Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Federal Department of Defence, Civil Protection and Sport (DDPS)
armasuisse
Science and Technology S+T

DEFTECH Newsletter

January 2017

Dear Reader,

This document summarizes emerging technology signals related by Strategic Business Insights' (SBI) Scan and Explorer services that the Technology Foresight Research Program from armasuisse Science + Technology subscribes to.

For each trend, we try to anticipate what could be the implication for the armed forces. Each trend is also related to the original signal of change elaborated by SBI that the interested reader finds at the end of this document.

The intent is to stimulate strategic technology forward thinking in a form that is pleasant and quickly readable.

We hope you enjoy the journey!

Best regards,

Dr. Quentin Ladetto
Research Director – Technology Foresight

P.S. As improvement is a non ending and continuous process, please don't hesitate to provide your suggestions to quentin.ladetto@armasuisse.ch

SCAN - November 2016

Alluring Reality: Augmented-reality (AR) and virtual-reality (VR) technologies capable of enhancing reality could improve people's health—both physically and mentally.

Implication for Defence and Security: *AR and VR could improve the wellbeing of defence personnel during long stints in hostile environments. For example, AR can make one's surroundings more enjoyable via gamification, or VR could be used as a form of escapism.*

Timing of Implication: ***now****/5 years/10 years/15 years*

Intelligent Cameras: Companies such as Cisco Systems, Honeywell Security Group, and IBM are developing intelligent cameras—internet-connected cameras that use artificial intelligence (AI) to observe and interpret what the camera sees.

Implication for Defence and Security: *New types of intelligent cameras could aid surveillance tasks. Intelligent camera technology may also contribute to autonomous and semi-autonomous weapon systems.*

Timing of Implication: *now/****5 years****/10 years/15 years*

Machine Learning for Robotics: AI researchers are working to close gaps in robot education. Multimodal learning—such as robots sharing their learning with one another, or placing robots in virtual environments—might be the best way to train robots.

Implication for Defence and Security: *The ability to teach robots how to perform different actions and how to act in different environments is important within military and security robotics. This learning ability will enable robots to improve with experience and training and to adapt to changing requirements.*

Timing of Implication: *now/5 years/****10 years****/15 years*

Medical Origami: Researchers are applying folding techniques in a variety of medical applications. Examples include a cardiac catheter that folds to be small enough to navigate a patient's blood vessels, and an ingestible origami robot that could use its folded structure to move to a desired location in the digestive system and perform tasks, such as release a medicine.

Implication for Defence and Security: *Light and compact medical equipment is highly desirable in military operations for treating injuries.*

Timing of Implication: *now/5 years/****10 years****/15 years*

Multi-Skilled Robots: To date, efforts to integrate multiple skills into a single robot have seen only moderate success. General-purpose robots will likely need to possess a range of basic skills, including voice recognition, object recognition, object grasping and manipulation, localization, and mobility control.

Implication for Defence and Security*: Robots that can perform a number of functions are important not only because they can serve multiple applications but also because they can react to changing situations more easily.*

Timing of Implication: *now/5 years/**10 years**/15 years*

Transparency in AI Decision-Making: Neural network software, including most deep-learning software, and machine-learning algorithms often give correct answers on tests but rarely show their work. Concern is mounting about whether big-data algorithms could be unfair and discriminatory. The AI research community is addressing the need for explanations.

Implication for Defence and Security*: Some defence decisions require justification to government organizations and to the public. As AI applications advance and are increasingly adopted, ensuring transparency in AI decision-making will help justify its use in military contexts.*

Timing of Implication: *now/5 years/**10 years**/15 years*

SCAN - October 2016

3D Printing Advances: New developments could see the pairing of 3D-printing technology with robots to enable advanced manufacturing applications. Developments include HP's 3D printers that can print many of their own components, and Siemen's 3D printers that move around their environment and work together to print a single object.

Implication for Defence and Security. *3D printing enables military organizations to create components and equipment necessary for specific situations or machinery, even when in remote locations. Improvements in 3D printing are beginning to make the technology more flexible and capable than in the past.*

Timing of Implication: *now/**5 years**/10 years/15 years*

Automating Transportation: Efforts to develop semiautonomous or fully autonomous versions of multiple types of vehicles are moving along surprisingly rapidly. Truck manufacturers are developing systems for heavy trucks that will enable semiautonomous *platooning*—vehicles travelling very close to one another at high speeds in highly coordinated groups. Companies are also offering retrofitting services to make trucks semiautonomous.

Implication for Defence and Security: *Retrofitting vehicles with autonomous driving capabilities saves costs by enabling defence organizations to use equipment they already have. Using autonomous vehicles together can make controlling their formation easier and improve the efficiency and effectiveness of transportation.*

Timing of Implication: *now/**5 years**/10 years/15 years*

Hearables: Apple, Samsung, IBM, and various start-ups hope to turn headphones into smart computing devices. Hearables add sensors to conventional wireless headphones (sensors in Bragi's Dash include an optical heart rate monitor, an accelerometer, a gyroscope, and a magnetometer). Hearables integrate with smartphone apps, and some also carry onboard applications.

Implication for Defence and Security: *In-ear communications already play a major role in defence and security. The addition of sensors, apps, and intelligent assistance could increase the capabilities of these devices and make them even more useful.*

Timing of Implication: *now/**5 years**/10 years/15 years*

New Ways of Hacking and Spying: In the past, malicious actors required digital access to a device to hack it. Today, researchers and cybersecurity experts are uncovering alternative ways to access information on digital systems unbeknownst to the systems' users. These alternative ways include gaining access to information via side-channel signals, crossing air gaps between equipment through electromagnetic noise, and recreating sounds from silent video by analyzing objects in the footage.

Implication for Defence and Security*: Novel methods of accessing digital information represent both threats to, and opportunities for, defence organizations. Keeping ahead of the current abilities of hackers and other potential threats is important.*

Timing of Implication: ***now****/5 years/10 years/15 years*

The Portable Medical Lab: Emerging portable diagnostic devices and point-of-care diagnostics could improve disease detection.

Implication for Defence and Security*: Diagnosing diseases in the field helps to accelerate their treatment. The increasing portability and ease-of-use in these diagnostic tools could one day make them a standard piece of military equipment.*

Timing of Implication: *now/***5 years***/10 years/15 years*

Renewed Interest in Fuel-Cell Vehicles: Fuel-Cell Vehicles (FCVs) typically use hydrogen as fuel; fuelling infrastructure limitations have restricted the uptake of FCVs, but these limitations are slowly being overcome. Industrial-gas manufacturer The Linde Group is launching an FCV sharing program to encourage adoption and investment. Technology advances could also help improve adoption of FCVs.

Implication for Defence and Security*: With increased consumer demand, the cost of FCVs will decrease, which could enable their adoption in the defence sector. FCVs offer a cleaner fuel alternative to fossil fuels and less reliance on their volatile prices.*

Timing of Implication: *now/5 years/***10 years***/15 years*

November 2016

P0988

Alluring Reality

By Cassandra Harris (Send us feedback.)

Augmented-reality and virtual-reality technologies capable of enhancing reality could improve people's health.

Abstracts in this Pattern:
SC-2016-10-05-020 on *Pokémon Go*
SC-2016-10-05-092 on art
SC-2016-10-05-032 on generational behavior
SC-2016-10-05-037 on Holodia Fitness

Niantic's (San Francisco, California) augmented-reality (AR) mobile game *Pokémon Go* (www.pokemongo.com) sends users to public spaces to hunt and capture virtual characters. Players of the popular game have used social media to complain about the muscle soreness they experience as a result of the amount of walking they did while playing the game. AR applications can transform ordinary environments into exciting environments, which could encourage people to engage in outdoor activities. For example, Artist Ivan Toth Depeña (http://ivandepena.com) created Lapse—an AR app that enables users to access virtual multimedia art experiences when they view specific sites in Miami, Florida, through the screen of their mobile device. AR and virtual-reality (VR) technologies capable of encouraging people to exercise may contribute to addressing problems such as obesity; however, generational behavior may have an effect on the success of such technologies. For example, a recent study by Intel Security Group (Intel Corporation; Santa Clara, California) suggests that Millennials (people ages 18 to 34) might be less dependent on devices such as cell phones than are Generation Xers (people ages 35 to 54). The researchers asked 14,000 participants about their device use during a vacation and found that 49% of the Millennials but only 37% of the Generation Xers were able to stay away from their devices while they were on vacation.

AR and VR technologies could find use not only to encourage people to exercise but also to enhance people's exercise experience. For example, Holodia (Strasbourg, France) developed the Holofit "VR fitness software platform" (www.holodia.com). Holofit works with the HTC Vive VR headset from HTC Corporation (New Taipei City, Taiwan) and Valve Corporation (Bellevue, Washington) and fitness machines such as elliptical trainers, stationary bikes, and rowing machines. Holofit enables a person who is wearing the VR headset and using, for example, a rowing machine to row through virtual destinations such as caves in Antarctica and the rings around Saturn. By making the experience of exercising more entertaining, the technology could encourage people to begin and continue exercising. AR and VR technologies that enable users to engage in immersive simulated experiences may be able to improve the users' physical and perhaps even mental health.

Signals of Change related to the topic:
SoC868 — …Content Is the Prize
SoC861 — …Nudges and Blunt Shoves
SoC826 — Virtual Reality's Human Side

Patterns related to the topic:
P0967 — …Digital Headgear
P0961 — The Emergence of E-Sports
P0859 — …Treating Mental Disorders

November 2016

P0989

Connected Objects

By Guy Garrud (Send us feedback.)

Companies are developing technologies that will enable objects to connect for Internet of Things applications.

Abstracts in this Pattern:
SC-2016-10-05-001 on RFID
SC-2016-10-05-004 on IoT networks
SC-2016-10-05-099 on intelligent cameras
SC-2016-10-05-055 on glitches

Researchers from Disney Research (The Walt Disney Company; Burbank, California) are working with researchers from other institutions to examine novel ways to use radio-frequency-identification (RFID) technologies. Recent papers by Disney researchers and colleagues discuss, for example, the use of RFID technologies to enable interactions between humans and robots and to identify electronic devices on the basis of their unique electromagnetic-wave patterns. RFID technology could be one of several technologies that serve as enabling components of the Internet of Things (IoT); however, RFID offers only short-range communication among devices in physical proximity of one another, and the IoT will not be truly disruptive unless IoT devices can communicate over a very wide area. Multiple companies are working on the networks necessary to ensure a connection among IoT devices. For example, Samsung Electronics (Samsung; Seoul, South Korea) and SK Telecom Co. (SK Group; Seoul, South Korea) recently launched a long-range wide-area network (LoRaWAN) that covers South Korea. And in June 2016, telecommunications provider KPN (The Hague, Netherlands) activated a LoRaWAN that covers the Netherlands.

In addition to enabling users to operate devices remotely, the IoT could enable the creation of smart devices capable of analyzing information to act without human direction. Companies such as Cisco Systems (San Jose, California), Honeywell Security Group (Honeywell International; Morris Plains, New Jersey), and IBM (Armonk, New York) are developing *intelligent cameras*—internet-connected cameras that use artificial intelligence (AI) to observe and interpret what the camera sees. For example, an intelligent camera could automatically contact emergency services if it observes someone collapse on the street or summon the police if it sees an intruder on private property. Using internet connectivity and AI to automate systems could greatly reduce the burden on human observers. Making life easier for humans was the idea behind PetNet's (Los Angeles, California) IoT-connected pet-food dispensers; however, a recent server failure prevented the devices from dispensing food for about ten hours. This incident illustrates the reliability problems that automated systems can have and highlights the need for effective backup systems as IoT technologies see increasing adoption.

Signals of Change related to the topic:
SoC886 — Putting the IoT in Perspective
SoC883 — …Fear of Automation
SoC853 — …Infrastructure Sensors

Patterns related to the topic:
P0946 — Enlightening Dumb Objects
P0894 — The Art of Packaging Sensors
P0813 — Infrastructure Sensors

Viewpoints

November 2016

Artificial Intelligence

By Michael Gold (mgold@sbi-i.com)

OK, AI, Explain Yourself

Why is this topic significant? The most successful AIs cannot explain why they produce their results. But some AI software has explanatory abilities, and researchers are working to improve those abilities.

Description

Neural network software, including most deep-learning software, often gives correct answers on tests but rarely shows its work. The same problem arises with other popular machine-learning algorithms. Unexplained results may be acceptable for AI systems that play games and sort smartphone photos. But at least for now, explanations are requirements in medicine and military intelligence, leading to limits on roles for AI. Concern is mounting about whether big-data algorithms could be unfair and discriminatory; explanations could make lending, hiring, and criminal-justice decisions more transparent. And the EU's General Protection Regulation, effective April 2018, even states that under certain conditions a web or mobile user will have the "right to obtain...meaningful information about the logic involved" in algorithmic decisions that make use of data that can identify a person.

During June 2016, dozens of presenters at the 2016 International Conference on Machine Learning revealed how the AI research community is addressing needs for explanations, given the success of black-box algorithms that confound human understanding. At the conference's 2016 Workshop on Human Interpretability in Machine Learning, some teams of researchers demonstrated ways to highlight areas in images or words in a document that had high influence on a result. Another line of research explores how users can understand and interact with models, not just receive explanations for individual results. Also, a concurrent 2016 Workshop on Visualization for Deep Learning explored how developers can understand and modify the models they are creating. Explanatory AI was part of a larger agenda at three other conferences during 2016 that focused on human-computer interaction, human-centered data science, and collaborative computing, respectively.

Implications

Confidence in AI systems is especially important in any case that could affect life safety, including in medicine, combat, and transportation. As a result, AI developers have been concerned with explainability since at least as early as the 1970s, concurrent with the development of early medical-diagnostic AI systems. But recent conference activities seem to indicate that the AI research community is increasing the level of effort applied toward explanatory AI; and a recent request for proposals indicates that the Defense Advanced Research Projects Agency (DARPA) will be supporting research about "explainable AI" during 2017 to 2020.

Impacts/Disruptions

Some conference reports and parts of the DARPA solicitation focus on psychological questions about what suffices as an explanation and what factors inspire confidence in technological systems. In some cases, a user wants an AI to comply with the same standards anyone would apply to a human analyst or medical diagnostician, and to be subject to a high level of scrutiny including rounds of natural-language questions and answers. Advanced user interfaces also have a role to play in possible hybrids of machine learning and expert systems that let humans understand and modify machine-learning models. In other cases, a user merely needs confidence that a system is reliable, and the user may be satisfied by looking at data about an AI's record of accuracy. Each user's precise needs for confidence and explanations could evolve as the user gains experience with a system, and as technology improves.

Scale of Impact	Low	Medium	**High**	
Time of Impact	Now	5 Years	**10 Years**	**15 Years**

Opportunities in the following industry areas:
Software development, enterprise information-technology development, software as a service, cloud services, personal assistant software

Relevant to the following Explorer Technology Areas:
• Artificial Intelligence • Big Data • Collaboration Tools • Connected Cars • Connected Homes
• Pervasive Computing • Robotics • User Interfaces

November 2016

P0990

Medical Origami

By David Strachan-Olson (Send us feedback.)

Researchers are applying folding techniques in a variety of medical applications.

Abstracts in this Pattern:
SC-2016-10-05-095 on catheter
SC-2016-10-05-016 on robot
SC-2016-10-05-025 on DNA origami

Origami—the traditional Japanese art of paper folding—enables the creation of complex structures and designs through the folding of simple materials. The ability to fold medical devices into compact shapes would enable the devices to travel through the body easily while maintaining their functionality.

University of Georgia (Athens, Georgia) graduate student Austin Taylor and colleagues are developing a novel cardiac catheter. A folding device on the tip of the catheter contains both a tool for cauterizing heart tissue and the wire coils necessary for magnetic-resonance imaging. Taylor chose a pinwheel-like shape for the device, which enables it to fold into a size small enough to navigate a patient's blood vessels. Once doctors position the device inside a patient's heart, the device unfolds to enable ablation and high-quality imaging of the heart.

Researchers from the Massachusetts Institute of Technology (MIT; Cambridge, Massachusetts), the University of Sheffield (Sheffield, England), and the Tokyo Institute of Technology (Tokyo, Japan) developed an ingestible origami robot. The researchers gave the robot accordion folds to enable it to move using *stick-slip motion*—a type of locomotion in which the robot's appendages use friction to stick to a surface but slip free when the robot's body changes its weight distribution by flexing. Researchers control this motion using an external magnetic field that acts on a magnet in the robot. Because the robot folds, the researchers can encapsulate it in an easy-to-swallow pill. The team believes the robot could remove button batteries from the stomach after people accidentally swallow them.

Researchers are also applying folding techniques at the nanoscale. For example, *DNA origami* is a technique in which researchers fold strands of DNA to create custom nanostructures of nearly any shape. Because manually manipulating DNA to create nanostructures is a complicated and labor-intensive process, few researchers possess the knowledge and experience necessary to use the technique; however, researchers from MIT and other institutions recently developed an algorithm that automatically determines the proper DNA sequence for a nanostructure on the basis of the nanostructure's desired 3D geometry. By simplifying this complex process, the algorithm will enable more researchers to work with DNA origami and should speed the development of nanostructures for use in applications in fields as diverse as vaccinology and genetic engineering.

Signals of Change related to the topic:
SoC878 — Genetic Games…
SoC872 — Brain Implants
SoC691 — Origami Engineering

Patterns related to the topic:
P0972 — Pushing Boundaries in Medicine
P0958 — Changing Pharmaceuticals
P0887 — Extreme Medical Advances

SoC906

Enabling Robotic Skills

By David Strachan-Olson (Send us feedback.)

Researchers are continually developing robots that possess new skills and abilities that enable them to complete specific complex tasks autonomously. Examples of such capabilities are manifold. A group from the University of Tokyo (Tokyo, Japan) has developed a robot capable of playing the game rock-paper-scissors with a human and winning every time. The robot uses a high-speed camera and image-processing software to determine the shape the opponent is making with his or her hand and then quickly articulates its hand into the winning shape. Researchers at the Georgia Institute of Technology (Atlanta, Georgia) have developed a wearable robotic arm to assist musicians in playing a drum set. The arm analyzes the drummer's movements, chooses an appropriate drum, and plays a rhythm in time with the drummer. Researchers from the Children's National Medical Center (Washington, DC) have developed a surgical robot capable of autonomously suturing incisions in the intestinal tissue of living pigs. The robot uses a 3D camera and fluorescent tags to track the soft tissue as it sutures an incision closed. Moley Robotics (London, England) is developing an automated-kitchen system that features two suspended robotic arms that mimic the movements of professional chefs. The company uses 3D-motion-capure technology to film a human chef preparing a dish, and the robotic arms learn to make the dish by replicating the chef's movements.

These examples highlight continuing advances in robotics research, but each project demonstrates a robot with only one very specific application. Although these projects prove that robots have many potential applications, they do not necessarily advance overall robotics research. Many potential commercial opportunities and applications depend on the development of a general-purpose robot with a broad skill set. To date, efforts to integrate multiple skills into a single robot have seen only moderate success. In June 2015, a number of the world's most advanced robotic systems competed at the finals of the Robotics Challenge hosted by the US Department of Defense's (Arlington County, Virginia) Defense Advanced Research Projects Agency (DARPA; Arlington, Virginia). For the Robotics Challenge, teams of researchers attempted to develop humanoid robots capable of completing eight tasks common in search-and-rescue operations, including walking over uneven terrain, walking up stairs, opening doors, turning valves, and operating power tools. Only 3 of the 23 teams that participated in the finals were able to complete all eight tasks. Many of the robots fell and suffered damages severe enough to prevent them from continuing through the course. After the event, DARPA posted a video that shows some of the more spectacular robot failures (www.youtube.com/watch?v=7A_QPGcjrh0). The competition demonstrated the difficulty of integrating multiple skills into a single general-purpose robot and highlighted the need for a substantial amount of additional research. For instance, SRI International (Menlo Park, California) is working with Yamaha Motor Company (Iwata, Japan) to develop a robot capable of autonomously riding a motorcycle. Rather than altering a motorcycle to make it suitable for use by a robot, the team is designing the robot to ride an unmodified motorcycle in the same way humans do. General-purpose robots will likely need to possess a range of basic skills, including voice recognition, object recognition,

To date, efforts to integrate multiple skills into a single robot have seen only moderate success.

object grasping and manipulation, localization, and mobility control (either through wheels or bipedal walking).

In addition to possessing a range of basic skills, robots will need a method to learn new skills. One approach is to enable robots to gain new skills through cloud-based knowledge sharing. RoboHow (https://robohow.eu) is a four-year European research project that is building on the progress of the RoboEarth (http://roboearth.ethz.ch) research project (see SoC680 — An Intelligent Robotic Internet). RoboHow's goal is to develop a platform that uses web resources and experience-based learning to enable robots to acquire new skills automatically. Researchers have used the platform to teach robots how to flip pancakes and roll pizza dough. A team comprising researchers from Stanford University (Stanford, California), Cornell University (Ithaca, New York), and other institutions is working on the Robo Brain (http://robobrain.me) cloud-based computational system. The system learns from online resources, computer simulations, and robotic trials to develop a single comprehensive knowledge base in the cloud. The team hopes that the system will enable robots to learn collectively and share maps, images, object data, and other information. SoC899 — In Deep Learning Quantity Matters highlights examples of efforts to use large data sets to train deep-learning algorithms.

Other researchers are investigating how individual robots can learn new skills automatically. Researchers from the University of Washington (Seattle, Washington) are developing algorithms that enable a dexterous robotic hand they built to perform complex object manipulations. Machine-learning algorithms use data that a variety of sensors and motion-capture cameras collect as the robotic hand moves to learn and improve the hand's ability to manipulate objects. A team from Google DeepMind (Alphabet; Mountain View, California) is developing *progressive neural networks*—multiple neural networks that link to enable each network to contribute the specific function it has learned. This architecture enables a system to learn new tasks very quickly if portions of those tasks relate to functions the individual neural networks in the architecture had learned previously. Initially, the DeepMind team used progressive neural networks to train an artificial intelligence to play classic video games. Since then, the team has been working to use progressive neural networks to train a robotic arm to perform various tasks. The team used a computer simulation of a robotic arm to train a primary neural network and then added additional neural networks that made use of information from the primary network while learning to control a real robotic arm. This method enabled the team to reduce significantly the number of integrations necessary to train the arm to perform simple tasks. This approach could give individual robots a way to leverage previous learning to decrease the amount of training time necessary for them to learn a new skill.

As SoC883 — The (Ir)Rational Fear of Automation highlights, many people are growing increasingly concerned that robots will replace a large number of human workers in the near future. Many of these fears stem from media coverage of rapid advances in artificial intelligence and deep-learning algorithms, but these advances have primarily been in software-only applications such as data analysis and image processing. Researchers are only beginning to apply such advances to solving complex problems in the field of robotics. Overall, progress in robotics has been limited, and developing a robot capable of automating a single task is a major accomplishment. Robots with a single skill will be able to automate only a specific portion of a human worker's job, and a general-purpose robot that can cook, clean, manipulate tools, and perform any physical task that humans can perform will remain elusive for years.

SoC906

Signals of Change related to the topic:
SoC865 — Wearable Robotics
SoC840 — Roaming Robots
SoC786 — Social Robots

Patterns related to the topic:
P0982 — Robots' Becoming Part of Society
P0947 — Robotkind
P0934 — Human–Robot Interaction

Viewpoints

November 2016

Artificial Intelligence

By Michael Gold (mgold@sbi-i.com)

Machine Learning for Robotics

Why is this topic significant? AI researchers are working to close gaps in robot education. Multimodal learning might be the best way to train robots.

Description

During March 2016, Google Research published findings about 14 identical robots learning "hand-eye coordination" by capturing images of 800,000 attempts to grasp various small objects for use as inputs to machine learning software. In effect, the robots shared their newly gained knowledge with one another. If Google had used only one robot, required training time would have greatly increased.

Researchers increasingly train real robots in virtual environments that simulate gravity and other aspects of real-world physics. Separate October 2016 technical reports from researchers at Google DeepMind and at OpenAI describe transferring knowledge from virtual robots (within MuJoCo's simulation platform) to real multijointed robot arms that learned to reach a designated destination from any starting position. The Google DeepMind robot continued its education in a real-world setting, without forgetting what it had learned from the simulation environment.

Often, a robot learns a task after a user manipulates the robot by hand (researchers call it learning by demonstration or learning by example). In January 2016, Cornell University researchers reported developing a web-browser-friendly training environment for robots and various coffeemakers, and recruiting users from Amazon's Mechanical Turk service to demonstrate how a virtual robot should make coffee. Users showed what trajectory a robot arm should follow and provided natural-language instructions to the machine-learning system. The fully trained mechanical robot can reportedly make coffee on machines that the system and the human users had not previously encountered.

Implications

Each method of training a robot has its strengths and weaknesses:

- Physics simulations economically generate big data for machine-learning algorithms. Computers can simulate many situations faster than real time, enabling large numbers of virtual trials. But many real-world situations are difficult to simulate.

- Training in the real world can be effective but time-consuming—or the training can be costly, if developers accelerate the learning process by having many robots concurrently engage in a trial-and-error process. Also, robots, still lacking the knowledge to be effective, might break things or harm people during the learning process.

- Training robots by hand is a traditional and effective method with further potential to contribute to machine-learning procedures. The method seems to have few drawbacks, but costs could mount if the procedures require many human-sourced demonstrations.

- Rules that experts generate, hand-coded features of objects in images, and other forms of prior knowledge are traditional inputs for controlling robot behaviors and will likely remain important.

As a result of these strengths and weaknesses, stakeholders can expect to see robots engage in multimodal learning processes, much as children learn from a combination of demonstrations, verbal descriptions, diagrams, and trial and error.

Impacts/Disruptions

Google's training program for "driver education" of driverless cars seems to rely mostly on costly and somewhat risky real-world (on-road) training. In contrast, Tesla seems to have an advantage in monitoring its cars' sensors plus drivers' control inputs. Tesla's user agreements do not rule out extensive collection of data that could include drivers' braking, steering, and throttle behaviors, concurrent with readings from radars, cameras, and ultrasonic sensors. (Some combination of selective uploading of data, syncing via Wi-Fi, and compression algorithms could control costs of wireless data communications.) Tesla could use learning by demonstration to teach cars how to drive themselves, with Tesla drivers the sources of the demonstrations.

Scale of Impact	Low	**Medium**	High	
Time of Impact	Now	5 Years	**10 Years**	15 Years

Opportunities in the following industry areas:
Entertainment production, distribution, and performance, software development, research, education

Relevant to the following Explorer Technology Areas:
• Artificial Intelligence • Big Data • Collaboration Tools • Connected Cars • Pervasive Computing
• Robotics • User Interfaces

CURRENTLY AVAILABLE TECHNOLOGY AREAS

3D Printing
Artificial Intelligence
Big Data
Biocatalysis
Biomaterials
Biopolymers
Biosensors
Collaboration Tools
Connected Cars
Connected Homes
Electronic Displays
Energy Storage
Engineering Polymers
Fuel Cells
Membrane Separation
MEMS/Micromachining
Mobile Communications
Nanobiotechnology
Nanoelectronics
Nanomaterials
Novel Ceramic/Metallic Materials
Organic Electronics
Pervasive Computing
Photovoltaics
Polymer-Matrix Composites
Portable Electronic Devices
Renewable Energy Technologies
RFID Technologies
Robotics
Smart Materials
Solid-State Microsensors
User Interfaces

STRATEGIC BUSINESS INSIGHTS

scan™

October 2016

P0984

Marriage of 3D-Printing Technology and Robots?

By Guy Garrud and Martin Schwirn (Send us feedback.)

New developments inspire speculation about the pairing of 3D-printing technology with robots to enable advanced manufacturing applications.

Abstracts in this Pattern:
SC-2016-09-07-031 on HP
SC-2016-09-07-013 on Siemens
SC-2016-09-07-025 on MIT

The capabilities of 3D-printing technology have been expanding for years, and HP (Palo Alto, California) CEO Dion Weisler recently revealed that HP's newest 3D printers can print many of their own components. Weisler insists that the company is using its 3D printers to manufacture components for its 3D printers because doing so is more economical than is manufacturing the components using more traditional manufacturing methods. HP's use of 3D printers in manufacturing illustrates 3D-printing technology's growing usability and provides an early example of 3D printing's ability to disrupt some manufacturing applications. Engineering company Siemens (Berlin and Munich, Germany) is building on the growing usability of 3D-printing technology and exploring a radical approach to 3D printing. Conventional 3D printers feature a single extrusion head and a rigid frame that surrounds the entire print area. A team of Siemens engineers has developed spider-like robots equipped with plastic extruders for printing objects. Onboard cameras and laser scanners enable the robots to navigate their environment with a high degree of precision. The team's goal is to enable multiple robots to 3D print a single object as a team. The team's approach could eliminate limits on the size of objects that 3D printers can produce. The use of a swarm of robots would also make incorporating multiple materials into a single object much easier for engineers.

Controlling and coordinating swarms of robots is technically challenging; however, the potential benefits of such swarms are substantial, making robot swarms a high-interest research area (see SoC740 — Swarm Robotics). For instance, researchers at the Massachusetts Institute of Technology (MIT; Cambridge, Massachusetts) have developed a "decentralized planning algorithm for teams of robots" that enables each robot in the team to map its surroundings and choose how to move while communicating with only its direct neighbors. Systems that decentralize control of the robots in a swarm could be crucial to the success of manufacturing applications that rely on the marriage of 3D-printing technology and robots.

Signals of Change related to the topic:
SoC883 — …Fear of Automation
SoC860 — 3D Technology and Tinkering
SoC809 — Industry 4.0

Patterns related to the topic:
P0875 — Printing Architecture
P0837 — …Advanced Engineering
P0677 — 3D Printing's Reality Check

October 2016

P0981

Automating Transportation

By Martin Schwirn (Send us feedback.)

Efforts to develop semiautonomous or fully autonomous versions of multiple types of vehicles are moving along surprisingly rapidly.

Abstracts in this Pattern:
SC-2016-09-07-073 on cars
SC-2016-09-07-010 on trucks
SC-2016-09-07-097 on ships

Several carmakers have announced plans to move ahead with the development of self-driving cars. For example, at the end of 2015, Toyota Motor Corporation (Toyota, Japan) established the Toyota Research Institute in Palo Alto, California, to develop artificial-intelligence technologies for autonomous vehicles and home helper robots. In addition, Toyota recently formed a strategic partnership with transportation-network provider Uber Technologies (San Francisco, California), which is also working on autonomous-car technologies. During the partnership, Toyota will invest in Uber, offer Uber drivers flexible leases for Toyota vehicles, and work with Uber to develop in-car support apps for Uber drivers. Other companies have already taken similar steps. For instance, Ford Motor Company (Dearborn, Michigan) established Ford Smart Mobility—a subsidiary that operates in both Palo Alto, California, and Dearborn, Michigan, and focuses on car-sharing and ride-hailing services. And General Motors (Detroit, Michigan) purchased autonomous-vehicle-technology developer Cruise Automation (San Francisco, California).

P0971 — Driverless Dynamics outlines efforts by truck manufacturers to develop systems for heavy trucks that will enable semiautonomous *platooning*—vehicles' traveling very close to one another at high speeds in highly coordinated groups. The Pattern also highlights Comma.ai's (http://comma.ai) interest in creating an aftermarket kit for equipping consumer vehicles with semiautonomous-driving technology. Start-up Otto (San Francisco, California) is now offering to equip conventional trucks with the sensors and other equipment necessary to make them self-driving. The company recently partnered with Uber to develop self-driving trucks and a new way to connect drivers and shippers.

Finally, Rolls-Royce (London, England) unveiled a concept design for a fleet of autonomous cargo ships in June 2016. The drone ships would use a combination of satellite navigation, radar, lidar, sonar, infrared sensors, and cameras to navigate. The autonomous ships do not require human crews or spaces for humans to live and work in.

Signals of Change related to the topic:
SoC866 — A Flock…a Shoal of Drones
SoC864 — Morphing Mobility
SoC841 — The New Role of Cars…

Patterns related to the topic:
P0971 — Driverless Dynamics
P0912 — The Driverless Industry
P0900 — Driverless Cars'…Effects

Strategic Business Insights

Explorer

Viewpoints

October 2016

User Interfaces

By Rob Edmonds (redmonds@sbi-i.com)

Hearables

Why is this topic significant? Apple, Samsung, IBM, and various start-ups hope to turn headphones into smart computing devices. The arrival of an omnipresent intelligent voice-in-the-ear could be disruptive, but the hearables market is uncertain.

Description

Apple's forthcoming AirPods are more than wireless headphones. Sensors detect when they are in ears (for example, to pause music) and a double-tap allows users to talk to Apple's personal assistant, Siri. Although reviews of the headphones are mixed, reviewers give kudos to hearables, a product category that vendors such as Bragi, Doppler Labs, and Samsung are also promoting.

Hearables add sensors to conventional wireless headphones (sensors in Bragi's Dash include an optical heart rate monitor, an accelerometer, a gyroscope, and a magnetometer). Hearables integrate with smartphone apps, and some also carry onboard applications.

Some hearables features simply enhance the convenience of conventional headphones (for example, detecting left and right ears to swap channels). Other features are more substantial. Manufacturers are optimistic about the potential of combining intelligent assistants and hearables. AirPods' audio features should enable Siri to hear a user's voice clearly in noisy settings. IBM has partnered with Bragi to deliver Watson cloud services to Dash in the workplace (possible applications include tracking the safety of workers, offering translation services, and providing guided instructions).

Other hearable features vary. Doppler Labs' Here One provides sound-filtering so that users can choose which sounds and frequencies they want to hear clearly. NEC hopes to use hearables for biometric identification (by playing an audio signal into the wearer's ear canals). Some hearables providers hope that their devices can replace Fitbits or Garmins and act as trackers and smart coaches for fitness enthusiasts.

Implications

Apple's removal of the headphone jack on the iPhone 7 suggests that wireless headphones are here to stay. Sensors and software that cancel noise, identify left and right ears, and pause music when headphones are removed are useful and will likely find their way into most wireless headphones in the future. Whether such smart headphones will evolve into hearable computing devices is uncertain. Applications such as fitness tracking show promise but are also served by other devices. Biometric identification is potentially very convenient—but only if a user already happens to be wearing the device for some other reason.

Some visions of hearables picture people talking to their personal assistants while out and about. However, few people today use personal assistants in public—perhaps because talking to a computer in front of other people feels awkward. A recent survey of 500 “mainstream” US consumers by Creative Strategies found that just 3% of iPhone owners used Siri in public even though 98% had used Siri at least once.

Impacts/Disruptions

Although the hearables market is uncertain, the potential of an intelligent voice in an ear, providing coaching, translation, advice, and information related to daily activities, could be highly disruptive. This development would require intelligent assistants to become far more useful and appealing than they are today—but Amazon, Google, Microsoft, Facebook, Baidu, and Apple (not to mention various start-ups) are all working toward this goal. If they succeed, then perhaps people will rely on hearables to deliver the always-available support and advice of artificial intelligence. Travellers could receive real-time translation, doctors could consult AI about diagnoses and treatments, and managers could receive subtle prompts and information to aid negotiations. Via hearables, consumers’ relationships with their computing services could also change (the 2013 movie *Her* depicts a man in love with a hearables-based personal assistant).

Scale of Impact	Low	Medium	**High**	
Time of Impact	Now	**5 Years**	10 Years	15 Years

Opportunities in the following industry areas:
All industry areas

Relevant to the following Explorer Technology Areas:
• Artificial Intelligence • Big Data • Connected Homes • Pervasive Computing • User Interfaces

Strategic Business Insights

Explorer

Viewpoints

October 2016

User Interfaces

By Rob Edmonds (redmonds@sbi-i.com)

The $400,000 AR Headset

Why is this topic significant? A state-of-the-art fighter-pilot helmet showcases the possibilities of augmented reality when cost is not an issue. Trickle-down technologies and features could reach industrial and consumer augmented-reality devices in the future.

Description

The Gen III Helmet Mounted Display System is a $400,000 helmet for pilots of Lockheed Martin's F-35 jet. The helmet is the result of a joint venture between Rockwell Collins and Elbit Systems. Features include integrated night vision with a wide field of vision, binocular vision with the ability to zoom in via a picture-in-picture display, and the ability to "look through" the aircraft at any angle (via video images from external cameras). In addition, eye-tracking software integrates with weapons-guidance systems such that pilots can guide missiles that they launch simply by looking at the target.

The helmet has faced a variety of challenges. Most seriously, testers found that the 2.3 kg weight of the helmet had the potential to break a pilot's neck during emergency ejection procedures (a lightweight version of the helmet is due in 2017). Some test pilots also say that the size of the helmet and its cabling restricted their head movements. Other stakeholders are concerned that the helmet's cutting-edge technology makes it unreliable. Dan Grazier of the Project on Government Oversight, a watchdog in Washington, DC, says that the helmet is the F-35's "weak link." Grazier says that complex products are prone to failure and that custom eye-tracking calibration requirements prevent pilots from easily swapping a broken helmet for a spare.

Implications

Fighter-pilot displays have long been at the leading edge of augmented-reality (AR) displays. For jets that cost hundreds of millions of dollars, $400,000 helmets are acceptable. For almost all other applications, prices need to be considerably lower. Electronics and software prices tend to get cheaper over time, so lower-cost versions of the helmet's features and technologies are likely. Rockwell Collins is apparently considering applications for the helmet outside the military—perhaps in firefighting, construction, or heavy industry. Developers of consumer-grade AR are already considering systems with some similarities to the Gen III helmet. For example, in 2015, BMW demonstrated prototype AR goggles with "X-ray vision" technology for Mini drivers.

Impacts/Disruptions

Designers of industrial and consumer AR systems might look to the Gen III helmet for inspiration and may benefit from trickle-down technologies and features in the future. Could industrial workers use a simpler version of the helmet for the remote control of equipment and vehicles? Could children guide AR-connected toy robots by merely looking at where they should go?

The Gen III helmet also provides a cautionary lesson for user-interface designers. Adding features increases complexity—perhaps reducing reliability—and can diminish a product's basic features. For example, even the weight-reduced version of the Gen III helmet is far heavier and apparently less maneuverable than standard helmets are.

Scale of Impact	Low	**Medium**	High

Time of Impact	Now	5 Years	**10 Years**	15 Years

Opportunities in the following industry areas:
Defense and security, oil and gas, construction, industrial, consumer electronics, entertainment, software services

Relevant to the following Explorer Technology Areas:
• Connected Cars • Electronic Displays • Pervasive Computing • User Interfaces

CURRENTLY AVAILABLE TECHNOLOGY AREAS

3D Printing
Artificial Intelligence
Big Data
Biocatalysis
Biomaterials
Biopolymers
Biosensors
Collaboration Tools
Connected Cars
Connected Homes
Electronic Displays
Energy Storage
Engineering Polymers
Fuel Cells
Membrane Separation
MEMS/Micromachining
Mobile Communications
Nanobiotechnology
Nanoelectronics
Nanomaterials
Novel Ceramic/Metallic Materials
Organic Electronics
Pervasive Computing
Photovoltaics
Polymer-Matrix Composites
Portable Electronic Devices
Renewable Energy Technologies
RFID Technologies
Robotics
Smart Materials
Solid-State Microsensors
User Interfaces

October 2016

SoC902

Unusual Hacking, Atypical Spying

By Martin Schwirn (Send us feedback.)

Because companies and individuals now use digital applications in some way in nearly every activity, the security of such applications has become a major concern. *Malware* and *ransomware* have become household terms and concerns. In the past, malicious actors required digital access to a device to hack it. Today, researchers and cybersecurity experts are uncovering alternative ways to access information on digital systems unbeknownst to the systems' users. Many system designers believe that *air gapping*—isolating a computer from other computers and the internet by eliminating wireless and physical connections—is a very effective low-tech way to secure digital devices; however, even air gapping might not eliminate the threats of hacking and spying completely. New security approaches under development aim to counter uncommon ways of gaining access to information, and Scan™ has covered related research during the past year or so.

Creating devices capable of providing users with benefits and convenience while protecting their data and privacy could become increasingly difficult as novel hacking and spying methods proliferate.

- P0792 — Eavesdropping by Proxy mentions that researchers at the Georgia Institute of Technology (Atlanta, Georgia) are investigating ways to gain access to information through *side-channel signals*—information-technology-equipment leaks in the form of electromagnetic or acoustic emissions, low-power electronic signals that laptops and smartphones emit, and sounds that electronic components make. And researchers at Stanford University (Stanford, California) have identified a method of determining the location of a smartphone on the basis of the smartphone's power consumption. A smartphone's distance from cellular towers determines the amount of power its cell radio consumes, enabling the researchers to estimate a person's movement by closely monitoring the power usage of the radio in the person's smartphone.
- P0708 — Indirect Eavesdropping highlights efforts by researchers at the Massachusetts Institute of Technology (Cambridge, Massachusetts) who claim to be able to recreate sounds from silent video by analyzing objects in the footage. Sound creates pressure waves that cause nearby objects—such as a bag of chips or water in a glass—to vibrate. The researchers were able to use these vibrations to reconstruct human speech. The approach essentially enables someone to eavesdrop on a conversation without even gaining access to one of the speakers' digital devices. And researchers from Stanford University discovered that the gyroscopes in modern smartphones are sensitive enough to measure the vibration of nearby acoustic signals. The researchers then created an app that enables a smartphone's gyroscope to "listen" to sounds in its vicinity continuously.
- P0850 — Cybersecurity's Air-Gap Conundrum details how a team at Ben-Gurion University of the Negev (Beersheba, Israel) found a way to bridge air gaps through the heat a virus-infected computer generates. Another research group from the same university demonstrated the ability to cross an air gap through the electromagnetic noise that computers generate. However, these air-gap bridges require physical access to the computer to implant malicious code, limiting the scope of this threat to sophisticated targeted attacks.

New developments indicate the existence of additional vectors through which criminals can gain access to an increasingly wide range of digital systems.

Researchers at the University of California, Irvine (Irvine, California), have demonstrated the ability to reverse engineer a 3D-printed object on the basis of the sounds the 3D printer makes as it creates the object. A simple smartphone audio recording of a 3D printer in operation contains enough information—including the printer nozzle's location and movements and how long the nozzle was extruding material—to enable the reproduction of the printed object with 90% accuracy. Audio information from one party's 3D printer could give an intrusive party insight into the objects the first party is printing and the designs it is using.

Researchers from the Cyber Security Research Center at Ben-Gurion University are continuing to investigate ways to eavesdrop on air-gapped computer systems, and they recently found a way to extract data from the sound that computers' cooling fans emit. Users of this approach are unable to steal a wide range of data but could gain access to, for instance, usernames and passwords. Like other approaches that researchers at the university have designed, this approach requires infecting the target computer with malware. The malicious software then instructs the computer's fans to speed up, thereby increasing the amount of noise they produce. A nearby device captures and decrypts the sound signals the targeted computer emits.

And researchers from the Stevens Institute of Technology (Hoboken, New Jersey) and Binghamton University, State University of New York (Binghamton, New York), have shown that a malicious actor can hack a wearable fitness tracker or smartwatch to steal a wearer's personal identification number (PIN) when the wearer inputs the PIN at, for instance, an ATM machine. Fitness trackers such as those from Fitbit (San Francisco, California) and smartwatches such as Apple's (Cupertino, California) Apple Watch feature very accurate sensors. Such accuracy is necessary for the devices to count steps correctly, distinguish among multiple activities, gather reliable health information, and so on; however, the researchers recently announced that this accuracy has a downside. During their study, the researchers asked a number of users to type their PINs while wearing fitness trackers. While users were typing their numbers, the researchers used a Bluetooth packet sniffer to gather sensor data surreptitiously. The researchers found that they were able to use the information they gathered to guess, in a limited number of attempts, wearers' PINs with an accuracy of more than 90%. Some design elements of the ATM machines work in the hackers' favor. For example, PIN pads are highly standardized, so users are accustomed to typing in their codes using specific patterns. In addition, the "Enter" key is almost always the last key users press, which gives hackers a way to calibrate their data.

As devices become increasingly sophisticated and researchers uncover an increasing number of potential attack vectors, uncommon ways of gaining access to information and unusual hacking methods will likely become increasingly serious concerns. Device designers and manufacturers will have to consider such security threats when they are developing new devices. Creating devices capable of providing users with benefits and convenience while protecting their data and privacy could become increasingly difficult as novel hacking and spying methods proliferate.

SoC902

Signals of Change related to the topic:
SoC875 — Hacking to Manipulate
SoC855 — Shadow IT
SoC797 — Internet of (Growing) Threats

Patterns related to the topic:
P0850 — Cybersecurity's…Conundrum
P0792 — Eavesdropping by Proxy
P0708 — Indirect Eavesdropping

October 2016

P0979

The Portable Medical Lab

By Ivona Petrache (Send us feedback.)

Emerging portable diagnostic devices and point-of-care diagnostics could improve disease detection.

Abstracts in this Pattern:
SC-2016-09-07-017 on LNNano
SC-2016-09-07-098 on MIT
SC-2016-09-07-086 on UCSD

Many developing countries face challenges in accurately identifying and diagnosing diseases. In addition, patients in remote rural areas have no access to diagnostic labs or may be unable to return to test centers to retrieve their results. Implementing low-cost portable diagnostic devices could help overcome these challenges. Researchers at the Brazilian Nanotechnology National Laboratory (LNNano; Campinas, Brazil) designed a portable organic biosensor that contains a peptide that reacts to a specific enzyme associated with breast cancer, Alzheimer's disease, and Parkinson's disease. The researchers intend to develop disposable paper-based biosensors to enable rapid low-cost diagnoses at the point of care.

Researchers from the Massachusetts Institute of Technology (MIT; Cambridge, Massachusetts) have developed RAM (Rapid Assessment of Malaria)—a mechanical device capable of rapidly detecting malaria in patients' blood samples. In India, human clinical trials showed that the device is between 93% and 97% accurate. The device costs between \$100 and \$120, and the researchers are commercializing it through their Disease Diagnostic Group (Shaker Heights, Ohio) start-up. The device warrants monitoring, because it could enable inexpensive, early, and presymptomatic detection of epidemic diseases. The commercialization of such quick-working and low-cost portable diagnostic devices will be of great benefit to the health-care-services industry and could also relieve overburdened medical professionals by enabling some patients to self-diagnose.

Portable wearable devices that measure chemical compounds the body excretes are also gaining more practicality and may have great potential for use in the fields of medicine, health care, and athletics. Researchers at the University of California, San Diego (UCSD; La Jolla, California), developed a fitness tracker that measures the wearer's heart-rate signals and analyzes the wearer's sweat to provide real-time physiological data. Currently in trial as a prototype, the tracker collects data and relays it wirelessly to a mobile app for cross-referencing with data from other consumer wearable devices.

Signals of Change related to the topic:
SoC767 — …Diagnostic Health-Care Tools
SoC574 — DIY Health Care
SoC571 — …Health-Care Diagnostics

Patterns related to the topic:
P0872 — Attachable Health Care
P0815 — …Medical Diagnostic Tests
P0620 — …Health-Care Devices