intelligent pilot,” says Project Manager Gesbert Lawitzky, a member of the Intelligent Autonomous Systems Department at Siemens Corporate Technology in Munich, Germany. “The idea and initial prototypes of Sinas, which stands for Siemens Navigation System for Autonomous Service Robots, originated at our research laboratories in Munich. Sinas was then developed to the product stage in collaboration with the Siemens Automation and Drives Group. Today, our system is the world’s most advanced navigation aid for self-propelled machines,” says Lawitzky. Sinas is useful not only for cleaning, but also for all types of transportation tasks. To navigate successfully, the pilot system must always know where it is and if there are any obstacles to avoid. Sinas achieves this by using sensors that supply it with continuous information regarding its position and immediate environment.

Seeing and Being Seen. Laser scanners and ultrasound systems serve as ST82 R’s eyes. “They enable cleaning robots to reliably detect persons or shopping carts in their paths, and to slow down or stop in time,” explains Lawitzky. “If there is no response to a request to step aside, the robot skillfully maneuvers around the obstacle and then returns to its route. Sensor signals are processed in the machine’s brain, a controller that performs complex computational processes. “The software we’ve developed evaluates all incoming environmental information 20 times per second.”
ment and memorizing readily recognizable landmarks. During a second guided tour, the coach explains which areas the robot is expected to clean and which are off-limits. It never even gets to see certain areas.

During autonomous operation, the robot follows exactly the same paths it was shown initially — provided, of course, it doesn’t encounter obstacles. During its progress, it continuously compares the route it has memorized with its current route by visualizing its environment and comparing it with a stored map.

New Worlds. Smart cleaning robots are currently employed mainly in supermarkets. But they’re entirely capable of exploring other new worlds, such as airports, railroad stations, factories, trade fair centers and hospitals. According to a study by the International Federation of Robotics, more than 3,000 cleaning robots will be carrying out tasks in non-domestic applications by 2005 (see page 64). But cleaning an entire airport terminal would be expecting a bit much of a single robot. Such a job would have to be shared by a team — and that means that each member would have to know exactly what tasks it was expected to perform. Just as with a human team, the work would progress as efficiently as possible. The good news is that the sort of problems that tend to complicate or disrupt teamwork among humans don’t seem to undermine cooperation among robots. That’s the conclusion of research scientists at the Department of Intelligent Autonomous Systems at Siemens Corporate Technology in Munich, Germany.

Pilot projects with three mobile test robots named R, G and B have demonstrated that robots clean only a predefined section. As with a human team, the work would progress as efficiently as possible. The good news is that the sort of problems that tend to complicate or disrupt teamwork among humans don’t seem to undermine cooperation among robots. That’s the conclusion of research scientists at the Department of Intelligent Autonomous Systems at Siemens Corporate Technology in Munich, Germany.

This mobile experimental robot scans its surroundings by using eight “eyes” that conceal ultrasound sensors. A sixth eye is a laser scanner (black box with the greenish light). The box above it contains a gyrocompass. A controller (gray box at rear) and SINAS handle navigation.

Simulations show a team of robots cleaning a supermarket in Bussum (The Netherlands). The area is divided into cells of similar size. When the communications radio of two robots intersect (right picture), the robots communicate which cells they have already been cleaned and which ones still need to be tackled (white area). The strategy is designed to avoid redundant work.

ROBOTS Cooperative Navigation Systems

and issues situation-specific commands to the machine’s steering mechanism in real-time,” reports Lawitzky. “Aside from determining its position and reacting to possible problem situations, the robot of course occupies itself with its primary task of scrubbing and drying the floor. Furthermore, I should add that its secondary job is to attract attention as an advertising medium: As it moves among shoppers, the robot announces ads and gives away freebies.”

What’s so special about SINAS is the fact that it doesn’t need any external navigational aids, such as reflective strips or guide wires,” says Lawitzky. “The robot collects the initial location data through special odometers mounted on its axles and with the aid of a gyrocompass, which provides continuous estimates of its orientation.” Since these data are too imprecise, an apprentice robot continuously records additional information about its position by scanning its environment and memorizing readily recognizable landmarks. Only when they happen to encounter each other during their work — in other words, when their 10-meter communications radii intersect, do they tell each other which areas they have already been cleaned by whom to avoid redundant work.

But regardless of the type of radio message, the objective is the same: to ensure that several robots don’t clean the same area simultaneously. If two units approach each other too closely in their work, they exchange information regarding their current locations and their intended routes. If a collision hazard ensues, one unit pauses and yields the right of way to the other. Exactly which robot does what depends on predefined criteria. What matters is that the best decision is reached for the system as a whole. As a case in point, it wouldn’t make sense to stop the faster-moving of the two robots. So the slower-moving unit yields the right of way until the collision hazard has passed.

“We are currently working not only to improve the way multiple robots share the work area, but also to make their route planning as efficient as possible,” reports Jäger. “We’ve performed a great many computer simulations. Now we’re conducting extensive tests in a real environment.” As far as the future is concerned, this means that cleaning robots may not have to work alone for much longer. Instead, they can look forward to being part of a team!”

Ulrike Zechbauer
Professor Gerd Hirzinger is Director of the Institute of Robotics and Mechatronics at the German Aerospace Center (DLR) in Oberpfaffenhofen near Munich.

Why Robots Are Just Around the Corner

How intelligent are the robots used commercially today? Ultimately, today’s industrial robots are still mere positioning machines whose design is meant to ensure mechanical precision. Their intelligence isn’t really that much greater than it was 15 years ago. One reason for the lack of progress is that many pilot projects in the field of sensors and sensor feedback have been discontinued. However, without appropriate sensors, a robot remains dumb and inflexible. Today’s household robots also don’t measure up to the current state of technology. The first vacuum cleaner robots, for instance, which are now entering the market, have no sense of orientation — they clean the carpet by some random route. And that isn’t very impressive when you consider that intelligent navigation systems have existed for years. Nevertheless, it’s important to note that industrial robots have become a lot cheaper. They only cost about one-fourth as much dumber than they ought to be?

To explain that you have to look at economics and legal factors. There’s a saying that’s especially popular in the auto industry: “The best sensor is no sensor.” The idea is to avoid liability issues from the very start because if something does go wrong, it is often very difficult to establish whether the manufacturer of the sensor or of the robot was at fault.

Can you imagine a factory of the future operated entirely by machines? Absolutely. Such a factory has already been in operation in Japan for ten years. But development in this field is progressing interminably, and a good many of the changes have been reversed. Over the longer term, there’s no doubt that humans will disappear from the production floor. I’m also convinced that we’ll be bringing production processes back to Europe that are currently outsourced to low-wage countries. On the one hand, people in these countries will want to — and certainly will — earn higher wages, while on the other hand, robots will continue to become more intelligent and better skilled. They’ll soon be able to perform most unpleasant chores reliably, fast and cost-effectively. In fact, manufacturers are beginning to refer to them somewhat unflatteringly as the “production slaves” of the future.

Robots will obviously have a lot on their hands. Will that make them job killers? I don’t think so. Experience has shown that industries that make the most use of robots, such as the automotive industry, have actually been increasing their workforces. In industrial societies there seems to be a general trend away from people working in production processes and toward other kinds of employment.

Is Japan the undisputed number one in terms of robotics? No. The media keep insisting that Japan is the leader in industrial applications. But that’s not true. In the past two years, two European manufacturers actually ranked among the top three. The global leader, with annual sales of about 10,000 industrial robots, is ABB of Sweden, followed by Fanuc of Japan. Kuka Roboter of Augsburg, Germany, is in third place. But it’s interesting to note how vigorously the Japanese are pursuing the development of humanoid robots — robots that look and move like people — as well as “artificial pets.”

What do you consider to be the most fascinating vision in the realm of robotics? For my own part, I have several “grand visions,” if you will, involving robots. One of these concerns space travel. At the DLR, we’ve been working for around 25 years to make robots suitable for applications in outer space. During the 1993 Spacelab mission, we were the first to successfully send a robot into space. One of our goals is to replace astronauts with machines — so-called robonauts — that can be controlled from Earth. These machines could be used to perform such functions as exterior repairs on spaceships.

As far as service robotics is concerned, I envision a household assistant for older people that obeys voice commands, never runs out of patience and is available around the clock, seven days a week. This would allow senior citizens to live at home longer. I would emphasize that such robot assistants should not take the place of loving human care. But it’s time to stop pretending that things are simply wonderful in today’s nursing homes, where there is often very little time for really caring attention.
When do you expect these mobile robotic helpers to become available?

In 20 to 30 years at most they should be commonplace — not only in nursing homes, but especially in private households. I’ve already mentioned my third vision about robots replacing factory workers in the future. But robotics is also continuing to become more important in medical applications: Replacement organs for humans, such as prosthetic hands and artificial hearts, will continue to be refined and perfected in the future. At the DLR we are also planning the development of a new kind of surgical robot that will be much lighter and more intricate in construction. The design will incorporate a degree of sensitive force feedback from inside the patient’s body — a feature that is still lacking in present-day systems.

What about the toy industry?

That’s a field that will continue to surprise us with ever more sophisticated innovations. Sony is already making more money with its Aibo Dog than leading manufacturers are earning with industrial robots.

What do you think the next major advance in robotics technology might be?

I can envision yet where the next great leap forward will come from. For instance, we’ve nearly exhausted the technological possibilities that can be realized with lightweight robots. Our newest robot has arms made of ultralight carbon fiber structures. We’ve also developed an entirely new motor that weighs only half as much as the best conventional motors. What’s more, we’ve even reduced power losses by half. As a consequence, our robot consumes very little power — in fact, it only requires about as much as a bright lightbulb. That’s significantly better than anything that’s been done with conventional industrial robots. The ratio of the weight of our robot arm to the payload is one-to-one. That’s the best that can currently be achieved. Of course, there’s the ancient dream of “recreating” human muscle tissue from chemical or organic materials. But we still don’t know how to do that. Interview conducted by Ulrike Zechbauer.

Robots: Facts and Forecasts

There are two kinds of robots: industrial and service, and they are headed in two different directions. Last year, the market for industrial robots dropped by about 32 percent, from $5.7 billion in 2000 to only $3.9 billion in 2001. In Japan, sales sank by close to 60 percent. Service robots are a different story. Their numbers — although still relatively small — are expected to skyrocket from around 190,000 in 2001 to more than 2.2 million within four years.

ROBOTS — Interview

Market Volumes for Industrial Robots in 2001 by Country


World Market for Service Robots by Area of Application


Robotics: Forecasted Technical Development and Future Application Areas

Gripping

- Gripping objects with soft surfaces; e.g. fruit
- Gripping soft, sliding material, e.g. fabric and clothing

Recognition

- Recognizing two-dimensional structures
- Recognizing three-dimensional structures

Interfacing

- Expression of emotion
- Free conversation between humans and machines
- Multimodal interfaces; e.g. gestures, facial expressions and speech
- Recognition of emotion from speech

Applications

- Production
- Service, e.g. cleaning
- Biotechnology: Molecular manipulation
- Biotechnology: Cellular manipulation
- Toys
- Orientation and outdoor work

Below left: Despite a dramatic fall in sales in Japan — a drop of almost 60 percent in 2001 compared with the previous year — the Japanese invested more in industrial robots in 2001 than any other country. With an investment of $1.1 billion, they took first place in this area, followed by the U.S., which invested almost $890 million, and Germany with a $579 million investment. The total market volume for industrial robots amounted to almost $3.9 billion in 2001. If associated investments in software and peripherals are also taken into account, the global market in 2001 for complete industrial robot systems was approximately $12 billion. For additional information, see “Industrial Robots” table on page 26.
Can We Build Intelligent Machines?

Our new companions are called Aibo, Asimo, Cog and Kismet. Their bodies are made not of flesh and blood, but of metal, circuits and sensors. Asimo looks like an astronaut. He can stiffly walk up a staircase on two legs. Aibo, the posho, barks and likes it when his master pets him. Cog, the tomo, is supposed to learn how to behave through interaction with his environment. And Kismet, the metallic head with the goggle-eyes and huge lips, can smile or show fear or anger (see article on page 68). Could we say that Aibo, Asimo, Cog and Kismet are intelligent? Being able to build machines that are like animals or people is an ancient dream that can be traced back at least as far as the 18th century. In 1738, French inventor Jacques de Vaucanson presented an amazing public a flute player that moved its tongue and lips like a person and pressed its fingers over the holes of the instrument to play various songs. Vaucanson built more automaton, which were followed by a veritable machine boom. The novel Frankenstein from the year 1818 reinforced the idea that one could build a copy of a person. But only with the advent of the computer did the dream of intelligent machines take on a tangible form. Nov, says Professor Marvin Minsky, artificial intelligence (AI) pioneer and founder of the famous AI Lab at the Massachusetts Institute of Technology (MIT), it’s only a matter of time before there are robots that measure up to people.

Other scientists offer similar predictions. Professor Hans Moravec of Carnegie Mellon University in Pittsburgh, Pennsylvania, believes that by 2010 robots will be able to move with the intelligence of small lambs. By 2020, says Moravec, machines will be as adaptive as mice; by 2030 as smart as apes; and by 2040 they will rival the full cognitive ability of human beings, having the power of imagination, and the ability to learn and modify their behavior. Eventually, says Moravec, they will be so perfect that people will implant their minds in them. Thus, by the end of the 21st century, human and artificial intelligence will merge, creating a new life form (see essay on page 71).

Simulating the Brain. Many bold visions of this kind are based on the assumption that intelligence can be created through sheer computing power. “We are looking for the gold of the Incas, but we haven’t even discovered America yet,” cautions Professor Christoph von der Malsburg, who designs software that recognizes faces at Bochum University in Germany and the University of Southern California at Los Angeles. On the one hand, he says, modern computing is trying to make models of the brain, despite the fact that researchers do not yet understand how it works. On the other hand, AI researchers are slowly realizing how difficult it is to generate reliable behavior in a natural environment. To put it differently: In the laboratory it may be possible to build a machine that recognizes faces, navigates a path or takes hold of objects. But the real world is incomparably more complicated — and yet people manage to find their way around in it. But if neither Cog nor Kismet, both of which are being developed at the AI Lab at MIT, nor Aibo (Sony) nor Asimo (Honda) can do anything like this, the questions then become: Do machines even have the potential for intelligence? How does one implant “common sense” into them? And how can they obtain knowledge of the natural world? Researchers are only slowly feeling their way around the question of what intelligence is. “There is no comprehensive theory of intelligence,” says Professor Helge Ritter, a neuro-computing specialist at Bielefeld University in Germany, who, together with his colleagues, is currently teaching a robot to recognize language and gestures. One thing, at least, is clear: Human intelligence can be traced back to the large number of specialized functions in our brains. We can identify objects of all kinds. We can move around without bumping into things. We can recognize the feelings of others and express our own emotions. We learn from experience.

We plan our future. All of this is based on the complicated interactions that take place between numerous parts of our brain. But because researchers are still a long way from understanding how these parts of the brain act in concert, and because each part is itself extremely complex, the builders of “intelligent” robots still have to limit themselves to small units of intelligence. Some therefore take up visual intelligence and make computers recognize images, others replicate spatial intelligence and train machines to find their way around a room. Two Research Groups. In Munich, two teams from Siemens Corporate Technology are working on modeling and imitating intelligence. Their approaches are very different, but they nevertheless complement one another.

Integration of Neurobiological Levels into Neural Network Technologies

Whereas the first generation of “neural networks” in the 1980s used very simple artificial nerve cells, temporal dynamics played an important role in the second generation (1990s). Neurons were no longer static, but instead operated with pulsed signals like natural counterparts. This time dependence allowed them to process input patterns far more complex than those that could be handled by static neurons. The third generation, which has evolved in the last few years, is referred to as “neurocognitive” because it takes into account knowledge concerning the organization of brain functions. Thus, in addition to the input of a certain visual pattern, the neurons in systems developed by Siemens researchers also receive data from other parts of the brain, such as the inferotemporal cortex. This area ensures that objects are recognized independently of their orientation in space. All of this, together with sophisticated sensor technology, lends a certain intelligence to machines.
Robots are being trained to recognize doorknobs and other objects, but also items of a specific color, such as red or blue doorknobs. As the brain, color and shape are processed by different networks of neurons, which then combine their information. The neurons that specialize in certain patterns — so-called “grandmother cells” — represent the optical common-sense knowledge of a robot. Thanks to the collective capacity of these cells, Deco’s artificial brain recognizes naturally-occurring patterns.

Deco, who recently became one of a handful of inventors of the year at Siemens, is currently engaged in a European-wide project designed to mold the software into something more than a bizarre concoction made of plexiglas, microchips, motors, cameras and small lights. Nevertheless, with its protruding eyes and lips of red cord, the robot looks somehow human, almost endearing. You automatically smile back and catch yourself wanting to talk to this artificial head. And indeed, Mexi can already speak short sentences and express emotions. For instance, he raises his voice when he’s happy, and lowers it when he’s in a bad mood.

Role Models. Does Mexi have feelings? “No, if he actually talks to,” says Kleinjohann, shaking his head as he opens the “Emotion Engine” on a PC, from which Mexi can be programmed. Three slide controls appear on the screen. They represent the alternating desires Mexi tries to satisfy: communication (looking at people), play (watching colored balls) and greeting the Linux mascot — a penguin doll. With the help of another control, Mexi can display a wider range of emotions. He can show fear, for example, by cringing when someone waves a hand in front of his camera eyes or comes too close for comfort.

Mexi has two famous role models: Cog and Kismet, both of which were built at the Massachusetts Institute of Technology (MIT) just outside of Boston. Robot pioneer Professor Rodney Brooks proceeded from the hypothesis that a robot can acquire attributes similar to those of a human being only if it is allowed to explore its surroundings in the same way a small child does. Cog is now able to distinguish the faces of its handlers from strangers’ faces, and he can tell whether or not a person is looking directly at him. Like Mexi, Kismet, the successor to Cog, has feelings. If no one pays attention to him, he looks sad. “Kismet was designed to emotion-ally blackmail people,” says his creator, Cynthia Breazeal.

The Need for Emotions. Neglected by cognitivists until recently, emotions now seem to be essential to the success of artificial intelligence, a field that has disappointed many since its promising birth in the 1960s and ’70s. The Affective Computing research group at MIT is proceeding from the assumption that emotions are important for the ability of intelligent machines to make flexible and rational decisions.

The researchers draw this inference in part from studies conducted by Antonio Damasio, a neurologist at the University of Iowa. In the course of his research, Damasio discovered that emotionally disturbed patients make their decisions much as computers do — inflexibly and according to simple if-then patterns.
user interfaces. This new discipline is called "robotic user interfaces,” and the objective behind it is not to build robots and avatars that resemble people, but to develop synthetic creations that can bridge the gap between human needs and the information present in the computer world. Kleinjohann imagines future information kiosks or cash machines that enter into spoken dialog with users through a device that might be similar to Mexi.

Christoph Bartneck of the Eindhoven University of Technology in the Netherlands imagines robot interfaces above all in the entertainment and educational sectors. He believes that robots could also take over the job of controlling an electronic home. In Japan, where the subject of humanoid robots is viewed with far fewer inhibitions than almost anywhere else, domestic helpers that resemble people, but to develop synthetic creations that can bridge the gap between human needs and the information present in the computer world. Kleinjohann imagines future information kiosks or cash machines that enter into spoken dialog with users through a device that might be similar to Mexi.

Kismet, Mexi's brother, was created at the Artificial Intelligence Laboratory of the Massachusetts Institute of Technology in Boston. Friendly Faces. But ease of use can be enhanced with the personal computer as well. Dr. Stefan Schoen, head of the User Interface Design department at Siemens Corporate Technology (CT) in Munich, Germany, emphasizes that finding the right mixture of user friendliness and attractiveness is crucial to the acceptance of user interfaces in PCs and PDAs. The attractiveness factor has a big influence on subjective first impressions, and therefore on sales. The same is true for voice-response systems. A friendly computer voice is interpreted as more helpful than a neutral or unfriendly one. Feelings can therefore be deliberately manipulated on a subliminal level. However, it is important that the interaction remain controllable, Schoen says. Although a machine may arouse emotions in people, it should not become unpredictable and iritate users with its own moods — like the depressive robot Marvin in Douglas Adams’ novel The Hitchhiker’s Guide to the Galaxy. Things can also backfire if an avatar acts too much like a person, since that might create expectations that the artificial creature cannot possibly fulfill. "Abstract gestures like pointing or head scratching when the computer is looking for an answer are very effective," notes Dr. Bernhard Kammerer, who is responsible for interaction technologies at Siemens CT. In principle, that also applies to Clippit, which pops up to offer help texts in Microsoft programs. Nevertheless, the virtual paperclip doesn’t go over well, because it appears without being invoked, says Stefan Schoen. "Many users feel controlled by Clippit," he says.

Schoen’s colleague Heinz Bergmeier is currently developing avatars for a future UMITS chat application. The new generation of figures resemble amusing cartoon characters and can depict the feelings of chat participants on a cell phone display. These figures work in much the same way as the emotions that many cell phone users like to use in SMS. Instead of “facies” produced from symbols such as :-) or :-(, a mobile chat can use humorous characters such as penguins or tortoises that act as avatars and smile or pout in a virtual chatroom. Using a slide control, the user can select from up to 13 different emotional states to transfer to his or her cell phone partner’s phone. If the participants like each other, they can even go into a private room and have the penguin and the tortoise kiss by pressing a button.

The Sound of Anger. Obviously, it is easy to call forth emotional reactions in people. A yapping plastic dog like Sony’s toy robot Aibo or a cartoon character on a cell phone display are all it takes. But could the reverse be true? Would it be possible for machines to recognize and use emotions? To date, achievements in this area have been modest. Researchers at the University of Munich have used a computer to interpret 80 percent of human gestures, but the number of gestures was small and they were performed by actors.

For Professor Harald Höge of the Interaction Technologies Department at Siemens CT in Munich, what is particularly interesting is how emotions are expressed in speech. In the future, says Höge, the voice response systems frequently used by call centers for preliminary customer guidance will put a caller through to a flesh-and-blood staff member immediately if they determine that the caller is angry. But this will not happen in the near future. “The most effective thing would be to tap right into the brain to determine a person’s feelings," says Dr. Martin Stetter of the Neurocomputing Center at Siemens CT. Stetter is developing a brain-computer interface that senses simple emotional states by means of electroencephalograms. Indeed, certain brainwaves are very reliable indicators of fright, relaxation or tiredness. This means that a cap fitted with sensors could be used to measure the effect user interfaces have on test subjects. The technology could, for instance, be adapted to automotive safety systems that would sound an alarm if the driver started dozing off.

Brain Piercing. In animal experiments, monkeys have learned to control a robotic arm with the power of their thoughts. To do so, however, a team led by Johann Wessberg from Duke University in Durham, North Carolina, had to implant electrodes in the brains of the test animals. Taking these thoughts a step further, Stetter believes that it may eventually be possible to transmit simple feelings from one individual’s brain to another or even to a robot by means of what he calls "brain piercing." Nevertheless, even he doesn’t believe that the entire gamut of a person’s thoughts and emotions will ever be transmitted in this manner: "That’s pure science fiction," he says.

Bernd Müller

The age of neural implants is well under way. We have brain implants based on “neuromorphic” modeling (i.e., reverse engineering of the human brain and nervous system) for a rapidly growing number of brain regions. A generation of cochlear implants now on the drawing board will provide levels of frequency discrimination that go significantly beyond that of “normal” hearing. And in Germany, researchers at the Max Planck Institute have developed noninvasive devices that can communicate with neurons in bothdirections. They have demonstrated a “neuron transistor” by controlling the movements of a living leech from a personal computer. Intelligent machines are already making their way into our bloodstream. There are dozens of projects underway to create blood stream-based “biological microelectromechanical systems” (bioMEMS) to intelligently scout out pathogens and deliver medications in very precise ways. For example, a researcher at the University of Illinois at Chicago has created a tiny capsule with pores measuring only seven nanometers (10).
The pores let insulin out in a controlled manner but prevent antibodies from invading the capsule. Similar systems could precisely deliver dopamine to the brains of Parkinson’s patients, and deliver cancer drugs directly to tumors.

By the end of this decade, computing will disappear as a discrete technology that we need to carry with us. We’ll routinely have high-resolution images encompassing the entire visual field written directly to our retinas from our eyeglasses and contact lenses. We’ll have very high-speed wireless connections to the Internet at all times. The electronics for all of this will be embedded in our clothing. Circa 2010, these very personal computers will enable us to meet with each other in full immersion, visual-auditory, virtual reality environments as well as augment our vision with location- and time-specific information at all times.

By 2030, electronics will utilize molecule-sized circuits, reverse engineering of the human brain will have been completed, and bioMEMS will have evolved into bioNEMS (bio- and nanoelectromechanical systems). It will be routine to have billions of nanobots (i.e., nano-scale robots) coursing through the capillaries of our brains, communicating with each other (over a wireless local area network) as well as with our biological neurons and with the Internet. One application will be to provide full-immersion virtual reality that encompasses all of our senses. When we want to enter a virtual reality environment, the nanobots will replace the signals from our real senses with the signals that our brain would receive if we were actually in the virtual environment. We will have a panopoly of virtual environments to choose from, including earthly worlds that we are familiar with, as well as those with no earthly counterpart. We will be able to go to these virtual places and have any kind of interaction with other real (as well as simulated) people ranging from business negotiations to sensual encounters. In virtual reality, we won’t be restricted to a single personality as we will be able to change our appearance and become other people. “Experience beams” will beam the entire flow of sensory experiences as well as the neurological correlates of their emotional reactions out on the Web just as people today beam their bedroom images from their Web cams. A popular pastime will be to plug in to someone else’s sensory-emotional beam and experience what it’s like to be someone else, à la “Being John Malkovich.” There will also be a vast selection of archived experiences to choose from. This design of virtual environments, and the creation of archived full-immersion experiences will become new art forms.

The most important application of circa 2030 nanobots will be to literally expand our minds. We’re limited today to a mere hundred trillion interneuronal connections, brains (a threshold we’ve already passed), it is logical intelligence gets a foothold in our brains (a threshold we’ve already passed), it will grow exponentially, as is the nature of information-based technologies. Note that a one-inch cube of nanobist circuitry (which is already working at small scales in laboratories) will be at least a million times more powerful than the human brain. By 2040, the nonbiological portion of our intelligence will be far more powerful than the biological portion. It will, however, still be part of the human-machine civilization, having been derived from human intelligence, i.e., created by humans (or machines created by humans) and based at least in part on the reverse engineering of the human nervous system.

Stephen Hawking recently commented in the German magazine Focus that computer intelligence will surpass that of humans within a few decades. He advocated that we “develop as quickly as possible technologies that make possible a direct connection between brain and computer, so that artificial brains contribute to human intelligence rather than opposing it.” Hawking can take comfort that the development program he is recommending is well under way. Ray Kurzweil, Ray has received a number of honorary doctorates in science, engineering, music recreation, financial analysis and medical education. In 1990, Ray’s first book, The Age of Intelligent Machines, was published by the MIT Press. In 1995, he published The Age of Spiritual Machines, wherein Computers Exceed Human Intelligence. Ray has received a long list of national and international awards, including the National Medal of Technology, the U.S. highest honor in technology – and nine honorary doctorates in science, engineering, music and humane letters.

As computers become more and more powerful...
The soccer robot is almost as real as the exciting events.

According to Professor Peter Gendolla, a specialist in contemporary literature from the University of Siegen, Germany, when it comes to science fiction, what we see at the movies and on our television screens are zombies made in our own image. Gendolla, who has written many essays on the subject of artificial humans in film and literature, finds that stories about androids emerge most often at times when a group or society is overwhelmed by its own technological progress. We identify with the creature, perfect in its artificiality, that threatens us. This enables us to deal with feelings of pain or loss of control. For example, during the advent of industrialization, individuals became little more than cogs in the impenetrable machinery of production. Jean Paul described the 18th century as the century of machine people. They repeatedly appear in the novels of Eichendorff and E.T.A. Hoffmann.

Blurring Boundaries. In the 20th century the boundaries began to blur. In film and literature, humans and machines become so alike as to be indistinguishable. Authors of all stripes are now playing on uncertainties created by this gray area. But researchers, vi- sionaries and some fanatics are also concerned with the question of whether robots will one day be able to develop their own emotions. Will they even fall in love, as in Steven Spielberg’s Artificial Intelligence? One computer scientist at Munich’s TU even ponders whether humans are actually highly developed robots — simply the sum of biochemical and physical processes. Professor Coy, who also studies philosophy, isn’t particularly disturbed by this line of thinking. “We’re certainly not robots,” she says, but then adds thoughtfully, “If we are, we’re so well programmed that we don’t notice it.” Obviously, scientists at Munich’s TU still have a way to go before their prototypes begin to challenge human capabilities. But perhaps one day their metallic soccer players will be able to celebrate victory and suffer the pain of defeat. Maybe they will even rebel against their masters. For now, however, their creation is simply furthering the development of the next world Cup.

Professor Andreas Kleinschmidt
Siemens supports young companies throughout all phases of their development — from initial idea to IPO and beyond.

Contrary to popular opinion, the demise of numerous companies in the New Economy does not mean that venture capital has dried up for promising start-ups. “As things have calmed down on the market, we can now take the time to even better analyze companies that interest us,” says Björn Eske Christensen, CEO of Siemens Venture Capital GmbH (SVC). “We’re also better equipped to help them achieve their objectives. Even in the past, we didn’t pursue financial goals exclusively. Instead, we saw ourselves as a long-term partner of those companies we invested in. And since we took a relatively conservative approach to putting together our portfolio, we weren’t as hard hit by the stock market crash and the busting tech bubble as others were. So now’s the best time for us to invest again.”

Siemens Venture Capital is headquartered in Munich, Germany and has offices in San José, CA, and Boston, MA, has invested 500 million euros for Siemens over the last five years. The funds have been invested into more than 70 start-ups and 25 venture capital funds, most of them in the U.S., Europe and Israel.

The Corporate Venture Organization focuses on young, innovative companies that operate in strategic technology fields in which Siemens is also active, such as information and communications, automation, medical engineering and energy. The companies targeted for investment also promise above-average returns. Fourteen companies in the SVC portfolio are now listed either on the NASDAQ or German stock exchanges.

Support for start-ups in the form of capital and know-how is generally divided into separate financing stages. Insulators and accelerators support firms during the seed phase — in other words, from the very beginning, when initial ideas are generated and patents are registered. SVC makes investments during subsequent financing rounds.

Siemens Technology Accelerator (STA), Munich, and Siemens Technology-To-Business Center (TTB) in Berkeley, CA, are both assigned to Siemens Corporate Technology (CT). STA focuses on turning technology that is not part of Siemens’ core business into promising ventures by giving young companies professional advice and financing to help them get established or launched as spin-offs. TTB specializes in nurturing radical innovations for the core business areas of its sponsors, CT and the Automation and Drives Group. These innovative ideas primarily originate from academic research activities in the U.S. Siemens Business Accelerator in Munich provides advice and practical support for young companies, but does not make capital investments.

Siemens Mobile Acceleration GmbH (smac) is a wholly owned subsidiary of the Siemens Information and Communication Mobile Group. It specializes in supporting innovative business ideas in wireless communications. smac’s services typically include support for start-ups around the world during the seed phase before market entry. smac provides extensive coaching and seed financing averaging approximately one million euros. It currently maintains offices in Germany, France, the UK, Italy, Sweden and China.

“Basically we help to ensure that the companies we support are involved in technologies that correspond to Siemens in one way or another,” says SVC’s Christensen. “This is not only because we can better assess their chances of success; it also means we can offer them the opportunity to establish a partnership with our globally operating company — for developing new technologies or optimizing sales, for example.” That’s a very appealing offer — which is why most of SVC’s start-up companies have business relations with Siemens. Ulrich Eberl
**FEATURES**

**Start-up Companies**

Minuscule Motors

Björn Magnusnuss has managed it all. His miniature piezoelectric motors are precise, cost-effective, silent and light — and they have excellent prospects worldwide.

Visitors at this year’s Nuremberg Toy Fair wore wide-eyed. The reason for their astonishment was a new toy locomotive that can raise and lower its pantograph just like a real train engine. Such fluid motion is made possible by a lightweight miniature piezoelectric motor. A revolutionary development, the device costs no more than a conventional electric motor but operates incomparably more precisely, and is also silent. “Our motors have neither rotors nor gears,” says Dr. Björn Magnusnussen, CEO of Elliptec Resonant Actuator AG in Dortmund, Germany, a company established in January 2001. “Since there’s no need to reduce any rotor momentum during braking, they come to a stop 60 times faster than electric motors when they’re switched off, and their braking distance is 2,000 times shorter.”

But the miniature drive system from Elliptec is ideal for far more than just model trains. The comliptec is ideal for far more than just model shorter.”

“Precisely, and is also silent. “Our motors have neither rotors nor gears,” says Dr. Björn Magnusnussen, CEO of Elliptec Resonant Actuator AG in Dortmund, Germany, a company established in January 2001. “Since there’s no need to reduce any rotor momentum during braking, they come to a stop 60 times faster than electric motors when they’re switched off, and their braking distance is 2,000 times shorter.”

But the miniature drive system from Elliptec is ideal for far more than just model trains. The comliptec is ideal for far more than just model shorter.”

Piezoelectric motors are not entirely new; they’ve been used in microchip manufacturing for several years now. But their price of up to $400 — and sometimes more than $5,000 in the case of piezoelectric motors used for positioning systems in microscopes — has thus far prevented them from being applied extensively. Researchers from Siemens, EPCOS and Elliptec were the first to achieve dramatic simplifications in the design, components and production process for the motors, thereby reducing the unit price to between two and four dollars. “At that price, we’ll soon be taking a lot of market share from manufacturers of electric motors,” says Magnusnussen.

Several years ago, during his tenure at Siemens Corporate Technology (CT) in Munich, Magnusnussen was already interested in piezoelectric ceramics. He took part in an internal business-plan competition where he proposed the idea of using a new type of piezoelectric technology worked out at CT as a basis for the development of a cost-effective motor suitable for mass production. He then won the opportunity to work with a team of researchers at the Siemens Technology-To-Business Center (TTB) in Berkeley, California. “For me, that was the big chance to follow up on my project idea and implement it,” says Magnusnussen. The TTB helped put together a research team, covered personnel costs, and equipped a laboratory. “We also got extensive training and support in areas such as business development, patenting and starting a company,” Magnusnussen recalls.

After staying in Berkeley for a year and a half, Magnusnussen, who is now 35, returned to Germany. He brought with him not only his first prototypes, but also five TTB staffers. All of this was so convincing that he received three million euros in venture capital to start a company; half of it coming from Cologne-based Intelligent Venture Capital GmbH and half from a technology investment association in Bonn — both in Germany. Siemens currently holds 24.9 percent of Elliptic stock.

“We have a technological lead of at least two years — so no one is going to catch up with us quickly,” says Magnussen. Production of the first batch of miniature motors got underway in June of this year at Ceramics GmbH in Redwitz, Germany. He brought with him not only his first prototypes, but also five TTB staffers. All of this was so convincing that he received three million euros in venture capital to start a company; half of it coming from Cologne-based Intelligent Venture Capital GmbH and half from a technology investment association in Bonn — both in Germany. Siemens currently holds 24.9 percent of Elliptic stock.

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**On the Road to the Petabit Router**

If Internet traffic continues to grow at the current rate, it will soon be necessary to manage data flows of several terabits (10^{12} bits) or even petabits (10^{15} bits) per second. John Mansbridge is developing the equipment to do just that.

At Roke Manor Research, a Siemens business in the UK, John Mansbridge has developed a technology that makes it possible to manage incredible volumes of data with a minimum of hardware. The RyeCore LightBus system needs only 14 glass fibers to interconnect more than 100 transmission and receiving units in order to produce a total processing capacity of more than five terabits per second. A router that uses this technology and serves as a kind of switching system for the dataflows of the Internet requires less than one-fourth of the space needed by comparable systems and uses less than half as much power.

LightBus architecture can be scaled up to 1.3 petabits (1,300 terabits) per second, thus making it possible to expand capacity step-by-step in line with changing needs — cost-efficiently and without maintenance downtime. For more, see “Building the Unlimited Expressway,” page 35.

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**Modeling the Brain**

The human brain is increasingly serving as a role model for technical systems. Gustavo Deco is an expert in this area.

What exactly is happening in the mind of a person who is focusing intently on a particular object within a very complex environment? Which portions of the brain are interacting, and what processes are occurring? Such are the questions that preoccupy Dr. Gustavo Deco at Siemens’ research laboratories in Munich, Germany (see article on page 66). He has developed a model based on a comprehensive theory that makes it possible for the first time to study the brain at all three levels of neuroscience — psychology, neurophysiology, and neurobiology.

Deco’s goal is to transfer human characteristics and capabilities to applications in medicine and technology, or at least to imitate them. As a case in point, Deco’s research could contribute materially to improvements in robots’ visual perception, to the design of powerful video monitoring systems, to improved interpretation of magnetic resonance tomography images, and to optimizing automotive navigation systems that can very rapidly and accurately recognize highway edge lines and other road markings or obstacles.

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**Licenses in the Bag**

Negotiating patent licenses on the international market takes nerves of steel, negotiation skills, prudence and a clear understanding of your company’s strengths and weaknesses.

When Dieter Reinhardt crams hefty files into his briefcases — as he’s done so often in recent years — he can be sure of one thing: the trip won’t be boring. As chief negotiator and manager of the Siemens License Center, he conducts licensing negotiations with companies around the globe. Often this involves delving into the smallest details, and it’s not uncommon to spend days arguing over this or that passage in a patent. Particularly difficult are negotiations concerning the issuing of licenses related to new standards — like the UMTS standard in mobile communication systems — when each tenth of a percent in royalties amounts to millions of dollars. What’s more, those kinds of patents may be of interest to ten or more companies. This leads to an odyssey of negotiations spanning several continents that may last several years. “Some licensing negotiations resemble a Middle Eastern bazaar,” says Reinhardt as he describes these marathon meetings. “In addition to meticulous attention to detail, they also require imagination and a thorough knowledge of all the technology Siemens has to offer.” In many cases the whole issue turns out to hinge on a patent belonging to an entirely different Siemens Group. For example, a Siemens patent related to defense technology that reduces transmission power during transmission pauses — to prevent the transmitter from being localized — played a crucial role later in the development of mobile communication standards. It helped to reduce battery usage. “Tracking down that sort of thing is ultimately what makes our work interesting,” asserts Reinhardt, who passionately disagrees with those who consider this sort of work boring. And since there’s always an interest in recruiting highly qualified new talent, another fact should not be overlooked: “Because of the required double-track education, our job also pays well,” he points out. But even the sharpest patent lawyers don’t have to know it all. They’re supported by a globally accessible database that documents the progress of all patent activities and contains information about all patents available to Siemens.

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**Dieter Reinhardt, head of the Siemens License Center, is a master negotiator.**

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**Features**

Researchers and Patents

This is the seventh time Siemens has honored 12 Inventors of the Year. Altogether, these innovative minds have created more than 360 inventions ranging from automotive electronics to medical systems; from optical networks to computational neuroscience. The locations where these inventors work — Austria, Germany, the UK, the U.S. and Canada — reflect the extent to which Siemens is a “global network of innovation.”

We are pleased to take this opportunity to introduce two inventors in this issue’s featured fields — robotics and the internet.

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**One of the World’s Largest Patent Law Firms**

With more than 220 patent specialists — nine of them in the License Center — Siemens’ Intellectual Property Department ranks among the world’s largest patent law firms. The department has a very respectable track record in licensing patents. Since the License Center was established in 1999, well over 100 licensing projects have been started. Twenty of these have already been successfully concluded: About 80 are in various stages of contacting potential licensees, negotiations, preparing contracts and preparing lawsuits. The department’s experts predict that in a few years the annual volume of licensing agreements will be in the hundreds of millions of euros.

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**Gustavo Deco wants to develop technical systems that can process information just as efficiently as their biological counterparts.**
New materials will transform our world. For instance, carbon nanotubes, which are 50,000 times thinner than a human hair and 1,000 times more conductive than copper, hold the potential for replacing silicon-based semiconductor technology. Other revolutions in the making include carbon molecules as organic photo-detectors, ceramic components built like bones, “color-on-demand” LEDs, new membranes for fuel cells, and turbine coatings that can withstand the highest temperatures.

In an increasingly mobile, networked world, the key question will be “How can security be guaranteed?” Answers are being provided by researchers developing intelligent surveillance cameras and building monitoring systems, secure data transmission systems, and face, iris and voice recognition systems.

Healing is an intrinsic part of the practice of medicine. But wouldn’t it be better to prevent illnesses from developing in the first place? Efficient processes for detecting and eliminating dangers at an early stage not only prolong life, but also lower health-care costs. Examples of such procedures include the application of virtual endoscopy to gastroenterology and cardiology, 3D ultrasound, retinal measurements, and biochip analyses.