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DEFTECH Update

February 2018

Dear Reader,

Welcome for this first 2018 release of the DEFTECH (Defence Future Technologies) Update. Building on last year efforts to bring insights about how the world of technology is evolving, we continue this year with this 360° approach.

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 implications 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.

If you desire to learn more about a specific topic or would like to access the SBI platform directly (Swiss government readers only!), please don't hesitate to contact me.

I hope you enjoy the journey!

Best regards,

Dr. Quentin Ladetto
Directeur de recherche – Veille Technologique

P.S. For question and suggestion, please contact me here: quentin.ladetto@armasuisse.ch

Image source: Alvin Baez/Reuters

Microgrids for Energy Security: Microgrids are small-scale generation systems that combine interconnected distributed-generation sources, energy storage, and management software and serve individual buildings or small communities. According to Navigant Research, 1,842 microgrid projects are under development, in operation, or at the proposal stage around the world. In late 2017, various companies installed solar microgrids at emergency-relief centers in Puerto Rico.

Implication for Defense and Security*: Government organizations (including the US Department of Energy) see opportunity to use microgrids as backup energy sources to improve the resilience of grids to cyberattacks. In addition, installations at emergency relief centers demonstrate the readiness of new small-scale generation systems for military operations.*

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

Image source: Georgia Tech News Center

Democratization of Robotics: New technologies and decreasing costs are democratizing access to robots. For example, Carnegie Mellon University's Robotics Institute is working on a system that could one day enable essentially anyone to design and fabricate custom robots. Separately, the Georgia Institute of Technology's Robotarium houses close to 100 swarm robots that anyone can write and upload programs for.

Implication for Defense and Security*: Robots that are easy to build and reconfigure could enable defense industry suppliers to provide flexible robot kits to armed forces. For example, on-the-ground forces might reconfigure robots to meet certain needs on demand (for example, to perform a specific rescue). In addition, terrorists and other hostile groups could make use of easy-to-build robots to launch hostile acts.*

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

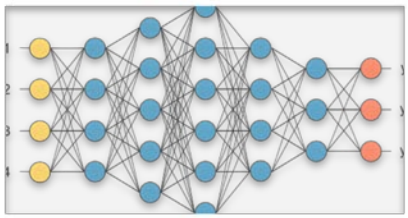

Image source: Artificial Intelligence Techniques website

Troubles with Neural Networks: Despite AI's recent successes from the use of deep neural networks, some thought leaders doubt that today's technology road maps are adequate to implement AI-based solutions across a truly wide range of applications. Alternatives include topological techniques, learning-to-learn technology, and custom forms of machine learning.

Implication for Defense and Security*: Deep-learning neural networks perform well for narrowly defined duties (such as recognizing certain images) but may struggle to perform tasks that require flexibility and more generalized intelligence (such as controlling an autonomous vehicle in unpredictable terrain). For the latter, defence and security organizations may need to look at other forms of AI.*

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

Image source: TechCrunch website

Self-Assembly: Researchers have already shown that self-assembly is feasible at small scales (for example, for electronics components). Larger scales may also be possible. For example, MIT's Self-Assembly Lab prototyped a self-assembling phone (with lock-and-key mechanisms in components) capable of putting itself together in a spinning cement mixer.

Implication for Defense and Security*: Self-assembly of larger objects is at an early stage but, long-term, could enable the safe and convenient transportation of weapons and equipment before their construction in the field. Further out, perhaps military forces could discretely deploy self-assembling devices on hostile sites that can be activated and assembled when needed (for surveillance, attack, and other purposes).*

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

Image source: Sion Power

Emerging Battery Technologies: Developers of alternative advanced-battery chemistries are making progress with new batteries that are safer, cheaper, and more powerful than current Li-ion batteries. Emerging technologies include nanostructured silicon anodes and new materials for Li-ion cathodes, using metallic-lithium anodes, zinc- and sodium-based batteries, and (longer term) lithium-air and magnesium batteries.

Implication for Defense and Security*: Next-generation batteries have the potential to supply safe and dependable power to military equipment and vehicles, with reduced need for battery replacement or recharging. New power sources may also make new kinds of equipment (for example, powered exoskeletons) feasible and cost effective.*

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

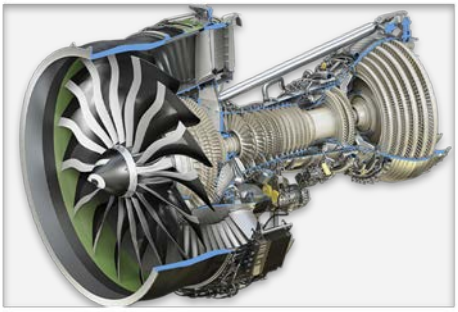
Image source: GE Aviation

Self-Healing Machines: Developments in materials, robotics, and artificial intelligence suggest that machines and systems may gain the ability to repair themselves. Electrolux is using a system that identifies malfunctions on a manufacturing press and, when possible, compensates for the malfunction without taking the machine offline. GE has developed small robots for jet-engine inspection and repair.

Implication for Defense and Security*: The combination of repair robots and complex digital models of equipment could one day enable fully automated inspection and repair of military vehicles and equipment. For example, robots could inspect machines and send their data to artificial-intelligence-based systems that then analyze the data, identify faults, and direct the robots to make repairs—all without human intervention. Such systems may enable military forces to repair battlefield equipment without putting engineers at risk.*

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

Image source: plainpicture/Tilby Vattard

Spoofing and Jamming: As device connectivity and access to digital information become increasingly important, interest in disrupting the usability of devices grows. For example, GPS-spoofing technology (perhaps from Russia) has disrupted ships in the Black Sea. And researchers from the Alibaba Security Response Center have demonstrated an ultrasonic gun that can impair the function of gyroscopes and accelerometers.

Implication for Defense and Security*: A market exists for spoofing and jamming technology and countermeasures. Some governments are interested in obtaining back-up systems using older technology. For example, The United States and several other countries are now considering reinstating loran systems that are harder to interfere with than satellite-navigation systems.*

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

Image source: Zurich Heart

3D-Printed Body Parts: Researchers at ETH Zurich have created a proof-of-concept 3D-printed soft artificial heart that can pump blood for about 30 minutes. Royal College of Art graduate student Dani Clode created the Third Thumb—a 3D-printed prosthetic digit that communicates with pressure sensors under the user's feet.

Implication for Defense and Security*: 3D-printed body parts could mean faster and more successful recoveries for wounded soldiers. 3D printing allows customization that makes for better prosthetics that can restore function. 3D bioprinting (especially of skin) can also help with recovery.*

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

Image source: FICO website

Artificial Intelligence Is Alien Intelligence: Although AI is becoming increasingly capable at performing human tasks, artificial intelligence is quite unlike human intelligence. For example, the mistakes that image classifiers make shows that the way such systems recognize images is quite different from the way humans recognize images.

Implication for Defense and Security*: The "alien" nature of AI is a particular problem for systems that must justify their reasoning, notably automated weapons systems. Efforts to create explainable AI are underway but outcomes are uncertain. Google research director and AI guru Peter Norvig is among those that have questioned the feasibility of such efforts.*

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

mage source: ITGS News website

Smart Infrastructures: Smart-city infrastructures are progressing. For example, Singapore's Smart Nation program includes the citywide deployment of sensors to capture and manage information about the day-to-day lives of citizens. Smart streetlights in US cities monitor traffic, weather, and air quality, optimize parking, and detect gunshots.

Implication for Defense and Security*: Terrorism prevention and response may drive some cities to deploy smart infrastructures. Such systems may use predictive analysis to provide early alerts of potential terror incidents and help track situations in real-time. Smart infrastructures may also provide surveillance capabilities for monitoring suspects.*

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

Image source: Sergey Nivens / Shutterstock

State Control of Cyberspace: Government authorities in Russia, China, and India are tightening their control over cyberspace. For example, Russia has outlawed virtual private networks and other technologies that enable people to browse the Internet anonymously. In China, the government is tightening its control over what passes through the country's cyberspace by creating new cybersecurity laws.

Implication for Defense and Security*: Increased state control by some regimes will increase their ability to control communications within their countries, and perhaps also improve their access to the communications of other countries. European and US government organizations may wish to invest in new cyberdefenses to protect their interests.*

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

Image source: Daimler AG

Electric Trucks: Automakers have begun to accelerate electric-truck development. Mitsubishi Fuso Truck and Bus Corporation has launched an all-electric light-duty truck, Tesla is working on an all-electric semitruck, and Deutsche Post manufactures an electric transporter to use in its own operations and to sell.

Implication for Defense and Security*: Until recently trucks and buses were beyond the reach of electrification—but battery progress and other developments have changed the picture. Changing costs and infrastructure may encourage the defence and security sector to increase its use of electric vehicles. Long term, petrol and diesel vehicles may become expensive and impractical in some regions.*

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

December 2017

P1145

Spoofing and Jamming

By Martin Schwirn (Send us feedback.)

As device connectivity and access to digital information become increasingly important, interest in disrupting the usability of devices grows.

Abstracts in this Pattern:

SC-2017-11-01-026 on GPS spoofing
SC-2017-11-01-023 on loran systems
SC-2017-11-01-092 on internet shutdown
SC-2017-11-01-043 on internet satellites
SC-2017-11-01-011 on device jamming

As navigation has become increasingly reliant on GPS, the system has become the target of nefarious activities. Operators of at least 20 ships in the Black Sea reported that an incident of GPS spoofing may have occurred on 22 June 2017, when the ships' GPS equipment indicated that the ships were actually at an airport more than 30 kilometers inland. Todd Humphreys, director of the Radionavigation Laboratory at the University of Texas at Austin (Austin, Texas), believes that this incident was a test of a GPS-spoofing technology by Russia. In 2015, the US Naval Academy (Annapolis, Maryland) reinstated celestial-navigation classes in case computer navigation systems become unavailable because of technical failure or enemy hacking (see SC-2015-12-02-091). The United States and several other countries are now considering reinstating so-called loran (long-range-navigation) systems. Loran systems rely on high-power radio beacons that use a lower frequency and stronger signals than do satellite-navigation beacons and are therefore much harder to interfere with.

In August 2017, local governments in Haryana and Punjab, India, temporarily shut down the region's internet and text-messaging services during the conclusion of a highly publicized trial in an effort "to prevent any disturbance of peace and public order." Technological developments may prevent governments from executing such shutdowns in the future. For example, Hughes Network Systems (EchoStar Corporation; Englewood, Colorado) recently became the first company to provide residential satellite-based internet service that meets the US Federal Communications Commission's (FCC's; Washington, DC) definition of broadband service. Because satellite-based internet service is more difficult to shut down than is terrestrial internet service, governments will struggle to exert control over it.

Because more and more devices depend on sensors to provide them with relevant information, sensors will likely become attack targets. Researchers from the Alibaba Security Response Center (Alibaba Group Holding; Hangzhou, China) and other institutions recently demonstrated an ultrasonic gun that can impair the function of gyroscopes and accelerometers such as the ones in drones and smartphones. Similarly, researchers at the University of Michigan (Ann Arbor, Michigan) demonstrated that sound waves can see use to hack into critical sensors in a wide variety of devices (see SC-2017-09-06-038).

Signals of Change related to the topic:

SoC963 — Hacking: Now…Pervasive
SoC946 — Diffusion of Hacking…
SoC875 — Hacking to Manipulate

Patterns related to the topic:

P1081 — Cyber(in)security
P1036 — Hacking's Reach Expands
P1021 — Proliferating DDoS Attacks

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P1146

State Control of Cyberspace

By Marianne Monteforte (Send us feedback.)

Government authorities in Russia, China, and India are tightening their control over cyberspace.

Abstracts in this Pattern:

SC-2017-11-01-015 on Russia
SC-2017-11-01-057 on China
SC-2017-11-01-092 on India
SC-2017-11-01-048 on government control

In Russia, a law that outlaws technologies that enable people to access websites banned by the Russian government went into effect recently. The law bans virtual private networks (VPNs) and other technologies that enable people to browse the internet anonymously. In addition to restricting political dialogue in Russia, the new law could have negative effects on foreign entities that aim to operate or provide services in Russia.

In China, the government is tightening its control over what passes through the country's cyberspace by creating new cybersecurity laws. Government regulators are conducting formal investigations into whether a few major social-media platforms—including the WeChat instant-messaging mobile app from Tencent Holdings (Shenzhen, China) and the Sina Weibo microblogging service from Sina Corporation (Shanghai and Beijing, China)—hosted content that violates a new cybersecurity law.

In India, local governments in Haryana and Punjab temporarily shut down the region's internet and text-messaging services during the conclusion of a highly publicized trial in August 2017. The shutdown, which affected some 50 million people for five days, was an effort "to prevent any disturbance of peace and public order." Although the shutdown failed to achieve this goal—as a result of violent protests of the verdict, 38 people died, businesses and schools closed, and train service experienced disruptions—it demonstrates that Indian governments can control access to the internet and could execute such shutdowns again.

Recently, JD.com (Beijing, China) founder Liu Qiangdong and Alibaba Group Holding (Hangzhou, China) founder Jack Ma discussed how new technologies could support communist forms of government. Ma commented that "with access to all kinds of data, we may be able to find the invisible hand of the market," referring to the term economist Adam Smith introduced to describe the effects of self-interested individuals' behavior on markets. Ma is therefore implying that governments may eventually control markets effectively.

Signals of Change related to the topic:

SoC949 — Stealth Privatization
SoC825 — The *Social* in Social Networks
SoC774 — The Reality of Net Neutrality

Patterns related to the topic:

P1133 — Connected Policing
P1081 — Cyber(in)security
P1064 — Data and Privacy…

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P1150

Body Shop

By Lucy Young (Send us feedback.)

Meeting the needs of the human body can require making use of resources as diverse as international trade and 3D printers.

Abstracts in this Pattern:
SC-2017-11-01-069 on plasma
SC-2017-11-01-070 on heart
SC-2017-11-01-055 on thumb

In China, demand for human blood plasma has increased as a result of an increase in liver diseases among the population. Because of rising incomes in China, the number of people who can afford treatment for these diseases has increased, creating more demand for products such as human serum albumin (human plasma's primary protein component). In 2016, China consumed about 50% of the world's serum albumin and imported roughly 60% of it. Demand for serum albumin in China is increasing by 15% each year, but because of "a stigma attached to paid plasma collection in China following a string of scandals" (in the 1990s, thousands of people in China who received pay for blood donations contracted HIV from unsanitary needles), China increasingly relies on imports.

Technological advances that improve the capabilities of prostheses can make the use of prostheses more effective and worthwhile. For example, researchers at ETH Zurich (Zurich, Switzerland) have created a proof-of-concept 3D-printed soft artificial heart that can pump blood for about 30 minutes. Artificial hearts—which typically see use only until a heart transplant can occur—usually consist of metal and plastic mechanisms and can be difficult to connect with tissue. In addition, they can damage the blood they pump. The researchers created the soft artificial heart by employing a 3D-printing method that enables them to "make a complex inner structure while still using soft, flexible material as its structure." Pressurized air repeatedly inflates and deflates a chamber between the silicone ventricles, which causes the heart to pump.

Tools such as 3D printers are becoming increasingly accessible and inexpensive, enabling almost anyone to experiment with them. For instance, Royal College of Art (London, England) graduate student Dani Clode created the Third Thumb—a 3D-printed prosthetic digit that uses a Bluetooth connection to communicate with pressure sensors under the user's feet. Pressing down with one foot sends a signal to a wrist Bluetooth receiver that transmits the information to the prosthesis on the hand, causing it to make a grasping motion. Although the Third Thumb aims to give the body new capabilities rather than replace lost ones or fix damaged ones, further development could enable it to find use in aiding disabled people. Furthermore, the prosthesis demonstrates how straightforward creating one's own additional body parts can be.

Signals of Change related to the topic:
SoC938 — …Human Augmentation
SoC828 — Augment Thyself
SoC564 — Printing Body Parts

Patterns related to the topic:
P1114 — Body-Part Developments
P1056 — Implants Overcome Paralysis
P1007 — Medical Implants

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P1151

Electric Trucks

By Susan Leiby (Send us feedback.)

Electric trucks will help to reduce emissions in urban areas and create large new markets for vehicle and battery manufacturers.

Abstracts in this Pattern:

SC-2017-11-01-054 on Deutsche Post
SC-2017-11-01-074 on Royal Mail
SC-2017-11-01-079 on MFTBC
SC-2017-11-01-091 on Tesla
SC-2017-11-01-067 on Siemens

In recent years, seven German cities—including Berlin, Hamburg, and Munich—have been pressing automakers to develop electric buses for their public transportation. Automakers have failed to deliver, but postal-service provider and logistics giant Deutsche Post (Bonn, Germany) purchased electric-vehicle manufacturer StreetScooter in 2014 and now manufactures an electric transporter to use in its own operations and to sell. Demand for the vehicle is growing: Deutsche Post hopes to increase annual production capacity from 10,000 to 20,000 vehicles by the end of 2017, and the company believes that it could sell 100,000 of the vehicles per year. In addition, Deutsche Post and Ford Motor Company (Dearborn, Michigan) recently debuted the StreetScooter Work XL—a large electric delivery van the two companies collaborated to develop. UK postal-service provider Royal Mail (London, England) is conducting trials of electric vans developed by Arrival (Banbury, England) and plans to use the vans for making deliveries in London. Royal Mail also purchased 100 electric delivery vans from Peugeot (Groupe PSA; Paris, France).

Many automakers have begun to accelerate electric-truck development. In September 2017, Mitsubishi Fuso Truck and Bus Corporation (MFTBC), of which Daimler Trucks (Daimler; Stuttgart, Germany) holds majority ownership, launched its Fuso eCanter—"the world's first series-produced all-electric light-duty truck." Customers in Europe, Japan, and the United States will begin receiving their vehicles in 2017. Daimler and Mitsubishi have a long history of success in the commercial-vehicles market, although their market involvement with electric vehicles has been minimal thus far. Also in September 2017, Tesla (Palo Alto, California) CEO Elon Musk announced plans to unveil an all-electric semitruck for use in freight transport.

New infrastructure for use in powering electric trucks on highways is under development. On a 10-kilometer section of autobahn in Hesse, Germany, Siemens (Berlin and Munich, Germany) is building a pilot eHighway—"an overhead contact line for electrified freight transport…. The line will supply electricity for the electric drive of a hybrid truck." The lines will connect directly to the electricity grid and could eliminate range anxiety for truckers who operate electric vehicles.

Signals of Change related to the topic:

SoC919 — Advancing Renewable Energy
SoC848 — Fossil-Fuel Headwinds
SoC746 — The…Power of Solar Energy

Patterns related to the topic:

P1135 — Electric-Vehicle Tipping Point?
P0983 — Tackling Fossil Energy…
P0969 — The Age of Solar Energy

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January 2018

P1162

Democratization of Robotics

By David Strachan-Olson (Send us feedback.)

New technologies and decreasing costs are democratizing access to robots, which could have significant social impacts.

Abstracts in this Pattern:
SC-2017-12-06-026 on design software
SC-2017-12-06-022 on Robotarium
SC-2017-12-06-010 on robot relationships

Companies continue to deploy more robots to perform manufacturing and service tasks every year. However, new technologies and decreasing costs are making robots more accessible to the public. Carnegie Mellon University's (Pittsburgh, Pennsylvania) Robotics Institute (www.ri.cmu.edu) recently created interactive design software that enables both nonexperts and experts to create robot designs quickly and easily. The software features a library of off-the-shelf components and a simple drag-and-drop interface. For nonstandard parts, the software creates structures that users can 3D print. The software also features a simulation environment in which creators can quickly test and adjust their robot designs before they fabricate their robots. The team hopes that such software will one day enable essentially anyone to design custom robots. Researchers at the Georgia Institute of Technology (Georgia Tech; Atlanta, Georgia) recently opened the Robotarium (www.robotarium.gatech.edu)—a 725-square-foot facility that houses close to 100 swarm robots that essentially anyone can access. Researchers and members of the public from anywhere in the world can write and upload programs to the Robotarium, and the facility's robots will carry out the programs' commands. The users receive the results and video footage of their tests. For many robotic researchers, developing and maintaining a multirobot lab is too expensive and time consuming. Magnus Egerstedt, executive director of the Georgia Tech Institute for Robotics and Intelligent Machines (www.robotics.gatech.edu), hopes the Robotarium will "do for robotics what MOOCs (massive open online courses) have done for education."

As robots become more involved in society, people will develop relationships with them. Researchers from the Massachusetts Institute of Technology (MIT; Cambridge, Massachusetts) are studying interactions between humans and robots and the relationships that humans form with robots. The team has discovered that children readily ascribe to robots the physical and mental attributes of living creatures. Such attributes include seeing, moving, thinking, feeling physical stimuli, experiencing emotions, and desiring companionship. Although robots do not currently find extensive use outside factories, new products such as robotic vacuum cleaners, smart speakers with speaking virtual assistants, and service robots are becoming increasingly common. Many questions remain unanswered, and the MIT research team will continue to evaluate the relationships that humans form with robots and other intelligent systems.

Signals of Change related to the topic:
SoC971 — …Efficiency versus Innovation
SoC924 — Interacting with Robots
SoC900 — Leveraging the Maker Movement

Patterns related to the topic:
P1042 — Robots Diffuse across Industries
P1030 — Peculiar Robotics of…Interest
P0982 — Robots' Becoming Part of Society

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P1163

Self-Repairing Machines and Systems

By Rob Edmonds (Send us feedback.)

Developments in robotics and artificial intelligence suggest that machines and systems may gain the ability to repair themselves.

Abstracts in this Pattern:
SC-2017-12-06-048 on European Union
SC-2017-12-06-056 on Vrije Universiteit Brussel
SC-2017-12-06-099 on General Electric

Predictive-maintenance systems—systems that use sensors and software technologies to predict machine failures—have reached commercialization. Although such systems are not yet perfect, researchers are already working on the next generation of such systems: systems that not only predict failures but also identify and resolve failures that do occur. For example, the European Union is funding a research project that focuses on self-sustaining manufacturing systems. Project participants—including the Fraunhofer Institute for Manufacturing Engineering and Automation (Fraunhofer Society for the Advancement of Applied Research; Munich, Germany), Electrolux (Stockholm, Sweden), and the Manufacturing Technology Centre (Coventry, England)—hope to develop systems capable of predicting equipment problems and automatically diagnosing and resolving at least some problems that have occurred. For example, Electrolux is using a technology that identifies malfunctions on a manufacturing press (for example, a sensor failure) and, when possible, compensates for the malfunction without taking the machine offline (by, for example, altering the machine's operating mode).

New materials could play an important role in creating machines capable of repairing themselves. Researchers at Vrije Universiteit Brussel (Brussels, Belgium) have built self-healing soft robots entirely out of rubbery polymers that, when damaged, first recover their shape and then heal completely. The researchers built a soft gripper, robotic hand, and artificial muscle and found that each component was able to recover from damage completely without developing weak spots.

Systems that combine predictive maintenance and automated repair could become highly capable. General Electric (GE; Boston, Massachusetts) is already developing small robots that can make their way into jet engines and gas turbines to perform inspection and repair tasks. In addition, the robots will be able to collect data for use in updating GE's *digital twins*—constantly improving digital models of industrial assets. GE's robots currently require considerable human oversight, but the combination of repair robots and complex digital models of equipment could one day enable fully automated inspection and repair systems. For example, perhaps robots could inspect machines and send their data to artificial-intelligence-based systems that then analyze the data, identify faults, and direct the robots to make repairs—all without human intervention.

Signals of Change related to the topic:
SoC979 — …Adaptable Materials
SoC918 — The Road to Industry 4.0
SoC739 — Healing Materials

Patterns related to the topic:
P1122 — Sound Science
P1073 — Transforming Products…
P0896 — …Sound and Sight Analysis

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December 2017

SoC983

Smart Infrastructures: Whole and Piecemeal

By Peter Batty and Martin Schwirn (Send us feedback.)

The sheer breadth of services, devices, and applications that claim to offer some degree of intelligence has perhaps diluted the meaning of the description *smart*. And people do not perceive all smart devices as useful. Many connected-home gadgets claim to offer added value in the form of their remote operability, but many consumers are indifferent to these gadgets. For example, many consumers believe that flicking a switch to turn on a light is just as convenient as unlocking their smartphone, opening the right app, and then operating the light. In 2016, research firm Gartner (Stamford, Connecticut) surveyed 10,000 consumers in the United States, the United Kingdom, and Australia about connected homes. Only 10% of respondents said that they had devices that worked as part of a connected-home solution, and 75% of respondents said that they were broadly content with manually controlling the lights and heating system in their homes. Moreover, only 25% of the respondents expressed any interest in devices or services that anticipated their needs at home. Privacy concerns abound when sophisticated machine-learning systems imbibe data about a multitude of users. Amazon.com's (Seattle, Washington) Echo smart speaker, which features the Alexa voice-controlled intelligent personal assistant, and similar devices from other companies learn to differentiate among the voices of multiple users and store purchasing preferences, and they use data analytics to develop an understanding of users' life patterns. People can choose whether they want to use such devices, but many smart systems operate in the background, invisible to users and out of their immediate control. Creating a smart city where advanced information technology monitors myriad connected infrastructure elements has become a goal for many city and regional governments and administrators around the globe; however, such interconnectivity creates privacy issues as citizens' lives become increasingly transparent.

A common requirement of and challenge for all smart-infrastructure efforts is to establish access to reliable networking capabilities.

In 2017, the Institution of Civil Engineers (ICE; London, England) launched *Smart Infrastructure and Construction*—a quarterly journal that aims to "provide a learned forum for documenting changes caused by the global adoption of emerging digital technology in the design, construction and management of infrastructure assets" ("New journal from ICE: Smart Infrastructure and Construction," Institution of Civil Engineers, 31 January 2017; online). The journal is accepting paper submissions and suggests topics such as the adaptive design and construction of structures, smart cities and construction technologies, and citizens' acting as sensors. One of city planners' major focuses is to ensure that cities' enabling networks—the various urban infrastructures—will be able to serve the needs of perpetually growing urban populations; therefore, existing initiatives will become important learning opportunities that inform future efforts. For example, Singapore's Smart Nation (www.smartnation.sg) program includes the citywide deployment of sensors to capture and manage information about the day-to-day lives of citizens. The program, which launched in 2014, intends to combine networking technologies with sensors to integrate infrastructure features from multiple sectors, including health care, transportation, and energy. For instance, the Elderly Monitoring System uses smart sensors to monitor the daily activities of elderly people in their homes and alerts caregivers about any anomalous activities. More than 80% of the

people in Singapore live in government housing, enabling the government to control smart-infrastructure technologies and to move rapidly to implement them. Similar initiatives are under way in other cities. For example, Amsterdam in the Netherlands has been running the Amsterdam Smart City (https://amsterdamsmartcity.com) initiative since 2009. The initiative focuses on six themes: Circular City; Citizens & Living; Energy, Water & Waste; Governance & Education; Infrastructure & Technology; and Mobility. In the United States, Columbus, Ohio, won the US Department of Transportation (DOT; Washington, DC) Smart City Challenge (www.transportation.gov/smartcity) in June 2016. The DOT recently released *Smart City Challenge: Lessons for Building Cities of the Future*, which provides details about what the DOT learned from the Smart City Challenge.

A common requirement of and challenge for all smart-infrastructure efforts is to establish access to reliable networking capabilities with the bandwidth sufficient to cope with the current and future communications needs of infrastructure elements as city planners increase interconnectivity. Fulfilling this requirement is a concern. For instance, despite the driving force of Silicon Valley, California, in information technology and data analytics, the United States generally has only patchy access to modern, high-speed internet. Geographic challenges are partially responsible for this condition, as is the high capital cost of installing telecommunications infrastructure. Some private companies are attempting to take up the challenge. For example, Alphabet (Mountain View, California), Google's parent company, is looking at developing the necessary communications capabilities. Its Access division is responsible for Google Fiber—an initiative to "engage locally to help improve Internet access, digital literacy and more" (https://fiber.google.com/about). Google Fiber started out in 2011 as a project to explore the provision of high-speed-internet access first in Palo Alto, California, and then prominently in Kansas City, Kansas, and Kansas City, Missouri. The service has since rolled out to other communities, but expansion plans ceased at the end of 2016. Alphabet's difficulties in making the service a viable business indicate the associated challenges of establishing the enabling infrastructure for smart-city projects. Entrepreneurs and city leaders in both Kansas Cities initially hoped that Google Fiber would attract high-tech companies to and create jobs in the region, but they found that mere access to broadband does not compensate for the absence of the advantages that Silicon Valley's commercial and research-driven environment provides.

Other companies are looking at leveraging existing infrastructure to establish new services and networks. For example, AT&T (Dallas, Texas) is working on AirGig—a communications technology that uses existing aboveground power lines to enable a type of wireless connectivity at multigigabit speeds. The signal does not propagate through the wire itself; instead, the AirGig device uses the wires to act as a guide for the wireless signal. In a very different effort, the company has partnered with General Electric (GE; Boston, Massachusetts) to install GE's CityIQ sensors in streetlights first in San Diego, California, and then in several other cities and municipalities in the United States. Once in the streetlights, the camera- and microphone-equipped connected sensors work with open platforms from AT&T to enable cities to monitor traffic, weather, and air quality and to optimize parking and even detect gunshots. Although AT&T's two efforts use different technologies and focus on different applications, they are similar in that they both utilize existing infrastructures to develop new and smart capabilities in urban environments.

SoC983

Signals of Change related to the topic:
SoC966 — Vendor Ecosystems and the IoT
SoC915 — …Urban Mobility
SoC913 — Making Urban Environments Smart

Patterns related to the topic:
P1107 — Connected Tech…
P1089 — …Infrastructure Replacements
P0987 — Rethinking Real Estate Use

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SoC985

Artificial Intelligence Is Alien Intelligence

By Rob Edmonds (Send us feedback.)

Artificial intelligence (AI) is developing humanlike capabilities and behaviors such as engaging in conversational speech, and it is increasingly cable of performing complex tasks that require creativity and judgment. But companies and individuals should not equate AI's humanlike capabilities with humanlike thought processes. P1136 — Unpredictable Artificial Intelligence mentions that AI applications can behave in ways that surprise users—but perhaps not some experts. Although AI is becoming increasingly capable at replicating human behavior and performing human tasks, artificial intelligence is quite unlike human intelligence.

AI certainly seems more humanlike now than it did in the past. For example, AI can now perform many tasks that researchers once thought were too complex for machines. In recent years, AIs have learned to master the game go, have become competent drivers, and have created music and art. In one recent example, a team of researchers at Google (Alphabet; Mountain View, California) created DeepDream—a neural-network system that creates new artworks by analyzing and augmenting existing photographs (SoC824 — Creative Machines describes other examples of software that can perform creative tasks).

Although AI is becoming increasingly capable at performing human tasks, artificial intelligence is quite unlike human intelligence.

Commercial AIs are beginning to automate complex tasks that professionals such as lawyers, doctors, and computer programmers typically must perform. For example, DoNotPay (https://donotpay-search-master.herokuapp.com) is an AI service for use in legal disputes. Programmed by entrepreneur Joshua Browder, the service provides information and generates letters and other legal documentation to assist people with legal issues, including parking-ticket disputes, maternity-leave requests, landlord disputes, insurance claims, and harassment cases.

As well as developing AIs that possess humanlike capabilities, some developers are attempting to develop AIs that seem human. Conversational interfaces such as the one in use by Amazon.com's (Seattle, Washington) Alexa voice-controlled intelligent personal assistant seek to offer "natural" ways for humans to interact with AIs. Emerging developments suggest that AIs could eventually behave in even more humanlike ways. During a recent study funded by the US Department of Defense's (Arlington County, Virginia) Defense Advanced Research Projects Agency (DARPA; Arlington, Virginia), researchers from Brown University (Providence, Rhode Island) and Tufts University (Medford, Massachusetts) attempted to create AIs and robots capable of adapting to social norms (for example, talking quietly in a room where people are studying). The researchers created a codable model of human norms and a machine-learning algorithm that attempts to learn norms in unfamiliar situations by drawing on data about human behavior. In another example, Computer scientists at the University of Washington (Seattle, Washington) developed a neural network capable of synthesizing a high-quality fake video of former US President Barack Obama. The team used hours of high-quality video of President Obama from the public domain to train the neural network.

Although AI may seem increasingly humanlike, technology pundit David Weinberger explains "that the nature of computer-based justification is not at all like human justification. It is alien" ("Our Machines Now Have Knowledge We'll Never Understand," *Wired*,

18 April 2017; online), implying that machine intelligence is quite unlike human intelligence. For example, Dr. Weinberger says that a machine-learning system might recognize the number *8* not by developing a recognizable rule (for example, an *8* comprises two vertically stacked circles) but by identifying complicated patterns of darker and lighter pixels encoded as matrices of numbers. Some leading AI researchers share Dr. Weinberger's view. As SoC620 — The New Machine Intelligence notes, AI expert Andrew Ng has dismissed the notion that artificial neural networks are comparable to the human brain, saying that "a loose and frankly awful analogy is that our numerical parameters correspond to synapses" ("How Many Computers to Identify a Cat? 16,000," *New York Times*, 25 June 2012; online). And SoC857 — Guesswork Computing notes that when several research teams tricked AI systems into misclassifying images, the mistakes the systems made highlighted the fact that the way such systems recognize images is quite different from the way humans recognize images.

The alien nature of AI is sometimes positive. Notably, AIs are developing capabilities that a human or animal could not. Although humans and animals are excellent at processing vast amounts of sensory data, they are limited in their ability to process abstract data; for example, a single person could not easily analyze patterns in a large collection of location data from cell phones or subtle patterns in financial data. A 2016 Accenture (Dublin, Ireland) report, *Why Artificial Intelligence is the Future of Growth*, argues that AI could become a new factor of production in an economy because AI will work beyond the capabilities of humans (in speed, scale, and perhaps reasoning). But some systems are perhaps not alien enough. As P0814 — Anthropomorphizing Social Robots notes, soldiers have risked their lives simply to "save" military robots from dangerous situations, prompting some researchers to argue that developers should redesign such robots to have minimal personality and be more like tools.

Alien decision making is also problematic. When trading algorithms have contributed to flash crashes on stock markets, experts have struggled to unpick the complex chain of events and algorithmic decisions that caused the crashes. Many AIs are black boxes—that is, their exact chain of reasoning is incomprehensible to humans. Although people may find these black boxes acceptable for use in advertising placement and machine translation, they may be concerned about their use in high-stakes tasks such as identifying diseases, making parole recommendations, and conducting drone strikes. The General Data Protection Regulation is a new privacy regulation in Europe that will give people the right to ask for an explanation of algorithmic decisions that have a significant effect on them; however, whether algorithm operators will actually be able to offer such explanations is uncertain. Efforts to solve some of these challenges are under way. In 2016, DARPA launched an effort to create explainable AI. Oracle Corporation (Redwood City, California) is apparently also working to make AI more transparent, and Microsoft (Redmond, Washington) CEO Satya Nadella has discussed the need for algorithmic accountability. But the outcome of such efforts is uncertain, and some experts—including Google research director and AI guru Peter Norvig—have questioned the efforts' feasibility.

AI systems are developing capabilities that match or exceed those of humans for some specific tasks and becoming good imitators of human behavior. That these humanlike systems are actually alien is likely good news, because intelligent machines will probably be able to perform tasks that humans cannot. In the meantime, individuals and organizations need to understand the alien nature of AI so they will not be caught out by assuming that machines will behave as humans do.

SoC985

Signals of Change related to the topic:
SoC857 — Guesswork Computing
SoC824 — Creative Machines
SoC620 — The New Machine Intelligence

Patterns related to the topic:
P1136 — Unpredictable Artificial Intelligence
P1117 — Voice Assistants for Everyone
P0814 — Anthropomorphizing Social Robots

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SoC990

Microgrids for Energy Security

By Cassandra Harris (Send us feedback.)

For more than a century, centralized fossil-fuel-power plants have made possible widespread access to affordable electricity; however, the rise of low-cost and low-carbon distributed generation is presenting an increasingly viable alternative to centralized generation. SoC919 — Advancing Renewable Energy discusses how renewable energy has become more widely cost competitive with conventional energy despite declines in global fossil-fuel prices. Small power-generation systems that install in proximity to end users and have the potential to bypass the electrical grid are strengthening electricity consumers' market power. Utilities and traditional energy producers are facing increasing pressure to adapt to evolving public and government priorities (as SoC848 — Fossil-Fuel Headwinds describes) and to provide new energy products and services that are more efficient, sustainable, and resilient to disruption. The increasing accessibility of distributed energy and data-driven energy-management systems is driving the deployment of *microgrids*—small-scale versions of centralized-generation systems that combine interconnected distributed-generation sources, energy storage, and management software and serve individual buildings or small communities. According to Navigant Research (Navigant Consulting; Chicago, Illinois), 1,842 microgrid projects are under development, in operation, or at the proposal stage around the world, and these projects represent a total capacity of nearly 20 gigawatts.

Energy decentralization faces a number of barriers, and its widespread development will not be straightforward.

The series of forceful Atlantic hurricanes that devastated parts of the Americas and the Caribbean in mid-2017 have focused attention on the role that solar microgrids could play in enhancing power resilience and reliability. According to the US Department of Energy (DOE; Washington, DC), 85% of Puerto Rico's 3.4 million residents remained without power for three weeks after Hurricane Maria hit in September 2017 and incapacitated much of the territory's electricity grid. In response to the crisis, efforts to partially restore power on the island by deploying solar microgrids commenced. For example, in October 2017, solar-panel-installation company Pura Energia (Aguadilla, Puerto Rico) and energy-storage-systems manufacturer Sonnen (Wildpoldsried, Germany) announced a partnership to install solar microgrids at 15 emergency-relief centers in Puerto Rico. And members of the Solar Energy Industries Association (Washington, DC) donated $1.2 million in solar technologies. Retrofitting solar installations with energy-storage systems is a means of deploying solar microgrids rapidly. Sunnova Energy Corp. (Houston, Texas) reportedly shipped battery systems to some of its 10,000 solar customers in Puerto Rico in an effort to help them generate power until the territory's grid resumes operation. And Tesla (Palo Alto, California) shipped hundreds of its Powerwall residential battery packs to Puerto Rico. These battery packs can store energy that solar systems generate during the day for later use. Restoring Puerto Rico's electrical grid will take several months, but the new network of solar microgrids will help improve conditions for residents until the grid is fully operational. In addition, the network could aid in maintaining a power supply in Puerto Rico if grid outages occur again.

Extreme weather events can have devastating effects, but they can also represent an opportunity for stakeholders to modernize electricity networks

by making them cleaner, more efficient, and more resilient to disruptions. Even before Hurricane Maria hit, power outages in Puerto Rico were common. In addition, Puerto Rico's electricity prices are the second highest in the United States, reflecting the territory's high dependence on oil imports. Puerto Rico Governor Ricardo Rosselló recently announced that he was considering wide-scale microgrid deployment in an effort to reduce Puerto Rico's reliance on grid electricity. The cost of frequently repairing or replacing electricity-transmission and -distribution infrastructure after extreme weather events is high, and grid restoration that takes many weeks or months has a negative impact on local economies. For the millions of people who permanently live off the grid in developing countries and geographically remote locations, microgrids could offer a bottom-up approach to expanding and eventually interconnecting energy infrastructures. In September 2017, Mozambique's Ministry of Mineral Resources and Energy (Maputo, Mozambique) introduced a $500 million electrification program that aims to provide power for some of the millions of Mozambique residents who live off the grid. Led by Fundo de Energia (FUNAE; Maputo, Mozambique), the program plans to deploy 343 solar-power systems—including 121 solar-plus-storage minigrids and microgrids that range in capacity from 1 kilowatt to 3 megawatts—in rural communities. In addition, 332 villages will gain access to hydropower minigrids with a combined capacity of about 1 gigawatt.

Microgrids can rapidly connect or disconnect from the main grid and function as backup power systems during grid outages, which makes deploying them an attractive solution to a variety of challenges that utilities and consumers face. In October 2017, the US Federal Bureau of Investigation (FBI; Washington, DC) and Department of Homeland Security (Washington, DC) issued joint technical alert TA17-293A—a warning to energy organizations that describes an advanced and persistent threat to the energy sector. The release of this alert follows a series of attempts by hackers in 2017 to gain access to the networks of power-plant and grid operators in the United States and Europe. Cyber-physical attacks against power-system and network operators have the potential to disrupt critical services in areas such as health care and defense, thereby compromising public safety. The US Department of Energy recently announced $50 million in funding for its national laboratories to support research that aims at enhancing grid resilience and cybersecurity. The DOE has allocated a portion of the funding for the development of cyberattack-resilient architecture for distributed-energy systems and microgrids and for the deployment of multiple-network microgrids in Alaska to provide power in the event that cyberattacks or weather events cause grid outages.

Energy decentralization faces a number of barriers, and its widespread development will not be straightforward. SoC799 — Renewable Considerations describes how renewable energy must come down in cost before it is genuinely able to compete on an economic basis with traditional energy. Furthermore, the applicability of renewable energy can be regionally limited, and many types of renewable energy have intermittency problems that necessitate the use of energy-storage solutions. Large-scale energy-storage systems can be expensive and suffer from performance problems, which can hinder their use in various applications (see SoC764—Large-Scale Energy Storage). Microgrids are not immune to physical attacks and cyberattacks, and microgrid deployment currently requires assessment on a case-by-case basis. Wide-scale microgrid deployment also requires the challenging task of developing new energy policies, business models, and financing schemes.

SoC990

Signals of Change related to the topic:
SoC919 — Advancing Renewable Energy
SoC848 — Fossil-Fuel Headwinds
SoC799 — Renewable Considerations

Patterns related to the topic:
P1101 — Solar-Power Enablers
P0970 — Balancing Act
P0959 — …Renewable-Energy Use

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SoC991

Self-Assembly and Self-Adaptation

By Martin Schwirn (Send us feedback.)

Self-assembly is a process in which components assemble themselves into some sort of structure or specific order without outside manipulation. Although a trigger of some kind might be necessary to initiate self-assembly, and the process may require certain conditions, self-assembly otherwise occurs without intervention. People often associate self-assembly with molecular self-assembly, but a wide range of applications exist. This Signal of Change takes liberty with the definition of the process and looks at a variety of approaches that include some type of self-assembly or self-adjustment. Self-assembly and self-adaptation are very different, but potential overlapping application areas exist. The approaches this Signal of Change presents enable objects and components to interact with materials or the environment in such a way that the objects' use potential and functionalities change. Applications this Signal of Change mentions have overlap with applications that see discussion in SoC910 — Origami-Inspired Design and Related Concepts, which looks at how the application of origami-inspired folding techniques to product design is finding use in new industries, and in SoC979 — MIT's Efforts in Adaptable Materials, which provides an overview of multiple adaptable materials under development at the Massachusetts Institute of Technology (MIT; Cambridge, Massachusetts).

Experimental materials and approaches might never commercialize, but they will drive further innovation in the search for commercial applications.

Self-assembly could enable researchers to continue decreasing the size of electronic components. A team of researchers from MIT, the University of Chicago (Chicago, Illinois), and Argonne National Laboratory (US Department of Energy; Washington, DC) have developed a three-step process that leverages self-assembly to produce fine patterns of wires. The researchers begin by using conventional lithographic techniques to etch patterns on a chip. Next, the researchers lay down a mixture of two polymers that naturally separate to form patterns. The researchers then cover those polymers with a protective polymer coating, which forces them "to self-assemble in a dense, vertically oriented way that produces four wires where there would usually be one" ("Self-assembling wires could lead to faster processors," Engadget, 29 March 2017; online). Meanwhile, researchers from the Leibniz Institute for New Materials (Leibniz Association; Berlin, Germany) are using a new self-assembling gold-nanowire ink with an imprint process to create flexible conductive grids that could find use in transparent electronics. To create the conductive grids, the researchers apply a layer of gold-nanowire ink to a substrate and use a stamp to force the ink into a pattern. As the gold-nanowire ink dries, the gold nanowires self-assemble into the large bundles that form the grid. The researchers then treat the grid with a plasma to condense the bundles into conductive wires. Stamp geometry determines the shape of the grid, and gold concentration determines the thickness of the grid.

Many other approaches do not necessarily meet a strict definition of self-assembly but enable researchers to change the shapes of materials in ways that affect entire components that thereby serve a variety of functions. For example, researchers at North Carolina State University (Raleigh, North Carolina) developed a new technique that enables the remote control of the order in which a 2D sheet folds itself into a 3D structure. This new approach builds on a technique a few of the researchers developed in

2011. In the older technique, the researchers print black lines on a sheet of polymer. The researchers then cut the sheet into a pattern and place it under a source of infrared light. Because the sections with black ink absorb more energy than do the ink-free sections, they contract in response to exposure to infrared light, which creates hinges that enable the sheet to fold into 3D shapes. The researchers can control how far and how quickly the hinges fold by varying the width of the black lines. The new technique relies on "the fact that different colors of ink absorb different wavelengths, or colors, of light.… For example, if one hinge is printed in yellow and another hinge is printed in blue, the researchers can make the yellow hinge fold by exposing it to blue light. The blue hinge won't fold, because blue ink doesn't absorb blue light. The researchers can then make the blue hinge fold by exposing the sheet to red light" ("Researchers Remotely Control Sequence in Which 2-D Sheets Fold Into 3-D Structure," NC State News, 3 March 2017; online). Furthermore, because the efficiency of absorption of wavelengths of light varies among colors, the researchers can place colors strategically to enable hinges to fold in a specific order on exposure to only one wavelength of light.

Similarly, some three-dimensional objects can change their shape. The term *4D printing* refers to the use of 3D printers to produce materials capable of transforming into a set shape after their production. Recently, a team of researchers from the Georgia Institute of Technology (Georgia Tech; Atlanta, Georgia), Singapore University of Technology and Design (Singapore, Singapore), Xi'an Jiaotong University (Xi'an, China), and Zhejiang University (Hangzhou, China) developed a printing method that uses layers of shape-memory polymers to enable the final object to transform into predetermined shapes on exposure to heat. For example, the team created a model of a flower with multiple layers of petals that bend in response to heat much like real flower petals respond to sunlight. Georgia Tech professor Jerry Qi explains that the team's method "allows high-resolution 3-D printed components to be designed by computer simulation, 3-D printed, and then directly and rapidly transformed into new permanent configurations by simply heating" ("New 3-D Printing Method Creates Shape-Shifting Objects," Georgia Tech News Center, 12 April 2017; online).

Other applications focus on the complete assembly of products. For example, scientists at MIT's Self-Assembly Lab (www.selfassemblylab.net) have prototyped a self-assembling phone capable of putting itself together in less than a minute. The prototype phone consists of multiple components, and each component has a lock-and-key mechanism. When the researchers place the components into a spinning cement mixer, the components bump into one another and lock together. The process is clearly exploratory, and its application in manufacturing is highly speculative. Nevertheless, the researchers have demonstrated how broad and diverse applications of self-assembly have the potential to be.

Researchers have tested self-assembly at small scales and the molecular level and proved its feasibility in these contexts. Self-adjustment—that is, objects' changing to meet specific needs—has seen use in shape-memory materials for decades. Self-assembly and self-adjustment are not new, but novel ways to use them indicate that they have even greater applicability across many industries. Experimental materials and approaches might never commercialize, but they will drive further innovation in the search for commercial applications.

SoC991

Signals of Change related to the topic:
SoC979 — MIT's Efforts in Adaptable Materials
SoC974 — Toolboxes for Materials Innovation
SoC910 — Origami-Inspired Design…

Patterns related to the topic:
P1108 — …3D-Printing Materials
P1054 — On-Demand Manufacturing…
P0990 — Medical Origami