Robotica (2006) volume 24, pp. 529–537. © 2006 Cambridge University Press
doi:10.1017/S026357470600302X Printed in the United Kingdom

Reports and Surveys

1. Automation and Robotics Worldwide

1.1. Belgium

1.1.1. InsBot–Sociable mini-robot. The Director of the Social Ecology Laboratory at the Universite Libre de Bruxelles has described the success of a €3 million European Union (EU) experiment for pest control. Dr. Jean-Louis Deneubourg believes that the EU funded initiative has many ramifications for more than just pest control.

This Belgium-led research team has spent over three years developing a mini-robot that can convince cockroaches to come out of their dark holes and gather in light areas so that they can be successfully controlled or exterminated. The mini-robot is named InsBot and resembles an ordinary pencil sharpener rather than another cockroach. The key we are told to its success is that it smells like a cockroach and apparently can pass for the American cockroach (*Periplaneta americana*). The mini-robot has a cocktail of pheromones and molecules painted on its body. This allows it to infiltrate the cockroach community.

Experiments have shown that cockroaches are highly sociable creatures. Dr. Deneubourg writes that

> If you're out with a group of friends and you need to choose between two pubs that offer roughly the same advantages, you're in the same position as a group of 20 cockroaches choosing between two identical holes. Each cockroach, including the InsBot, has the same degree of influence. But we found that if the InsBot went to one hole and stayed there for 10 or 15 seconds, it would soon be joined by another roach. The longer the two roaches stayed in the hole, the more chance there was of them being joined by others.

This robot research project is called 'Leurre'—the 'Decoy'. The researchers believe that the project could expand and be applied to herds of animals. Further work is considering how the robot could be used to create 'intelligent nests'. This initiative may well assist in understanding how decentralised communities of beings, like cockroaches or ants reach collective decisions. The study of robotics is full of fascinating examples of the application of studies of nature to the design and production of systems. Nature has provided many solutions to our problems and the particular study, called biomimetics is currently receiving a great deal of attention in the scientific community.

1.2. Japan

1.2.1. The world's most lifelike robot?. Prof. Hiroshi Ishiguro of the Department of Adaptive Machine Systems of Osaka University, Japan, believes he has created the world's most lifelike robot.

It is called ReplieeQ2 and has the ability to 'seem to breathe' as well as talk and 'flutter her eyelids'. Using his daughter Risa as a model some five years ago, he began the development of a robot that would look like a human. Prof. Ishiguro regards the appearance of a robot as being of primary importance because it affects human's interactions. Simply studying the engineering element of robotics is not considered sufficient by this researcher. He has his own robot venture company Vstone. His team has produced an adult-sized android that looks like a Japanese television news presenter. Her face is perfectly copied using a 5 mm thick flexible silicone skin. Under the skin are sensors that make it more sensitive than a human and 42 actuators that translate electrical signals into mechanical motion. Compressed air is used to make her upper arms move like a human. It is important that all the 42 actuators are controlled to make a single motion that is 'human-like', since an individual does not make a movement in isolation.

The robot is able to go through a series of pre-programmed movements, but she can also 'see' quite independently and can turn her head to follow a person walking around the room. When the robot talks she moves her lips.

Readers will recall that the robot gave demonstrations at the World Expo 2005. The developers say that the robot shown at Expo 2005

> understood and responded to questions for directions to various attractions on the site and that in a test, 77% of people did not realise she was a robot, even when they were near.

This leads to another line of interesting research that examines the reactions people express when they meet a human-like robot that speaks and responds to their actions and reactions. The researchers are now engaged in a number of other projects including a robot called ReplieeQ3, which is a model of a human that has a full-body mechanism.

1.3. United Kingdom

1.3.1. Novel information systems.

1.3.1.1. Information system utilizes 'robot' agent. The UK National Health Service (NHS) has developed many sophisticated information systems often at great cost. A recent NHS report describes a new system for dealing with patients' complaints. It is an example of an online information system that can deal with aggrieved patients using computer software and in some cases resolve a complaint without resort to human assistance. The software has been developed at the Kingston University, UK, and although currently being modified is to be tested at the Royal United Hospital, Bath, UK.

Using the new system, the patients will be able to complain online, and the university developers claim 98% of their complaints could be settled. Use is made of a so-called 'robot agent' which informs the relevant hospital or doctor's surgery and decides how to investigate it. In relatively minor cases, such as criticism of car-parking facilities, the 'agent' may even be able to resolve the complaint online without human help. In more complicated cases, the 'agent' can hold meetings between the two sides in secure Internet chat rooms or by using video-conferencing. In the few remaining cases, we are told that the 'agent' can refer the complaint to lawyers.

The software system is called *MeDispute*. It was designed to speed-up the time it takes to deal with complaints and, of course, to avoid expensive court cases. It is basically aimed at getting rid of routine complaints. According to the software team, it carries out its function well.

The original technology upon which it is based was developed in France as part of a £1 million EU project to find ways of improving arbitration. The original programme has already been tested at the European Court of Arbitration.

Health trusts using the new system would be expected to review it after a reasonable time to assess its usefulness.

A British Medical Association spokeswoman believes that any changes that make it easier for patients to express their views and make valid complaints are to be welcomed.

1.3.1.2. Novel access to information system. A simple advancement in technology pioneered by the IT company *Magicomm* may well herald a change in the way we access our computing machines. *Magicomm* have produced a £100 pen, which in its application to Police service routine is likely to cut down the amount of paperwork, and provide more time to the officers to fight crime.

The pen is designed to work like a normal ballpoint but has a camera under the nib that records what an officer has written. The data is then sent by mobile phone to a central police computer where it is automatically converted into text. It therefore forms a very useful interface device for inputing data into an information system. The camera lens is only 5 mm × 3 mm in size and is quite unobtrusive.

The police personnel who have tested the device already say that by using it the officers are not required to return to the police station and fill information on the usual forms or spend time finger-typing data into a computer system.

We are told by the Dorset Police, UK, that officers typically spend a quarter of their time filling forms. The police department has purchased 30 such pens at a cost of £30,000 and have spent another £17,000 for developing the system. After being on trial for a year, the system is now being used permanently. The information system allows the pen to talk to a mobile phone via Bluetooth and a PDF file is then activated. It has, of course, the advantage that if any words are not recognised they can be checked with the handwritten notes and if it fails the original notes are still available.

Other such systems that are both aural and visual are also being developed. Currently, this system meets the requirement to store, access and process information in a more efficient way than the traditional means. It may well be that advances in the researches of those involved with pervasive computing and communication will in due course produce a more sophisticated system.

1.4. United States

1.4.1. Spin-offs from NASA enhance systems. The spin-offs from NASA research and development have in the past produced some very unusual applications. The space agency has now developed sensors that are capable of working out what someone is preparing to say even though the words are never spoken. If this can be successfully produced there must be a range of potential applications just waiting to be exploited. We are told in a NASA report that instead of the appearance of phrases, for example when spoken into a voice interface of a computer, they would appear on the screen without the human user uttering a sound. This silent input could be used with mobile phone systems where the unuttered words are converted into speech data and transmitted around the network. The era of the silent mobile phone call may well be at hand.

NASA designed the system to enable astronauts to communicate more easily with the earth from space. The agency has already tested the system with firefighters who need to stay in touch while working in noisy environments.

The space agency reports that

> The 'silent speech interface' reads electrical current between the brain and speech muscles as sentences are formed in the head. These signals can be detected by button-sized sensors under the chin and beside the Adam's apple.

Such a marketable system that simply lets people speak without moving their lips or even making a sound can make a very worthwhile contribution to human–machine research and development.

1.4.2. Electronic ink makes a breakthrough. The disadvantages of using computer screens for displaying information is that they are likely to flicker. This is an enormous disadvantage to anyone who wants to read any displayed information that extends to a fairly large number of frames. This is quite evident when electronic books or online journals are accessed and displayed on a normal computer screen. Soon the eyes are tired and a headache occurs.

A US company believes that it has the answer. The company, E Ink is an offshoot of the Massachusetts Institute of Technology, and it has developed an electronic ink that works by arranging thousands of tiny black and white capsules to form characters. The result they claim is a set of characters that are almost as sharp as a printed page. The screens on which they appear are bendable and paper-thin, but are not back-lit. The effect is achieved using less power and is free from flicker. A number of manufacturers are now beginning to use the system. March Seiko is producing a watch that can bend around the wrist and is said to be superior to a digital watch's LCD screen. Some companies are working on displays that can be rolled up like a newspaper. Sony is currently producing a 'reader device' that is the size of a slim paperback, but can store as many books as there are in a library. These are downloaded from the Internet. This device has a 6-in screen, weighs about 250 g and is able to allow 7500 display page-turns before the battery needs recharging. It costs about £198 ($349) and is being marketed now. This development has enormous possibilities for producing information systems of all descriptions.

2. Gait Recognition Systems

2.1. Automatic gait recognition

A report from the Electronics and Computing Department, Southampton University, UK, provides details of studies

https://doi.org/10.1017/S026357470600302X Published online by Cambridge University Press

that show that every person has a distinct walk. We are told that this is because of subtle differences in muscle strength, tendon and bone length, bone density, visual acuity, coordination skills, experience, body mass, centre of gravity, muscle or bone damage, physiological conditions, and a personal walking ‘style’.

Prof. Mark Nixon of the same department believes that

> . . . it is very difficult for someone to disguise the way they walk and they could still be identified whether casually ‘sauntering’ or ‘sprinting’.

Speaking to the *London Times* (No. 68748/2006) he said that his research team

> believes that gait recognition has advantages over facial mapping. Gait recognition could have significant implication for police where, for example suspects could be seen walking away from a crime scene but with their faces not visible.

2.2. *Current research*

Current research of this team has also shown that people would recognise someone they knew with 80% confidence. The Southampton researchers have built up a databank of images on volunteers to measure the differences in the way people move in order to test out their theories.

2.3. *Biometric tunnel*

Obviously, if this research is successful it will contribute greatly towards the discipline of biometrics. Movement patterns are caught by using a ‘biometric tunnel’ through which individuals can walk. In addition, studies of this nature can make valuable contributions to kinematics and other branches of science, particularly robotics. Progress in these fields has, of course, proved more fruitful in the last decade as a result of advances in computer technology and software engineering.

2.4. *Researches worldwide*

While this report has been concerned with progress in the United Kingdom, work in this area is being carried out worldwide, particularly in the United States, Australia, Japan and China. In the United Kingdom, backed by the Ministry of Defence and a grant of £500,000, scientists are working on projects of gait recognition that will allow the police and the courts to compare images captured on CCTV with the walks of suspects. In other researches, groups are experimenting with radar guns similar to those used to track speeding cars. In the United States, for example, a system has been developed that sends out a pulse of radar energy and receives reflected off signals from objects, so that when an individual walks the radar signals change and a gait profile can be formed. Different profiles are recognised and individual radar signatures are created that can be screened in the form of ‘matchstick’ type figures.

2.5. *Early developments*

It should be noted that although the techniques are still in a state of early development, they have been used successfully in a number of high-profile cases by the police, the law courts and the security services.

3. Global Investment in Robots

3.1. *Worldwide advances in robotics 2004–2008*

Reports from the United Nations Economic Commission for Europe (UNECE) Information Service, in conjunction with the International Federation of Robotics (1) provide us with an insight into the advances that robotics is making worldwide. The statistics included here are published in World Robotics 2005 (2) and updated in the following issue released in 2006 (3).

3.2. *Significant trends*

Significant trends are reported and the following are pointed out:

1. Worldwide investment in industrial robots was up 17% in 2004.
2. In the first half of 2005, orders for robots were up another 13%.
3. Worldwide growth in the period 2005–2008 is forecast at an average annual rate of about 6%.
4. Over 1,000,000 household robots are in use with several millions expected in the next few years.

3.3. *Global statistics*

After two years of reduced demand for industrial robots, a strong recovery has already begun in 2003 with a growth of 19% all over the world. In 2004, again 17% more robots were sold compared to 2003. This was the result of a strong demand in all Asian markets and robust growth in Europe and America.

In 2004, more than 52,000 robots were supplied to the Asian countries (including Australia and New Zealand), almost 29% more than 2003, as a result of strong investments within the automotive industry and the electrical/electronics industry.

After two years of falling sales in Japan, a sharp recovery already started in 2003 when the market grew by 25%. In 2004, the increase of installations continued: about 37,100 units, 17% more than in 2003, were sold in Japan. Robot installations in the automotive industry as well as in the electrical/electronics industry surged by 42 and 64%, respectively. An increase of about 16% was recorded in the motor vehicle industry, while in the automotive parts industry, installations surged by 64%.

Installations in the Republic of Korea also increased by 17%, mainly due to investments by the combined branches of the automotive industry (motor vehicle producers and parts suppliers). The installations in the other Asian markets including China, India, Indonesia, Malaysia, the Philippines, Singapore, Thailand and Taiwan (Province of China), surged by an average of about 125%. Most of these markets are still relatively small, but are gaining importance as a result of expanding investments by the automotive industry.

In North America (United States, Canada, Mexico), the number of installations increased by 6% in 2004, to more than 13,400 units, the highest sales of multipurpose industrial robots (strictly defined) ever recorded. After reaching a peak level of 13,000 units in 2000, sales dropped in 2001 and 2002 to just under 10,000 units. In 2003, however, there was a sharp recovery; the market expanded by 28% to about 12,700 units. In 2004, North America was the second largest market for robot installations, although behind Japan but just ahead of Germany. Automotive parts manufacturing and other industries were responsible for the growth, while car manufacturers did not increase their robot investments.

In Europe, sales of multipurpose industrial robots rose by 18% in 2000 to 30,600 units. In 2001, sales continued to grow, but only by a modest 3% reaching 31,600 units. In 2002, the market fell by 15% to 26,700 units. In 2003, there was a slight recovery of 4% to 27,800 units. In 2004, again, modest growth of 5% was achieved to about 29,300 units. Installations in the automotive industry as a whole—the most important customer for industrial robots in Europe—increased by 5%. However, whereas investments by automotive parts suppliers surged by 23%, end-manufacturers of motor vehicles decreased theirs by 6%. Other industries recorded remarkable increases in robot investments. Sales to the chemical industry surged by 72%, the machinery industry by 22% and the food industry by 24%. In Europe, more robots were installed in the food industry than in both America and Asia. The share of total supply here was more than 3% in Europe, and under 1% in America and Asia.

3.4. Europe and North America catching up with Japan

The survey reports that Europe and America are rapidly catching up with Japan. It says that in the early 1990s, installations of multipurpose industrial robots in Europe and North America only totalled about 25 and 7%, respectively, of Japan's installations of (all types of) industrial robots. Following more restrictive reporting by Japan, recent data shows that in 2001–2002 more multipurpose industrial robots were installed in Europe than in Japan. However, since 2003, the market in Japan has again increased compared to that of Europe.

Looking at the operational stock of industrial robots, and again comparing Japan's stock (to which all types of robots were added up to and including 2000) of multipurpose robots with that in Europe and North America, the same pattern prevails: the European stock rose from 34% of that of Japan in 1994 to 78% in 2004. The corresponding figures for North America were 13 and 34%, respectively.

3.5 Stock of industrial robots

An estimate of the worldwide operational stock of industrial robots was made. This indicates that

1. Total accumulated yearly sales measured since industrial robots were introduced into the industry at the end of the 1960s, amounted at the end of 2004 to some 1,500,000 units, including, as mentioned before, the dedicated industrial robots installed in Japan up to and including 2000. Many of the early robots, however, have by now been taken out of service. The stock of industrial robots in actual operation is therefore lower.
2. The estimate by UNECE and IFR is that the total worldwide stock of operational industrial robots at the end of 2004 is between a minimum of 848,000 units and a possible maximum of 1,120,000 units.

The minimum figure given here is based on the assumption that the average length of service life is 12 years. A UNECE/IFR pilot study has indicated that the average service life might in fact be as long as 15 years, which would result in a worldwide stock of 1,120,000 units.

When the minimum 2004 stock of almost 848,000 units is compared with the 800,000 units at the end of 2003, it represents an increase of 6%. Japan accounts for just under half the world's robot stock—largely because the Japanese figures include all types of robots. Its share is, however, rapidly diminishing.

3.6. Forecasts for 2005–2008

In the near future, the reasons for investments in robots are

1. to save costs;
2. to increase productivity;
3. to raise quality;
4. to remain competitive in a global market;
5. to transfer dangerous and laborious work from man to machine.

In 2004, the demand for robots among the end-producers in the motor vehicle industry decreased, while it increased in the automotive parts industry. During the last few years, motor vehicle suppliers have found it difficult to increase sales in the big, traditional markets, especially Western Europe, US/Canada and Japan. Neither new model offensives nor special sales discounts have succeeded in fundamentally changing the demand. In the last two years, the new model strategy has caused an increase in investments in new production sites and in reorganisations of the existing plants. This brought about high levels of investment by automotive parts suppliers in 2004, which has apparently been continuing into 2005. From 2006, the saturation of the automotive market in the countries concerned may affect the demand for robots. Although there is still a large market for replacement investment, the number of new robot installations in the automotive industry could be flat in these regions.

3.6.1. Robust growth in worldwide robot installations. Between 2005 and 2008, a robust growth in robot installations worldwide can be expected. Although demand for robots within the automotive industry in Europe, North America and Japan may decrease, there is still a growing demand in all the developing markets in the world. Installations in general industry—especially the packaging industry, the food industry, the rubber and plastics industry and the machinery industry—will grow all over the world as a result of technical developments. Improvements in robot technology, such as new control systems and safety systems to permit interactive operations of man and machine, as well as improved sensor technology and robot-vision applications, will further promote robot installations.

The world market for industrial robots is projected to increase from 95,400 units in 2004 to 121,000 in 2008, or by an yearly average of 6.1%.

3.6.2. Sales in Japan. Between 2004 and 2008, the yearly sales are projected to increase from 37,100 units to some 45,900 units. In 2005, a continued expansion of sales in Japan will be driven by a strong demand from the automotive industry taken as a whole (i.e. including parts suppliers) even with a small reduction in the supply to the electrical/electronics industry. During 2006–2008, a demand for replacement investment and an increase of installations in new applications will ensure the sustenance of robust growth.

3.6.3. Robust growth in North America. The market in North America will surge in 2005 thanks to investments by the automotive industry. Japanese motor vehicle suppliers, in particular, will increase their capacities in the United States as a result of increasing sales, which have seen them gain market share from their American competitors. In Mexico, huge investments by the motor vehicle suppliers as well as the automotive parts suppliers are being made. Between 2004 and 2008, sales are projected to increase from 13,400 to 16,500 units, an yearly average of 5.3%.

3.6.4. Slow increase in sales in Europe. The robot market in Europe is expected to grow from 29,300 units in 2004 to over 33,700 units in 2008, representing an average annual growth of 3.6%. In Western Europe, the investments of the motor vehicle industry will decrease, while in the Eastern European countries, sales will increase at the above-mentioned average rate. There will still be a growing demand from the automotive parts suppliers in 2005 and 2006. Increased installation in the non-automotive sector will not compensate for the falling demand from within the automotive industry as a whole. In 2004, 60% of all new installed robots were still supplied to the motor vehicle industry including automotive parts suppliers.

3.6.5. The operational stock of industrial robots continues to grow. In terms of units, it is estimated that the worldwide stock of operational industrial robots will increase from about 848,000 units at the end of 2004 to 1,000,000 at the end of 2008, representing an average annual growth rate of 5.3%. It is interesting to note that the operational stock of robots in Japan decreased for the first time in 1998. In 1999–2001, it decreased at an even higher rate. In 2002 and 2003, however, the rate of decrease slowed down significantly. In 2004, for the first time since 1998, the Japanese robot stock increased again.

In North America, the operational stock of multipurpose industrial robots is forecast to reach 156,000 units in 2008. The projection for Europe is 348,000 units out of which 151,000 units are projected for Germany, 66,000 for Italy, 36,000 for France and 14,000 for the United Kingdom.

These estimates of stock data represent minimum figures. Assuming a longer average service life of robots (15 years instead of 12 years) would significantly increase the estimated stock.

3.7. Increased automation and its effect on society

3.7.1. Measurements of robot density based on the total number of persons employed. In 2004, Japan had the highest robot density with 329 robot installations per 10,000 employed in the manufacturing industry. The Japanese operational stock of industrial robots still includes all types. Therefore, the rate is overestimated compared to other countries. However, Japan has the most automated industry in the world. It is followed by Germany with a robot density of 162. The Republic of Korea also counts all kinds of industrial robots; therefore, the rate of 144 seemed to be overestimated. Italy has a robot density of 123, followed by Sweden with 107, Finland with 86, Spain with 81, and France with 78 robots per 10,000 employed in the manufacturing industry. The United States has a robot density of 69.

Despite this large range in the robot densities of the European countries mentioned, it is interesting to note that the robot density in Europe is about 25% higher than that in the United States.

3.7.2. Robot densities—1 robot per 10 workers in the motor vehicle industry. Regarding the data on the number of multipurpose industrial robots per 10,000 production workers in the motor vehicle industry, Japan and Italy are in the lead with almost 1600 robots per 10,000 workers, but, bearing in mind that Japan includes all types of robots (up to and including 2000), it is not comparable with the densities of other countries. Thereafter follows Germany with a density of 1140, France 1030, Spain 870, United States 800, United Kingdom 680 and Sweden 610. The technological level with respect to robotics is thus rather homogeneous in the motor vehicle industry in most of the above-mentioned countries.

3.7.3. Installations of advanced multipurpose industrial robots by types. In 2004, 62.5% of the installed robots were articulated robots, 14.5% linear/Cartesian/gantry robots, 9.7% cylindrical robots and 11.6% Scara robots. About 59,600 articulated robots were installed in 2004. About 90% of the installed robots were articulated in America, 74% in Europe and only 49% in Asia. However, in terms of units, most of the articulated robots were supplied to Asia, which is about 25,500 or 43% of the total supply of articulated robots. In Europe, 21,800 articulated robots were installed, which is about 37% of the total supply. Articulated robots are all-purpose robots. They are used in nearly all industries. The main operations of articulated robots are welding and handling, but they also operate in dispensing, assembling and processing.

3.8. Where and how are robots used?

The UNECE/IFR survey (2005b) provides data about the sales of service robots broken down by the application area.

3.8.1. Service robots for professional use: 25,000 units installed up to the end of 2004. With 5320 units, underwater systems accounted for 21% of the total number of service robots for professional use installed up to the end of 2004. These were followed by cleaning robots and laboratory robots with 14% each, and construction and demolition robots with 13%. Medical robots and mobile robot platforms for general use accounted for 11% each. Field robots, e.g. milking robots and forestry robots, had a share of nearly 9%, and defence, rescue and security applications had a share of 5%. Minor installation numbers were counted for logistic systems (270 units), inspection systems (235 units) and public relation robots (20 units). The value of the stock of professional service robots is estimated at $3.6 billion.

The unit prices for professional service robots differ significantly—from less than $10,000 to more than $300,000, depending on the type of application. The most expensive robots are underwater systems (from $300,000 to more than $1,000,000), medical robots (from $100,000 to $1,000,000) and milking robots ($200,000).

3.8.2. Service robots for personal and private use. About 1.2 million units for domestic use and more than 900,000 units for entertainment and leisure have been sold up to the end of 2004. Service robots for personal and domestic use are recorded separately, as their unit value is only a fraction of that of many types of service robots for professional use. They are also produced for a mass market with completely different marketing channels.

So far, service robots for personal and private use are mainly in the areas of domestic (household) robots, which include vacuum-cleaning and lawn-mowing robots, and entertainment robots, including toy and hobby robots. Sales of lawn-mowing robots have started to take off very strongly, with sales in excess of 46,000 units, and it is expected to boom further. The market potential is very large. The vacuum-cleaning robots were introduced into the market at the end of 2001. The market expanded rapidly in 2002–2004 and at least one million units have been sold.

Of the 1.2 million robots for domestic household work that were in use at the end of 2004, about 550,000 were installed in 2004.

3.9. What are the future projections?

3.9.1. Projections for the period 2005–2008: 50,000 new service robots for professional use to be installed. Turning to the projections for the period 2005–2008, the stock of service robots for professional use is forecast to increase by some 50,000 units. Application areas with strong growth are humanoid robots, underwater systems, defence, rescue and security applications, laboratory robots, professional cleaning robots, medical robots and mobile robot platforms for multiple uses.

3.9.2. Projections for the period 2005–2008: About 7 million units of service robots for personal use to be sold. It is projected that sales of all types of domestic robots (vacuum-cleaning, lawn-mowing, window-cleaning and other types) in the period 2005–2008 could reach some 4.5 million units with an estimated value of $3 billion.

The market for entertainment and leisure robots, which includes toy robots, is forecast at about 2.5 million units, most of which, of course, are very low cost. The sales value is estimated at over $4.4 billion.

3.9.3. Further information and reading.

[1] UNECE/IFR—United Nations Economic Commission for Europe (International Federation of Robotics (Statistical Department), *2005 World Robotics Survey—Summary* (UNCE Information Service, Geneva, Switzerland, 2005).

[2] UNECE/IFR, *World Robotics 2005: Statistics, Market Analysis, Forecasts, Case Studies and Profitability of Robot Investment* (United Nations Economic Commission for Europe and International Federation of Robotics, Geneva and Frankfurt, 2005) (also as Interactive CD-Rom).

[3] *World Robotics 2006* —published by the UNECE and the IFR, is in preparation for publication in the Autumn 2006. The quoted summaries are produced from statistical data obtained using software and databases created by the UNECE and produced by the IFR Statistical Department.

4. Information Gathering Systems

4.1. New technology a challenge to society?

Governments, companies and organisations of all descriptions now demand the right to use modern technology to collect information, with or without the permission of the individual. This is an issue that can be pursued by the many concerned research groups that are investigating the effects of advances in technology on society.

Current technology allows the chip in its various forms to be the kingpin of new information-gathering systems. Some of these innovative systems are described in the following sections.

4.2. Hidden surveillance chips

When a Professor from Washington University, St. Louis, USA described the new ‘tagging’ chips that supermarkets are now experimenting with, we become aware that we could soon be monitored both in a store and outside it. The tags would give the companies the power to ensure that all items were individually ‘numbered, identified, catalogued and tracked’. The report claims that

> If you have one in your jeans, it could trigger an advertisement to play when you walk past a shop. Once it is in a product it is there and it can always be read. There is no legalisation which says that a customer should be notified when a product is tagged.

Once implanted, the chip offers a potential to track items. For example, when embedded in a pair of shoes they could be linked to the original purchaser whenever they pass a scanner.

We are told that the technology is already in use in some supermarkets and is being used in a wide range of products and services.

Some suppliers say that they have no plans to use the technology for customer profiling or for monitoring products after they have been bought. But the system has been used already to activate CCTV cameras each time packs of razor blades were moved, by a well-known chain. The aim this time was to deter shoplifters. Another major shopping chain uses tags to monitor items in store and claims that they are removed at the checkout.

We are told that Michelin has embedded chips in tyres, and that Oyster tickets issued for transport in London are used to record a passenger’s movements around London. It is also claimed that some banks have embedded the chips in credit cards. Since a tag only costs some 20p at present, this is a very good investment for any organisation that wishes to secure a product or gather information about its use and whereabouts. Developers of the systems say that surveillance chips

1. have the potential to trace the life of goods from manufacture to the refuse tip;

2. are based on radio frequency identification (RFID) tech–nology;
3. will replace barcodes probably by 2015.

The miniature tags contain silicon chips and antennas that transmit information to a receiver very much as the listening 'bugs' used by the security services. The variety of tags that are described as passive do not require any power source such as a battery but when they are targeted by a radio signal they produce a small electrical charge that can carry out the transmission of data.

The arguments about their use are just starting to hit the supermarkets and service companies. Customer groups object that detailed data about shoppers is being built up without their consent. Many want the tags deactivated after the product is purchased and ask for shops to guarantee that this has taken place.

The information-gathering systems may be in their infancy and the public as yet unaware of their existence but when their potential is understood there may well be strong objections and demands for control on their use.

4.3. Tags that affect the workplace—Monitoring the worker

One of the most controversial uses of information monitoring has to be the applications that are now occurring in the workplace. When workers are asked to wear a wrist or ankle tag, a whole host of problems arise. Not the least of these is the reaction of the various unions that soon become involved. The question has been asked: 'Does a wrist tag make your time at work more productive, or does it turn you into some kind of robot?' The innovative monitoring systems are now being introduced in warehouses and distribution centres with employees made to wear electronic wrist tags to monitor their actions. Ankle tags are not so popular in the United Kingdom and the United States because of their use in monitoring released prisoners. Essentially, these are surveillance tags that pick up satellite signals and tell employees to carry out tasks while being monitored for the time taken and movements in the area. The term 'battery farm' is already being used to describe such monitored workplaces.

A report that Dr. Mike Blakemore of Durham University, UK, compiled for the GMB General Union says that

> the use of the wearable satellite devices was growing throughout the logistics industry and had escalated in the past few months.

The GBM has estimated that

> between 5000 and 10,000 workers are asked to wear the mini-computers, which is triggering walkouts and a rise in staff turnover. The technology is in use in warehouses and distribution points at more than 30 locations from Aberdeen to Maidstone. Companies that use the devices include Tesco Marks & Spencer, Sainsbury's B&Q, boots and Homebase.

Dr. Blakemore's report also informs us

> that the electronic tagging was one stage along a process towards full automation of certain jobs.
>
> If automated picking machines can be produced that have the sophistication and flexibility of human fine motor control then one human advantage is removed.
>
> The use of headsets, voice recognition, arm-mounted wearable computers in effect make the humans become an extension of the information systems that drive the supply chain. The information system plans the best route for the human to take.

We are told that this technology, which is now in the process of spreading worldwide, originated in the United States. Wearable devices are not new but their increasing use in the workplace does cause concern. Not all unions and their workers are perturbed by their introduction in their present form. At one centre in Wales, UK, some 28 workers have been fitted with the devices and we are told that they are a great success, which has had a positive impact on the morale, and has lead to efficiency and improvements.

Prof. Blakemore's report also indicates that

> since the specific location of all products are known the system can be programmed to estimate the amount of time the human takes to obtain the products, and can build the item-by-item information into an asset-tracking process that provides continuous and comprehensive performance information for managers.

4.4. Innovative chip implants

As a result of this new technology, more and more applications are emerging, In fact, embedding or implanting a chip in humans, animals or indeed any object that needs to be monitored is now a universal operation. Some of these applications are included in the following sections.

4.5. Scientists at Imperial College, London

The United Kingdom have invented a device they believe will enable hospital patients and others to lead a normal life while being kept under constant watch from implanted computerised sensors. The sensors detect tiny changes in metabolism, and transmit data via a mobile phone to the patient's doctor or health centre.

4.6. The aviation industry

The aviation industry is using the RFID technology to cut the number of baggages lost or stolen each year. A pinhead-sized chip is embedded in the baggage label that can then be read by hundreds of sensors dotted around an airport, tracking the suitcase from check-in to the arrival carousel. This is known as the 'tag and beacon' technology and is already a well-tried system used in car congestion schemes in Singapore and in Stockholm, and has also been tested at a number of airports. It will replace the barcodes currently in use. Some 200,000 bags are lost or stolen each year while an estimated 30 million go missing but are later recovered.

5. Innovations

5.1. Robot helikite

An event held at the UK's Science Museum, London (2006), was organised to 'produce a fun-filled entertaining show for families' based on the field of robotics. Known as *Roborama*, it aimed at challenging and stimulating public thinking about the latest developments in robotics. Researchers from the United Kingdom described many of the fascinating projects now being tackled not only in the United Kingdom but also worldwide. New ideas were propounded and many of the

https://doi.org/10.1017/S026357470600302X Published online by Cambridge University Press

latest developments presented. One interesting report was given by a team of researchers involved with planetary robotics at the University of Wales, Aberystwyth, UK. The team had previously been concerned with the development of a robotic arm on the space probe Beagle 2 that was lost on its approach to Mars in 2003. They introduced their designs for a 'robot' helikite, which they believe will be able to work in extreme environments such as Mars. A helikite we are told is a cross between a hot air balloon and a kite. Tethered by a line to a robot-rover unmanned vehicle, it will be able to lift a small set of scientific instruments to approximately half a kilometre above the surface.

The team explained that the design is

1. based on an earlier commercial development and has included a gondola which could carry equipment to measure atmospheric conditions;
2. able to house an on-board camera for autonomous navigation of the rover;
3. backed by *Techniquest* —a project development initiative of the North East Wales Institute (NEWI), UK.

If it comes to full fruition, the project should result in the development of a revolutionary 'birds' eye' way of plotting the movements of the robot-rover exploration buggy as it travels over the surface of Mars or indeed on any terrain.

5.2. Smart shirt

A new market product has been introduced by *Sensatex*, a US-based company. Known as 'Smartshirt', it consists of a cotton shirt that is machine washable and, the producers say, monitors everything from your heartbeat to your location.

The manufacturers describe their product as follows:

1. It is able to monitor movement, heart rate, breathing rate and energy use.
2. It is made of lightweight cotton and contains a grid of flexible fibres in contact with the skin.
3. The sensors in the fibres can pick up electrical signals from the chest.
4. The sensors have the facility to transfer collected data to a personal controller unit held in the shirt's pocket.
5. It can be fitted with a GPS device to detect the wearer's location.

This, in essence, means that any information collected such as the wearer's vital signs can be beamed to a computer several hundred yards away and be transmitted to any other location. The sensors fitted include accelerometers or motion sensors, which are able to detect and analyse movement in 3D. Temperature sensors can be fitted, which can measure the amount of heat generated and consequently the energy burned by the wearer. There are many obvious applications such as athletics coaching, monitoring patients after an operation, identifying fatigue in public service drivers and private motorists. The producing company says that the shirt has already been tested with firefighters in Virginia, US, with further trials planned for 2006–2007.

5.3. Minute remote-controlled robot

Researchers at Dartmouth College, US, have highlighted what they claim is the world's smallest untethered, controllable robot. The device measures a hundredth of an inch by one four-hundredth of an inch. We are told that

> The robot contains no motors or circuitry. Rather, it is a carefully carved piece of silicon that moves across a special surface that contains an embedded electrical grid. The main rectangular piece has one edge bent downward; from the side, it looks like an L that has toppled forward.

Prof. Bruce R. Donald of Dartmouth's Department of Computer Science is the leader of the research team that has produced this microrobot. He describes its functions as follows:

> When an electrical voltage is applied, the silicon buckles, and the long leg of the L is pulled down against the surface. When an opposite voltage is applied, the silicon rectangle pops back and pushes the robot forward. It crawls along like an inchworm.
>
> At top speed, the robot zooms around at nearly a hundredth of an inch a second.
>
> To turn the robot, a stronger voltage pulse lowers an arm extending off one side of the rectangle. At the end of the arm is what looks like a tiny lollipop with a pointy thorn at the centre. The lollipop snags the surface, and the robot runs in circles around it. Another pulse lifts the arm, and the robot heads straight again.

The researchers say that more sophisticated versions of such robots may in the future be used to inspect or repair chips or to interact with individual cells.

Microrobots are already being designed for applications in biomedicine. Such a minute remote-controlled robot, which is hardly bigger than a piece of household dust could well form the basis of such systems. The research team at Dartmouth College has indicated that such robots of different shapes could snap together to build larger structures.

More details of this research project are to be published in the *Journal of Microelectromechanical Systems* in 2005–2006.

5.4. Underwater robots that imitate real fish

Dr. Huosheng Hu of Essex University, UK, has designed and built a carp-shaped robot, with an artificial intelligence system that has the ability to control itself autonomously. Three such carp-like fish are destined for the London Aquarium, UK. They swim around the aquarium in an 'intelligent' fashion, navigating to avoid each other and any other real fish or obstacles. Prof. Hu says that at the next stage of his project the robot fish will be capable of finding a station to recharge themselves.

The research project has taken the team of scientists at Essex University over three years to develop the new cyberfish. They claim that their fish are the most intelligent yet. The researchers have chosen the carp, which is common in the United Kingdom as their inspiration. Their cyberfish has bright scales that reflect light and house-embedded sensors to make them completely autonomous and AI-based. They swim in a specially designed tank mingling with real fish. The new breed of fish are now a major attraction in London. The inventors are already answering the question 'What are they for?' Although at present, they are a source of attraction only for the aquarium visitors, but they might be used to explore the seabed, or detect leaks in underwater oil pipelines or even act as undercover underwater secret agents some day.

6. Software that can Sense Emotion

6.1. Criteria for software design

The task of producing a computer system that can sense and possibly analyse emotions has been attempted earlier. So far, success in this endeavour has been very limited. Such a system could be embedded in machines and robotic devices. The main task is to define the criteria to be used and link the human brain by a software to a computing system that can process one's thoughts and feelings. It is, however, seen as a challenge for the software engineer who simply needs the data from a human being that can be analysed by a clever program. The first task is to decide what data is required from the human that would indicate a change of mood or an emotional state. Capturing the chosen data is another problem. The final task is, how the data is to be analysed and what criteria are to be used to measure it and analyse the information received. Since the information is obtained by the interaction of the human with the computing machine, it will be constantly changing in the same way as the 'mood' swings occur, sometime violently but at other times more subtly. The benefits of producing such a system are enormous and the applications wide ranging.

6.2. Developing the project

Recently, a report from the Fraunhofer Institute for Graphics Data Processing, Rostock, Germany, gave details of a system, which, it is claimed, monitors and reacts to the mood of the operator. Scientists have tackled the problem of collecting data about the computer user's mood by fitting monitoring equipment into a special fingerless glove that can be worn by anyone using the computer. The research and development team at Fraunhofer Institute says that

> they have taught their program to recognise the physical signals, such as cold hands and sweaty fingers, that warn when the operator is beginning to feel stressed. Heart rate—another reliable stress alert—is measured with a conventional heart monitor.
>
> Soon other symptoms, including changes in voice pattern and even facial expression, will be picked up by microphones and cameras feeding information into the computer.

The data collected from the monitoring equipment in the glove is received by the computer's emotion-recognition program. This software is capable of analysing what it has been fed with and also capable of identifying changes that warn of stress. Having picked up the changes, the system can then take action. It has, for example to decide whether to intervene and how to handle this. If only slight changes are detected then the intervention might calm things down before the stress explodes into fury. The program reactions are geared to the data, and the responses are made accordingly. In developing this software, the response can be sophisticated but is obviously dependent on the quality of the data and, of course the analysis criteria devised.

It should be noted that this system is devised to deal with stress alone. Developing emotionally intelligent machines is another matter, and the data capture and analysis software would have to be highly sophisticated. It requires both, a study of the human brain as well as a high system expertise.

6.3. Applications of the software package

The invention of the Fraunhofer researchers led by Christian Peter may result in the production of a new generation of desktop machines that can monitor the stress of their operators while allowing normal computer usage. Obviously, the software and the special glove could be used on any linked terminal. In its present form, it can recognise the early signs of stress and show a pre-programmed reaction. Some employers will require their systems to be shut down, others will wish some calming measures be built into the system. There is plenty of scope for producing tailor-made systems. To this end, the system is being shown at various trade exhibitions and was demonstrated at the CeBIT International Trade Fair in Hanover in March 2006.

6.4. Testing the criteria

If a computer system can tell whether we are happy or angry, full of frustration, even shaking and hitting the machine, it is desirable to be certain that the criteria used is indeed valid. This means that the methods used and the technology that captures data about a computer user are fully evaluated before being used to assess the mood or emotional state of a human.

6.5. Future developments

The researchers developing this software cannot ignore the progress being made in artificial intelligence. While it appears possible that a working system can be marketed, the target will obviously be a sophisticated program that can be transferred to other systems and applications. Whether such a package can be adapted to wider applications such as robotic initiatives remains to be explored.

Acknowledgements

I would like to thank Prof. J. Rose, the founder editor of *Robotica*, for the opportunity to compile this section over the last 23 years. His encouragement and advice is very much appreciated.

Dr. C. J. H. Mann has assisted in this work too, and my thanks are due to her for the painstaking researches she has carried out.

Finally, *Robotica* will, of course, continue to lead the field under its new editor, and I wish him and the CUP staff every success in their future endeavours.

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https://doi.org/10.1017/S026357470600302X Published online by Cambridge University Press