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DEFTECH Update

April 2018

Dear Reader,

Welcome for this first 2018 release of the DEFTECH (Defence Future Technologies) Update.

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
Research Director – Technology Foresight

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

Image source: NEC

Recognizing and Analyzing Faces: Advances in camera technology are enabling mass-scanning of faces at football matches or other crowded gatherings. In addition to identifying individuals, facial-analysis software can detect signs of fatigue, disease, and attention level.

Implication for Defense and Security*: As well as discerning between friendly and hostile individuals in combat situations or scanning crowds for known suspects, facial-recognition technologies could help inform defense strategies and planning. For example, the technology could be used to identify fatigued enemy personnel that could represent weaknesses in lines of defense.*

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

Image source: Desktop Metal

Advances in Metal 3D Printing: Companies including GE Additive and Desktop Metal have developed improved methods of 3D-printing metals. New 3D printing technologies enable faster printing of components in a variety of materials including copper, titanium, and steels. Researchers at Lawrence Livermore Laboratory have also developed a new form of 3D-printed steel that is three times as strong as previous 3D-printed steels.

Implication for Defense and Security*: Smaller and faster metal 3D printing enables wider use of the technology. 3D printing can produce high-quality spare parts for vehicles or other equipment in hours without relying on warehouses or supply chains. In particular, 3D printing can keep older equipment in action for longer. Other applications include printing steel or titanium implants.*

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

Image source: Bluebay/Shutterstock

Living in a Predictive World: Developments in AI are enabling a wide range of phenomena to be interpreted and predicted ahead of time. For example, analysis of large numbers of health records enables doctors to detect patterns in how likely certain patients are to develop illnesses. In another example, analysis of social-media data can identify problematic social behavior or mental illness.

Implication for Defense and Security*: Predictive AI has many potential applications including monitoring the health of personnel, optimizing training regimes, and supporting strategic and tactical planning. Predictive AI can also enable predictive maintenance systems that can detect when a piece of equipment is about to break and cue maintenance or repair work before this happens, minimizing down-time for important assets.*

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

Image source: Benoit Godde

Robots' Newest Moves: Research and development in robotics hardware and software continues to advance. Boston Dynamics has demonstrated a bipedal robot that can jump onto and off objects and even perform a back flip. NASA's jet Propulsion Laboratory recently completed a project enabling an AI system to pilot unmanned aerial vehicles (UAVs) through cluttered environments.

Implication for Defense and Security*: Advances in robotics that allow robots or drones to operate without a human pilot even in crowded conditions have potential applications for search and rescue, reconnaissance, and enabling large numbers of UAVs to operate effectively alongside one another.*

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

Image source: Bollinger Motors

Growth in the EV-Battery Market: Manufacturers of electric vehicles (EVs) are driving a global manufacturing boom for Lithium-ion batteries. Global production could double to 275 GWh. Key players driving this boom include Panasonic, LG Chem, Samsung SDI, and Chinese firms BYD and Contemporary Amperex Technology.

Implication for Defense and Security*: Booming production means lowering cost for Lithium-ion batteries. Growing consumer demand for EVs is likely to dramatically reduce the cost of EVs in defense and security markets. In the medium term EVs could become more cost-effective than internal-combustion vehicles. Mass-production EVs will also realize economies of scale for fleet managers.*

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

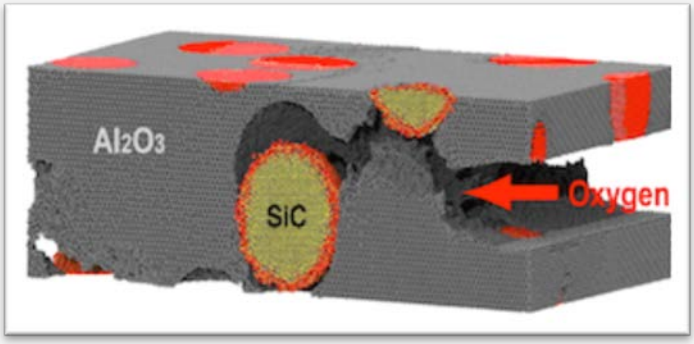

Image source: Argonne National Laboratory

Self-Healing Ceramic-Matrix Composites: Researchers at the National Institute for Materials Science (Yokohama, Japan) have developed a method of doping a ceramic-matrix composite with a healing agent that can self-repair small cracks (100 microns) when exposed briefly to high temperatures (1,000 °C). The healing agent greatly reduces the exposure time and temperature necessary to trigger the self-healing effect.

Implication for Defense and Security*: Ceramics offer lightweight, strong components for vehicles and aircraft. Self-healing ceramic-matrix composites could be an important enabler for next-generation jet engines and could find use in high-temperature exhaust systems. Other equipment including weapons and UAVs could make use of self-healing ceramic-matrix composites.*

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

Image source: UCLA Engineering

Novel Cooling Technologies: Researchers are exploring a range of novel cooling techniques that are smaller and less complex than conventional heat exchangers. Novel cooling technologies under development include light-filtering paints that can help keep buildings and vehicles cool; liquid-coolant systems to regulate the temperature of electronic components; and solid-state flexible cooling devices.

Implication for Defense and Security*: Thermal management is a key component of human comfort and fitness. Novel cooling devices could enable thermally regulated uniforms and small energy-efficient refrigerators for perishable food or medicines. Larger cooling systems could help protect vehicle engines and electronics from overheating.*

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

Image source: Jeong Lab, University of Colorado Boulder

Medical Sensors, Data, and AI: Advances in medical sensors are enabling doctors to gather much more patient data than was previously possible. Biocompatible sensors can be ingested and developers are making improvements in the durability of smart skin patches and ultra-thin temperature sensors. Combining this plethora of medical data with artificial-intelligence systems is leading to new avenues of medical research and potential early-warnings for a wide range of medical conditions.

Implication for Defense and Security*: Military personnel often live in close confines, presenting a high risk of communicating illness. Real-time monitoring of the health of personnel can enable early diagnosis of illnesses. In particular, early detection of potentially infectious diseases can prevent spread to other personnel and allow pre-emptive measures such as inoculations or quarantining of at-risk soldiers.*

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

Image source: FreshRealm

Ensuring Food Security: Researchers are developing several technologies that could help improve food safety and longevity. Korean researchers have developed a nanospray that prolongs the shelf life of perishable foods. Swiss researchers have developed biodegradable ultra-thin temperature sensors for use with foodstuffs. Scientists in Korea are also developing advanced sensor systems to rapidly check food for the presence of harmful bacteria.

Implication for Defense and Security*: Food technology can help increase the shelf-life of soldiers' rations, simplifying logistics operations, helping prevent potential cases of food poisoning, and potentially lowering costs. Long-shelf-life food can also be an important enabler for disaster relief efforts.*

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

Image source: Yank Design

Fluid Design for Homes and Workplaces: Furniture manufacturers and interior design companies are offering products that enable more fluid use of spaces. Fast turnaround furniture supply and on-demand interior design services are emerging in response to changing attitudes to home and workspaces that value the freedom to use spaces for different purposes as and when people need them. Ikea has developed a highly streamlined supply chain to offer furniture at low prices with rapid delivery and emphasizing adaptable furniture.

Implication for Defense and Security*: Adaptable interior design could make more efficient use of space, with a building switching from being a barracks, meeting room, data center, or infirmary, according to demand. This could enable smaller, more-efficient, military bases, in particular enabling greater portability and adaptability of in-the-field buildings.*

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

Image source: Sander van der Werf/Shutterstock

New Surgical Sealants: Researchers are developing new biological sealants that can quickly and easily close wounds but are more biocompatible than existing sealants. University of Sydney researchers have created a light sensitive molecule that forms a biodegradable elastic gel on contact with tissue. Gecko Biomedical (Paris, France) is commercializing a biocompatible photo-polymer sealant. The photopolymer cures on exposure to UV light and can be used in wet environments including vascular surgery.

Implication for Defense and Security*: Easy-to-use and effective biocompatible surgical sealants could enable personnel with relatively limited training to perform simple medical procedures at field hospitals, freeing up more senior medics for other tasks. These sealants are also an improvement on currently available sealants in battlefield first-aid kits, potentially helping stabilize injured personnel while waiting for medical evacuation.*

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

Image source: Airbus

Self-Diagnostic Smart Skin on Vehicles: The US Army Research Laboratory is running a project to develop self-diagnostic vehicles that can detect damage automatically. As part of this project, researchers have developed a composite laminate that incorporates a layer of magnetostrictive material. The magnetostrictive material responds to changes in stress by altering its magnetic field. This change in the magnetic field is readily detected and signals that the laminate component is damaged.

Implication for Defense and Security*: Much routine mechanical maintenance involves replacing components after a set amount of use as a precaution. Real-time monitoring of the stresses on, say, engine components or rotor blades could reduce the costs and time associated with vehicle maintenance.*

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

February 2018

P1171

Ensuring Food Freshness and Safety

By Martin Schwirn (Send us feedback.)

New applications aim to ensure the freshness and safety of foods and beverages from their manufacture to their sale to consumers.

Abstracts in this Pattern:

SC-2018-01-03-016 on KAIST
SC-2018-01-03-045 on ETH Zurich
SC-2018-01-03-096 on The Wave Talk

Researchers are experimenting with new technologies to extend foods' freshness. Researchers at KAIST (Korea Advanced Institute of Science and Technology; Daejeon, South Korea) have developed an edible antibacterial nanospray that prolongs the shelf life of some perishable produce by more than a month. The researchers "combined the chemical properties of polyphenol-iron complexes with spray techniques to develop a sprayable nanocoating technique that can be applied to any surface. This new nanocoating process forms nanometer-thick films, allowing for the coating of commodity goods." According to the researchers, this spray method coats produce more quickly than do conventional immersion methods.

Other researchers aim to gain more accurate data about the conditions in which food products ship. Researchers at the Swiss Federal Institute of Technology in Zurich (ETH Zurich; Zurich, Switzerland) have developed a biocompatible and biodegradable ultrathin temperature sensor that, according to the researchers, could attach to food products such as fish and monitor the products' temperature during transportation between countries. Such monitoring can reveal whether the products remained in the correct temperature range during shipping, enabling more accurate expiration dates for the products. The sensors could also see use in improving processes that aim to provide ideal conditions for food products during shipping, thereby extending the products' shelf life.

According to the US Centers for Disease Control and Prevention (Atlanta, Georgia), food poisoning kills roughly 3,000 people in the United States every year. Typical approaches in use to test foods and beverages for bacterial contamination are complex, costly, and time consuming, but a new system under development could streamline bacteria detection and aid in making foods and drinks safer. The Wave Talk (Daejeon, South Korea) is developing a sensor system that uses a laser to detect the presence of harmful bacteria in homogeneous liquids. The company claims the system works very quickly, requires no specialist operators, and installs easily on production lines. The Wave Talk has also developed a prototype handheld liquid scanner for consumers and intends eventually to work on technology capable of scanning solid objects for bacteria.

Signals of Change related to the topic:

SoC981 — CPG: *C* Is for *Change* in Retail
SoC950 — Addressing Food Security
SoC859 — Nanoparticles and Food

Patterns related to the topic:

P1176 — Global Sustenance
P1166 — Dynamics in Grocery Provision
P0884 — Food (of) Concern

February 2018

P1172

Novel Cooling Technologies

By Marianne Monteforte (Send us feedback.)

Advanced cooling technologies can benefit a range of industries.

Abstracts in this Pattern:

SC-2018-01-03-002 on cooling buildings
SC-2018-01-03-067 on cooling processors
SC-2018-01-03-023 on cooling mobile phones

Running space-cooling air-conditioning systems during summer months increases businesses' energy consumption and therefore operating costs. To address this problem, some start-ups are developing novel approaches to cool buildings from the outside. For example, start-up SolCold (Herzliya, Israel) is commercializing a light-filtering paint that uses sunlight to cool buildings. The paint absorbs light from the sun and reemits it at a higher, and therefore more energy-carrying, frequency, thereby transferring energy away from the building. Despite the high up-front cost of the paint ($300 per 100 square meters of coverage), the paint has the potential to offer long-term energy savings by reducing air-conditioning costs.

Novel cooling methods also offer the electronics industry the opportunity to improve the performance of a wide range of components. The need for thermal management is one of the limiting factors that computer engineers face when they attempt to improve the performance of computers. Research efforts to increase the processing power of computer components typically include the development of novel cooling components. For example, engineers at the Fraunhofer Institute for Reliability and Microintegration (Fraunhofer Society for the Advancement of Applied Research; Munich, Germany) developed a novel liquid-based cooling system capable of cooling microchips from both above and below. The researchers installed microchannel structures in the silicon interposer, which sits between the processor and the printed circuit board. Coolant that flows through the microchannels pulls heat away from the processor.

Novel cooling devices under development could find use in a variety of applications. For example, engineers from the University of California, Los Angeles (UCLA; Los Angeles, California), and SRI International (Menlo Park, California) are developing a solid-state cooling device that is energy efficient, flexible, and thin (only 5 millimeters thick). In a demonstration, the engineers used a prototype of their cooling device to lower the temperature of a hot smartphone battery by 8˚C within five seconds. Further development could enable the device to see use in applications such as personal coolers that users place in their shoes or hat, portable food coolers for use during hiking or camping trips, and even low-power refrigerators that keep heat-sensitive medicines and vaccines cold in regions that have limited access to electricity.

Signals of Change related to the topic:

SoC991 — Self-Assembly and Self-Adaptation
SoC968 — Stronger Materials
SoC703 — …Energy-Efficiency Gains

Patterns related to the topic:

P1138 — Energy from Everywhere
P1126 — Hot Computing
P1043 — …Thermoelectric Materials…

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P1183

Advances in Metal 3D Printing

By Guy Garrud (Send us feedback.)

Research in 3D printing metal is active, and new commercial developments exist.

Abstracts in this Pattern:

SC-2018-02-07-046 on GE Additive
SC-2018-02-07-054 on GE Healthcare
SC-2018-02-07-078 on Desktop Metal
SC-2018-02-07-056 on LLNL

In late 2017, General Electric's (GE's; Boston, Massachusetts) GE Additive division unveiled the first Beta metal 3D printer it developed as part of its Project A.T.L.A.S (Additive Technology Large Area System). The goal of this project is to develop large-format (on the order of meters) metal 3D printers for key industries, including the automotive and aerospace industries. GE Additive arose in part from GE's acquiring controlling shares of Concept Laser (Lichtenfels, Germany) and Arcam (Mölndal, Sweden), which are leaders in the metal-3D-printing space. GE is making use of 3D printing in some of its other divisions as well. For example, GE Healthcare has opened a 3D-printing lab in Sweden that focuses on medical products. The Innovative Design and Advanced Manufacturing Technology Center for Europe in Uppsala, Sweden, uses 3D printers, including metal 3D printers, with robots to augment traditional manufacturing techniques.

Desktop Metal (Burlington, Massachusetts) is commercializing an approach to metal 3D printing that could prove transformative. Current-generation metal 3D printers typically user laser-based techniques, but Desktop Metal's printers use an inkjet-like technology that places layers of metal powder on top of one another and "sprays layers of wax and a plastic binding agent in very specific patterns. The final printed part is then first placed in a 'debind' fluid that breaks down the wax and most of the plastic before being placed into a furnace where the rest of the binding agent…is burnt off, leaving just the metal." Desktop Metal claims that its technology enables metal 3D printing at a small fraction of the cost of competing technologies in a small fraction of the time. If the company's technology can deliver on these promises, it could compete not only with other metal-3D-printing technologies but also with some other types of current-generation manufacturing systems.

Another important differentiator in the 3D-printing space is the variety of materials that machines can print. For example, Desktop Metal's machines can print copper, titanium, and steels. Improving the quality and variety of 3D-printing materials is an active area of research. Researchers at the Lawrence Livermore National Laboratory (LLNL; Livermore, California) collaborated with researchers from other institutions to develop a new method of printing stainless steel that reportedly triples the strength of the steel and improves the steel's ductility.

Signals of Change related to the topic:

SoC979 — MIT's…Adaptable Materials
SoC972 — Computer-Aided Construction
SoC968 — Stronger Materials

Patterns related to the topic:

P1160 — Toward Mass Customization
P1108 — …3D-Printing Materials
P1054 — On-Demand Manufacturing…

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P1184

Robots' Newest Moves

By David Strachan-Olson (Send us feedback.)

Robotics research—particularly research concerning robotics software and control systems—is giving robots an ever-increasing range of physical capabilities.

Abstracts in this Pattern:
SC-2018-02-07-043 on Atlas
SC-2018-02-07-075 on NASA
SC-2018-02-07-042 on Embodied Intelligence

Researchers continue to endow robots with new physical capabilities that enable them to complete new types of tasks. In 2016, Boston Dynamics (SoftBank Group Corp.; Tokyo, Japan) unveiled a new Atlas robot with the capability to walk over uneven terrain and move boxes with handless arms. In late 2017, Boston Dynamics released a video of an Atlas robot with impressive new movement capabilities. The video shows the robot jumping vertically a few feet into the air and landing on boxes. Once on a box, the robot could perform a 180-degree jump turn, hop off the box, and even backflip off the box. This robot appears to have leg components that older Atlas robots did not have, and it likely has an improved software control system.

Many new capabilities that robots are gaining are not a product of innovative physical design but a result of rapid advances in robotic intelligence and machine perception. Researchers from NASA's (Washington, DC) Jet Propulsion Laboratory recently completed a two-year research project to develop an artificial-intelligence (AI) system for flying a drone in a cluttered environment. The system uses Google's (Alphabet; Mountain View, California) Tango mapping technology to collect visual information that the AI uses to fly the drone. To test the system, the team raced custom AI-operated drones around an indoor obstacle course against a drone operated by a human who participates in a drone-racing league. The human-operated drone was ultimately faster than the AI-operated drones but not by a significant margin.

New AI start-up Embodied Intelligence (Emeryville, California) is hoping to apply emerging AI techniques to teach robots new physical skills quickly. The company plans to focus on developing AI technologies that will enable existing industrial robots to learn new skills with minimal hardware modifications. Embodied Intelligence's researchers intend to use the latest advances in deep reinforcement learning, deep imitation learning, and few-shot learning in developing their AI software. Robots that use the company's AI system would be able to learn new skills without the need for explicitly programmed trajectories, which would enable robots to learn new tasks more quickly.

Signals of Change related to the topic:
SoC996 — Industrial Robots…
SoC971 — Robots: Efficiency…
SoC962 — …Automation's Implications

Patterns related to the topic:
P1162 — Democratization of Robotics
P1088 — Automation Reaches…
P1042 — Robots Diffuse…

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SoC997

Sensors, Data, and AI in Health Care

By Peter Batty (Send us feedback.)

Innovative sensors are gathering prodigious amounts of physiological data. With the help of artificial intelligence (AI), these data may improve diagnostic and monitoring applications and enable better treatment outcomes for many people. Three developments contribute to such advances in health care: a proliferation of inexpensive, adaptable sensors; vast amounts of data either in raw form or as an amalgamation from multiple sources; and AI's and data science's learning from these troves of data, turning them into actionable evidence that could diagnose health conditions.

Sensors acquire data and, in general, the closer they are to the subject under investigation, the more accurate their results will be. The US Food and Drug Administration (FDA; Silver Spring, Maryland) recently approved a digital pill for use in treating patients with schizophrenia and related conditions. The pill is novel in that it contains an ingestible—and therefore biocompatible—sensor that relays data to a wearable patch when the pill has reached the patient's stomach. The patch then relays these data to a companion smartphone app, which records when the patient took the pill and notifies (with the patient's permission) caregivers and physicians of any missed doses. Proteus Digital Health (Redwood City, California) developed the sensor technology in use in this pill, and the FDA cleared the company to market the technology back in 2012. Biocompatibility and biodegradability are both important features for technologies that see use in and on humans. For example, swallowable devices must not harm the patients who swallow them, and they should not harm the environment when they reach the end of their usefulness. Researchers at the Swiss Federal Institute of Technology in Zurich (ETH Zurich; Zurich, Switzerland) have developed a biocompatible and biodegradable ultrathin temperature sensor that, according to the researchers, could attach to food products such as fish and monitor the products' temperature during transportation between countries. This technology highlights three developments: a rapid reduction in sensing-technology costs that makes the technology employable in disposable applications, the proliferation of devices that tie into the Internet of Things to provide ready access to data, and advances in materials science that enable conformal electronics that are biocompatible.

Biocompatibility and biodegradability are both important features for technologies that see use in and on humans.

Most recent developments focus on pills and patches that patients or fitness enthusiasts use or wear for only a short period. The durability of devices for use inside or in close contact with the human body is still questionable, and the challenges are numerous. Researchers from the University of Tokyo (Tokyo, Japan) and other institutions have developed a temporary-tattoo-style sensor patch that a person can wear comfortably for up to a week for medical and athletic applications. The sensor patch is apparently more durable than are similar temporary-tattoo-like technologies such as the gold-leaf temporary tattoos researchers from the Massachusetts Institute of Technology (Cambridge, Massachusetts) developed to enable remote control of electronics. The Japanese researchers' sensor patch comprises a gold nanomesh that is supported by a water-soluble polymer. During application of the patch, a spray of water dissolves the polymer, enabling the nanomesh to conform to the wearer's skin. A trial in which multiple subjects wore a sensor patch for a week showed that the patch held up mechanically to repeated bending and stretching and was able to measure electrical activity from

the wearers' muscles. This work suggests that wearable sensors that monitor physiological data continuously for medical and athletic applications may be able to function for extended periods. In the United Kingdom, the National Health Service (NHS; London, England) Innovation Accelerator is backing RespiraSense—a device developed by PMD Solutions (Cork, Ireland) that sticks to a person's rib cage via an adhesive patch and monitors a wearer's respiration via a single-use piezoelectric sensor that attaches to a reusable plastic housing that contains the processing electronics and rechargeable battery. Because changes in respiration often precede health conditions such as sepsis and pneumonia, an early warning may help to save lives. Like temporary-tattoo-style patches, health-monitoring devices are beginning to feature body-conforming designs that enable patients to wear them for extended periods.

Ubiquitous sensors that record myriad types of physiological data can generate such an overwhelming amount of data that physicians cannot monitor it all continuously. Information technology does not suffer from such a shortcoming, and artificial intelligence—enabled by the capability to learn on the job via machine learning—may be the key to dealing with the torrent of data. For example, IBM Watson Health (IBM; Armonk, New York) offers multiple platforms that use IBM's Watson AI system to help doctors diagnose cancers, discover new drugs, and interpret genetic tests more rapidly than conventional methods permit. Watson and other information technologies can access not only medical records but also the latest research and use these data to synthesize hypotheses and diagnoses for patients. Alphabet's (Mountain View, California) AI-research subsidiary DeepMind Technologies is working with "hospitals on mobile tools and AI research to help get patients from test to treatment as quickly and accurately as possible" (https://deepmind.com/applied/deepmind-health). And researchers at the University of Nottingham (Nottingham, England) have developed AI algorithms capable of estimating with a significant degree of accuracy the likelihood that a patient will experience a cardiovascular event such as a heart attack. The estimations of cardiovascular risk produced by the algorithms were more accurate than those produced by doctors using cardiovascular-risk guidelines developed by the American College of Cardiology (Washington, DC) and the American Heart Association (Dallas, Texas).

Whether data analytics will enable advances in medicine and health care depends on how comfortable individuals and groups will be with sharing across networks the fundamentals of their biology and physiology. If the success of social networks is any indication, the potential privacy-concerns hurdle may represent little of a barrier if the payoff is worthwhile. AI is proving effective in virtually every field in which it is finding use, and AI's progress in health-care applications merits close monitoring.

SoC997

Signals of Change related to the topic:
SoC954 — AI in Unexpected Places
SoC944 — Exploring Biobased Materials
SoC899 — …Deep Learning…

Patterns related to the topic:
P1109 — Machine Learning's…Data
P1062 — AI Goes…
P1052 — Better Than Human

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SoC1002

Recognizing and Analyzing Faces

By Rob Edmonds (Send us feedback.)

SoC586 — From Face Recognition to Interpretation from 2012 notes early examples of face-imaging software's moving from simply recognizing faces to interpreting and analyzing them. In recent years, face-recognition and face-analysis software have progressed rapidly, as has imaging software in general (see SoC955 — Vision and Imaging Technologies). Deployments of face-recognition and face-analysis software are increasing in number across commercial and government applications, and faces are becoming valuable data sources. Already, face data can reveal signs of fatigue, disease, and interest in brands. In the long term, software may be able to deduce far more from faces than humans can. Rapidly improving face-recognition and face-analysis systems are creating new opportunities for governments and companies—and new challenges for society.

Rapidly improving face-recognition and face-analysis systems are creating new opportunities and new challenges.

Even without the ability to perform complex facial analysis, software that can reliably recognize faces is very useful—and a fairly recent development. Talking about speech-recognition technology—which, like face-recognition and face-analysis software, has become more reliable and expanded its scope of uses—machine-learning expert and former Baidu (Beijing, China) chief scientist Andrew Ng said, "Most people underestimate the difference between 95% and 99% accuracy—99% is a game changer" ("Ever better and cheaper, face-recognition technology is spreading," *Economist*, 9 September 2017; online). Increased reliability in face-recognition software is partly the result of the use of machine-learning software, including deep-learning software, and partly the result of improved camera technologies. For example, Huawei Technologies Co. (Shenzhen, China) has developed a new depth-camera system that can create a depth model that is ten times more detailed than is the one that Apple's (Cupertino, California) system creates for its iPhone X's Face ID system (although Huawei's device needs ten seconds to create a depth model). Microsoft Corporation's (Redmond, Washington) Kinect first popularized depth cameras several years ago. Although Kinect was not popular with end users, depth cameras are enjoying a resurgence within smartphones.

Face recognition (rather than face analysis) often serves authentication applications—and many such authentication applications extend far beyond unlocking smartphones. The Chinese market is particularly advanced. Millions of people in China already use face recognition to authorize smartphone payments. Some bank ATMs (automated teller machines) in China use face recognition, a few physical stores in China are experimenting with the use of face-recognition-based payment systems, and China Southern Airlines Company (China Southern Air Holding Company; Guangzhou, China) is using face recognition in place of airline boarding passes.

Face recognition, like other biometric solutions, is fairly secure and reduces the need for people to remember passwords; however, the security is not foolproof. Cybersecurity firm Bkav Corporation (Hanoi, Vietnam) has shown that a 3D-printed mask can fool Apple's Face ID. And security experts have tricked other face-recognition systems with 3D images they created from standard photographs. Nevertheless, newer face-recognition systems are more secure than are older systems—and face recognition can certainly enhance multifactor authentication, which requires several authentication methods.

Governments are interested in the use of face recognition for surveillance and law-enforcement applications. Already, police forces scan crowds at sports events and other strategic locations to identify faces already known to authorities—an approach that has led to arrests. China has ambitious plans for crowd scanning. One project aims to connect security and surveillance cameras around the country to face-recognition and artificial-intelligence systems that could track suspects, spot suspicious behaviors, and even predict crime. A current pilot program in Chongqing is testing some of these concepts.

Efforts are under way to use current and emerging technologies to enable face-recognition software to perform complex face analysis and interpretation. Examples of such analysis software range from already-commercial software that can identify certain facial expressions to experimental software that aims to identify lifestyle, health, and character traits that most humans cannot identify from merely looking at faces.

Walmart (Bentonville, Arkansas) has patented a face-recognition system to detect unhappy or frustrated shoppers. Pharmaceutical company Bayer (Leverkusen, Germany) has tested face-scanning technology in Austrian pharmacies to advertise age- and gender-appropriate products. Perhaps more ambitiously, FDNA's (Boston, Massachusetts) Face2Gene can identify potential genetic conditions from facial images. FDNA crowdsources its facial data from real-world patient cases and claims to have data about more than 8,000 rare diseases and genetic disorders. And in a somewhat controversial development, researchers at Stanford University (Stanford, California) trained a face-recognition system to determine people's sexual orientation.

Some systems could combine face-recognition and face-analysis technology with online data. For example, Facebook (Menlo Park, California) has applied for a patent for a crowd-scanning system that uses information from shoppers' Facebook profiles to analyze the shoppers' emotions and brand choices.

Widespread use of face-recognition and face-analysis software concerns some privacy advocates. Bayer stopped its face-scanning project after only two days because of complaints from data-protection organizations. A September 2017 *Atlantic* article expresses concern that US law-enforcement agencies will force people to use their faces to unlock their smartphones, perhaps violating the spirit of the Fifth Amendment, which protects individuals from providing potentially incriminating information. And Adrian Zenz, an academic from the European School of Culture and Theology (Korntal-Münchingen, Germany) is among the people who criticize the Chinese government's use of face-recognition technology for surveillance. Dr. Zenz says that "surveillance technologies are giving the [Chinese] government a sense that it can finally achieve the level of control over people's lives that it aspires to" ("China's watchful eye," *Washington Post*, 7 January 2018; online).

Face-recognition and face-analysis software could change people's relationship with digital technology—and make disconnecting from the digital world difficult for them. Cameras and software can collect detailed data about people even if those people are otherwise disconnected from digital devices. In-store systems might identify people, predict their mood, and perhaps even identify their health conditions. These in-store (or environmental) cameras could link people to online profiles that store new data about them from the camera images. Consumers may monitor and analyze one another. Even without wearable cameras, smartphone apps may scan pictures of friends (and perhaps strangers) to identify and analyze them in myriad ways.

Face-recognition and face-analysis software will continue to improve, becoming more reliable and more capable of performing detailed analyses. Opportunities for companies and governments to leverage the new technology will develop, but emerging societal issues will require resolution.

SoC1002

Signals of Change related to the topic:
SoC955 — Vision and Imaging Technologies
SoC811 — Visionary AI
SoC586 — From Face Recognition…

Patterns related to the topic:
P1022 — Ubiquitous Cameras
P0609 — Imaging in 3D
P0464 — Smartphone Vision

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SoC1003

Living in a Predictive World

By Martin Schwirn (Send us feedback.)

Highly connected networks, ever-more-powerful artificial intelligence (AI), and increasingly comprehensive databases enable researchers and practitioners to foresee a wide range of phenomena at an earlier stage now than they could in the past. Such predictive capabilities enable users to identify issues early and potentially avoid problematic outcomes. As more and more data see collection across an increasingly broad range of fields, many application areas will emerge. This Signal of Change looks at two areas that saw interesting developments in recent years—the areas are distinct but indicate how predictive analytics can find use across application areas. Early detection of medical issues and health crises can help health-care professionals address emerging health threats early. And anticipating criminal behavior can help law enforcement prevent crime or can guide strategies that address criminal developments.

Algorithms are guiding strategies in law enforcement.

In predicting health issues and identifying problematic situations, novel AI can employ as much knowledge as can human experts—or even more. Researchers at the University of Nottingham (Nottingham, England) have developed AI algorithms capable of estimating with a significant degree of accuracy the likelihood that a patient will experience a cardiovascular event such as a heart attack. The algorithms used data from the medical records of hundreds of thousands of UK patients to generate, test, and refine the predictive models they employ. Similarly, social media's expansive and diverse collection of information—including personal data, pictures, and conversations—enables service providers to identify potentially problematic behavior. For example, Facebook (Menlo Park, California) is developing AI technology capable of spotting posts and comments that suggest, for example, thoughts of self-harm or suicide. Facebook employees can then check the posts and comments and offer ways for troubled users to seek help. The company is also leveraging the power of its massive community of service users. The suicide-prevention tools the company integrated into its Facebook Live live-streaming service enable users who notice problematic behavior and situations to connect directly with the person streaming or notify Facebook to prevent self-harming.

Government institutions can make use of predictive models to improve health-care policies and strategies more broadly. Recently, the Chicago Department of Innovation and Technology and the Chicago Department of Public Health (both Chicago, Illinois) worked together to develop a model that can predict one week in advance whether specific areas will see an emergence of mosquitos that might carry the West Nile virus. The model uses data from a previously established surveillance-and-control program to generate a score that guides health officials about where and when to conduct mosquito-spraying efforts. The ability to investigate massive databases and correlate information also offers a wide range of application opportunities that will only increase in number as databases grow in size and connect with one another. Researchers at the Washington University School of Medicine (Washington University in St. Louis; Saint Louis, Missouri) have created an algorithm capable of predicting with significant accuracy whether a patient will eventually develop Parkinson's disease. To create the algorithm, the researchers analyzed data from claims that more than 200,000 people made through the Medicare (US Department of Health and Human Services; Washington, DC) national health-care-insurance program from 2004 to 2009. The researchers then identified which

of these more than 200,000 people received a Parkinson's diagnosis in 2009 and which of these people did not. Using only Medicare-claims data and demographic data, the algorithm was able to identify 73% of the people who did and 83% of the people who did not receive a Parkinson's diagnosis in 2009.

New algorithms are also guiding strategies in law enforcement. Axon Enterprise (Scottsdale, Arizona)—formerly Taser International—is a leading provider of body-camera systems and other products for the law-enforcement market. Body-camera systems have seen adoption by law-enforcement agencies across the United States, and Axon is developing an AI platform capable of reading and analyzing the stream of video data coming from police officers' body-camera systems in real time. The long-term goal is to develop systems that anticipate illegal activity.

The large communities of social-media users and social-media services' ability to capture information in real time can also find use in preventing criminal behavior by identifying developing issues early. For example, a recent study by researchers at Cardiff University (Cardiff, Wales) showed that analysis of Twitter's (San Francisco, California) social network could enable detection of potentially dangerous situations before they escalate. The researchers analyzed 1.6 million tweets that people posted during the lead-up to the riots in London, England, in 2011, using event-detection algorithms to cluster tweets with similar content. The researchers found that some people started tweeting about disruptive and violent events as much as an hour before police became aware of them. Algorithms capable of flagging posts about events as people post them on social-media networks could augment the event-detection methods already in use by law-enforcement agencies. Similarly, analysis of other types of networks can highlight potential geopolitical-crisis spots. Western Union Company (Meridian, Colorado) runs one of the world's largest money-transfer businesses. The company has developed a big-data-analytics operation that is capable of spotting impending human disasters before they reach the attention of governments. Because money transfers are highly sensitive to flows of migrants and emergencies, Western Union's ability to follow the money gives it the capacity to sense emerging challenges. Many flows of cash are remittances sent by workers living abroad to their families back home, and they constitute a stable set of flows in the Western Union network, which includes some 550,000 offices in 130 countries (many of which operate in partnership with local convenience stores, shops, and so on). When people are trying to escape from areas that are on the brink of civil war or about to experience economic collapse, remittances jump; likewise, when people escape to new places—from Syria to Greece, for example—destination countries of remittances change. Because Western Union tracks the names of senders and recipients, the amounts of money people are sending, and the destinations of money, the company collects data that it can use to warn of impending crises. For example, Western Union agents in Greece saw an uptick in transfers from and to people with Arabic-sounding names just as the Syrian and North African refugee crises were starting.

Many of the above applications just look at a causal relationship between medical information and diseases or provide real-time information that was previously unavailable. The term *predictive* therefore relates to the need to take action rather than to the development of a particular situation. Nevertheless, the use of applications that provide a head start for medical personnel, law-enforcement agents, and professionals in many other industries could make the difference between success and failure in addressing emerging issues.

SoC1003

Signals of Change related to the topic:
SoC920 — Halt the Epidemics!
SoC885 — Uncertain Predictability…
SoC857 — Guesswork Computing

Patterns related to the topic:
P1163 — Self-Repairing Machines…
P0913 — Certainty of Uncertainty
P0779 — The Future of Forecasting