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DEFTECH Update

August 2017

Werter Leser

Die vorliegende Newsletter bildet eine Zusammenfassung von sich abzeichnenden Signalen für technologische Entwicklungen, die mit den Diensten "Strategic Business Insights' (SBI) Scan" und "Explorer" verknüpft sind. Diese wurden für das Forschungsprogramm Technologiefrüherkennung in armasuisse Wissenschaft und Technologie abonniert.

Für jeden Trend versuchen wir vorauszusehen, welche Anwendungen es für die Streitkräfte geben könnte. Jeder Trend bezieht sich auch auf das ursprüngliche Signal der Veränderung, das von SBI ausgearbeitet wurde und das der interessierte Leser am Ende dieses Dokuments findet.

Die Absicht ist es, strategisches Vorausdenken in Hinblick auf Technologien in einer süffigen und rasch lesbaren Form anzuregen.

Hoffentlich gefällt Ihnen die Reise!

Freundliche Grüsse,

Dr. Quentin Ladetto
Leiter Forschungsprogramm Technologiefrüherkennung

P.S. Bemerkungen, Anregungen oder Diskussion ist erbeten an: quentin.ladetto@armasuisse.ch

Bildquelle: Webseite The Verge

Aufbau von drahtlosen Verbindungen: Neuartige Ansätze zum Einrichten von drahtlosem Aufladen (auch im Innenraum-Massstab) oder drahtloser Kommunikation könnten die Kosten bei der Markteinführung neuer drahtloser Anwendungen senken. Einige Unternehmen, darunter AT&T, entwickeln Systeme, mit denen bestehende Infrastrukturen nachgerüstet werden können. Andere Unternehmen, darunter der Mobilfunkanbieter EE, wollen temporäre Infrastrukturen mit mobilen Luftschiffen und Drohnen schaffen, um drahtlose Verbindungen zu ermöglichen.

Anwendung auf Verteidigung und Sicherheit: Verteidigungs- und Sicherheitsorganisationen könnten manche militärischen Gebäude mit drahtlosen Ladetechnologien nachrüsten, um sicherzustellen, dass zentral wichtige militärische Geräte immer vollgeladen sind und für den Einsatz zur Verfügung stehen (z. B. in einem Lager mit Betriebsausrüstung). Es bestehen auch Möglichkeiten, neuartige Infrastrukturen wie mobile Luftschiffe und Drohnen zu entwickeln, die drahtlose Verbindungen zu entfernten Standorten oder zu sich verschiebenden Truppen bereitstellen können.

Zeitpunkt der Anwendung: **heute/5 Jahre**/10 Jahre/15 Jahre

Bildquelle: Webseite Road to VR

Erweiterung des VR-Ökosystems: Neue Headsets und Anwendungen für virtuelle Realität (VR) schaffen ein wettbewerbsfähiges und zugängliches Ökosystem von VR-Geräten. Mittels Hardware-Partnerschaften bringt Microsoft's Software für VR und Erweiterte Realität erschwingliche und technologisch wettbewerbsfähige Headset-Optionen (z. B. von Dell und HP), von denen einige mit Handgeräten zur Bewegungssteuerung ausgeliefert werden. Mittlerweile arbeiten Oculus und HTC an eigenständigen drahtlosen VR-Headsets, die keine Verbindung zu PCs benötigen.

Anwendung auf Verteidigung und Sicherheit: Neue Optionen für VR eröffnen Chancen für Verteidigungs- und Sicherheitsorganisationen, um immersive Trainingsumgebungen zu erweitern, um die Rehabilitation von verletzten Soldaten zu unterstützen (z. B. um posttraumatische Belastungsstörungen zu behandeln) und um visuelle Systeme für die Fernsteuerung von Drohnen, Robotern und Militärfahrzeugen zu schaffen. Windows-kompatible Headsets für VR wie die von Dell und HP sind kostengünstig und einfach anzupassen.

Zeitpunkt der Anwendung: **heute/5 Jahre**/10 Jahre/15 Jahre

Investitionen in Cyber-Sicherheit: Die Zunahme in Umfang, Schweregrad und Komplexität von Cyberattacken führt zu Rekordinvestitionen für Start-ups in Cyber-Sicherheit, welche die Bedrohungen mindern können.

Anwendung auf Verteidigung und Sicherheit: Cyber-Attacken haben das Potenzial, den militärischen Betrieb zu lähmen und wesentliche Beeinträchtigungen bei den Diensten und Netzen zu verursachen. Obwohl die Bedrohungen zunehmen, sollten die Rekordinvestitionen neue Technologien und Ansätze zur Schadensminderung hervorbringen - zum Beispiel auf künstlicher Intelligenz (KI) basierende Systeme, die sich die Verteidigungs- und Sicherheitsorganisationen zu Nutze machen können.

Zeitpunkt der Anwendung: heute/5 Jahre/10 Jahre/15 Jahre

Neuromorphe Chips: Grosse Technologie-Unternehmen und Start-ups verwenden neurowissenschaftliche Erkenntnisse, um neuromorphe Chips mit künstlichen Neuronen zu entwickeln, die so konfiguriert sind, dass sie dem menschlichen Gehirn nachempfunden sind. Auch wenn neuromorphe Chips noch viele Jahre von einer Vermarktung entfernt sind, schreitet die Technologie voran und es bestehen Aussichten auf schnelle Prozessorchips, die mit hirnähnlichen Geschwindigkeiten bei gleichzeitig geringem Energieverbrauch arbeiten.

Anwendung auf Verteidigung und Sicherheit: Neuromorphe Chips könnten in militärischen Geräten, die energetische Beschränkungen haben und die komplexe Aufgaben wie die Analyse von Sensordaten ausführen müssen, eine Anwendung finden. Beispiele sind Sensoren für das Gefechtsfeld, autonome Fahrzeuge, Satelliten, Höhenflugzeuge und Drohnen. In Zukunft könnten künstliche Gehirne, die aus neuromorphen Chips aufgebaut sind, in militärischen Feldrobotern und in anderer autonomer Ausrüstung Verwendung finden.

Zeitpunkt der Anwendung: heute/5 Jahre/10 Jahre/15 Jahre

Prädiktive Instandhaltung: Dienstleistungen zur prädiktiven Instandhaltung verwenden Gerätedaten, um die Wartung zu optimieren und Fehler vorauszusehen. Zum Beispiel analysierte die Software von Caterpillar's Marine-Abteilung die Bord-Sensordaten von Schiffen, um einen optimierten Zeitplan für die Reinigung des Schiffsrumpfs zu liefern, der es erlaubt, in einer Achterflotte pro Schiff $ 400'000 zu sparen. Und General Electric betreibt eine Cloud-Plattform, um den Betrieb seiner Industriemaschinen zu optimieren.

Anwendung auf Verteidigung und Sicherheit: Nebst einer potenziellen Reduktion von Instandhaltungskosten (durch Vermeidung unnötiger Reparaturen) könnte die prädiktive Instandhaltung die Verfügbarkeit von militärischen Fahrzeugen und Geräten erhöhen und eine Methode zur Kontrolle von eventuellen Ausfällen von Geräten im Feld bieten. Hersteller von Rüstungsmaterial können prädiktive Instandhaltung als laufenden Service anbieten.

*Zeitpunkt der Anwendung: heute/5 Jahre/10 Jahre/15 Jahre*

Sprachassistenten: So wie das Ökosystem von Sprachassistenten wächst, nimmt der Wettbewerb zwischen den Herstellern zu. Deshalb stellen die Anbieter neue Anwendungen vor und erweitern die Einsatzmöglichkeiten von Sprachassistenten, beispielsweise um Anrufe zu tätigen, Mehrfach-Nutzer zu identifizieren und Berührungs-Schnittstellen zu aktivieren.

Anwendung auf Verteidigung und Sicherheit: Es ist denkbar, dass Verteidigungs- und Sicherheitsorganisationen die Technologie von Sprachassistenten mit massgeschneiderter Hard- und Software umfunktionieren können, um Sprachschnittstellen für militärisches Personal zu entwickeln. Zum Beispiel könnten In-Ear-Assistenten mit dem Personal im Feld kommunizieren, indem sie Echtzeit-Informationen etwa über feindliche Stellungen oder das Gefechtsfeldgelände liefern.

Zeitpunkt der Anwendung: heute/5 Jahre/10 Jahre/15 Jahre
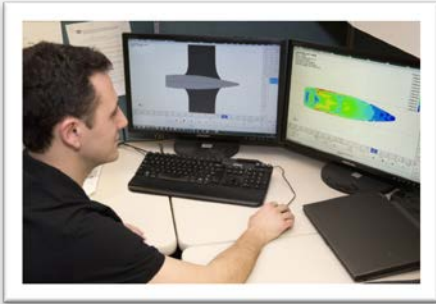
Bildquelle: Webseite der U.S. Army

Computermodellierung als Wegbereiter: Anwendungen von Computermodellierung machen Fortschritte. Beispielsweise verwendet das Start-up Motorrad-Unternehmen Vanguard Moto Ansätze von Computermodellierung, um Fahrzeuge und Komponenten zu entwerfen und Produktionsmethoden zu simulieren. Auch Forscherteams entwickeln Ansätze zu Computermodellierung, welche den Stadtplanern neue Software liefern können, mit denen ganze städtische Umgebungen modelliert werden können und die Materialwissenschaftlern fortschrittliche Simulationsansätze bieten, die bei der Konstruktion und Prüfung neuer Materialien unterstützen können.

Anwendung auf Verteidigung und Sicherheit: Computermodellierung könnte militärischem Personal helfen, Gefechtsfeldumgebungen für die strategische Einsatzplanung und virtuelles Training zu entwerfen. Andere Arten von Modellen könnten Ingenieuren helfen, neue militärische Ausrüstung und Munition zu konstruieren und zu testen (z.B. um die Leistung des Materials zu optimieren).

*Zeitpunkt der Anwendung: heute/**5 Jahre/10 Jahre**/15 Jahre*


Bildquelle: Webseite Defense Systems

1'001 Verwendungen für Drohnen: Vor kurzem hat das US-Verteidigungsministerium einen Schwarm von 104 elektrischen Mikrodrohnen Perdix getestet und ihre Fähigkeit zur autonomen Schwarmbildung aufgezeigt, die selbstheilende Kommunikation, selbstanpassender Formationsflug und kollektive Entscheidungsfindung umfasst. Auch H3 Dynamics enthüllte eine durch Brennstoffzellen angetriebene Leichtgewichtsdrohne, die zehn Stunden lang fliegen kann (Flugstrecke von 500 Kilometern), ohne nachzuladen.

Anwendung auf Verteidigung und Sicherheit: Das militärische Interesse an der Drohnentechnologie wächst, so wie die Technologie fortschreitet. Vernetzte Drohnen mit geringem Energieverbrauch können unter Umständen eine Vielzahl von Rollen übernehmen, einschliesslich kostengünstige Überwachung (Boden und Luftraum), zusätzliche Luftverteidigung und als Angriffswaffe für das Gefechtsfeld.

*Zeitpunkt der Anwendung: heute/**5 Jahre/10 Jahre**/15 Jahre*
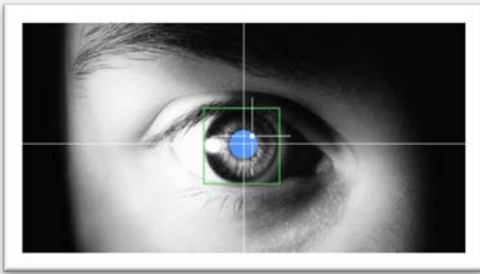
Bildquelle: Webseite Digital Trends

Verbesserung von Eye-Tracking-Schnittstellen: Die Bemühungen zur Entwicklung von Eye-Tracking-Software und Hardware haben mit dem Wachstum von Technologien der virtuellen und der erweiterten Realität zugenommen. Eye-Tracking-Geräte und Sensoren werden wahrscheinlich eine fortschrittliche Navigation und Steuerung von Geräten und Anwendungen ermöglichen.

Anwendung auf Verteidigung und Sicherheit: Eye-Tracking-Technologien könnten militärischem Personal bei der Navigation und der Steuerung von Geräten helfen - zum Beispiel um eine autonome Ausrichtung und Abschuss von Raketen zu ermöglichen. Die Technologien könnten auch medizinischen Anwendungen dienen. Beispielsweise können Eye-Tracking-Technologien bei der Rehabilitation behilflich sein und möglicherweise diagnostische Tests unterstützen.

Zeitpunkt der Anwendung: heute/**5 Jahre/**10 Jahre/15 Jahre
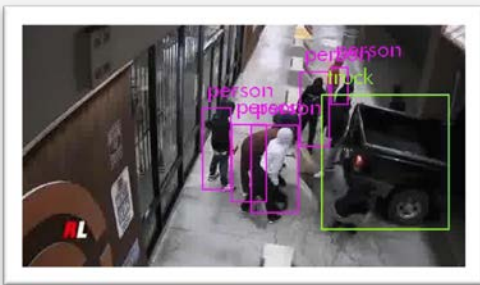
Bildquelle: Scorchai website

Schnelle Inferenz-Algorithmen: Die Start-ups Aipoly, Scorchai und Xnor.ai entwickeln Software, die die Ausführung von Anwendungen zur Bilderkennung auf Smartphones und anderen Geräten beschleunigt. Viele Anwendungsgebiete würden einen Nutzen von batteriebetriebenen Systemen ziehen, die Videoszenen interpretieren können ohne eine Netzwerkverbindung zu benötigen und die keine zusätzlichen Chips brauchen.

Anwendung auf Verteidigung und Sicherheit: Fortgeschrittene Bilderkennungssysteme könnten in batteriebetriebenen militärischen Geräten wie Drohnen oder tragbaren Kameras eingesetzt werden (z. B. um mitzuhelfen eine mehrfache Anzahl von Objekten oder Personen umgehend zu identifizieren) oder in Headsets zur erweiterten Realität, um eine Zuordnung von Objekten rasch herzustellen. Da diese Bilderkennungssysteme auch keine Netzwerkverbindung benötigen, werden sie den Geräten dazu verhelfen, autonom und an entfernten Standorten zu laufen.

*Zeitpunkt der Anwendung: heute/**5 Jahre/**10 Jahre/15 Jahre*

Verbesserung der künstlichen emotionalen Intelligenz: Unternehmen wie Affectiva, nViso, Microsoft und Eyeris arbeiten auf die letztendliche Entwicklung von künstlicher emotionaler Intelligenz mittels Bilderkennung hin. Microsoft hat vor kurzem Emotion API (Application Programming Interface) herausgegeben, das Gesichter analysiert um Emotionen zu erkennen. Eyeris, mit seiner EmoVu-Software, nutzt Deep Learning und Convolutional Neural Netzwerke, *Verteidigung* um Gesichter zu verfolgen und Emotionen in einem Video zu erkennen.

Anwendung auf und Sicherheit: Fortschritte bei Bilderkennungssystemen mit Erkennung von Emotionen könnten Systeme von Sicherheitskameras und Körperkameras ermöglichen, die Emotionen in Echtzeit erkennen und gegebenenfalls böse Absichten vorhersagen oder verdächtiges Verhalten feststellen können. Darüber hinaus könnte künstliche emotionale Intelligenz den Sicherheitsorganisationen für Text-, Sprach- und Bildanalyse von Nutzen sein.

Zeitpunkt der Anwendung: *heute/**5 Jahre**/10 Jahre/15 Jahre*

P1090

Establishing Wireless Connections

By Lucy Young (Send us feedback.)

Novel approaches to creating wireless charging or communications could lower the costs of rolling out additional wireless capabilities.

Abstracts in this Pattern:
SC-2017-06-07-028 on AT&T SC-2017-06-07-067 on EE
SC-2017-06-07-038 on Disney Research

Because of the spread of Wi-Fi and the introduction of induction charging, wireless connections are quickly becoming the norm for many devices. Some companies are developing systems that retrofit established infrastructures or create temporary infrastructures to enable wireless connectivity. In September 2016, telecommunications company AT&T (Dallas, Texas) revealed details about AirGig—a communications technology that uses existing aboveground power lines to enable a type of wireless connectivity. The wireless signal itself does not travel through the power lines; instead, the AirGig device uses the wires to act as a guide for the wireless signal. AT&T claims the technology could provide homes and mobile phones with multigigabit internet speeds and is currently in discussions with power companies to begin trials of the technology by the end of 2017.

Scientists from Disney Research Pittsburgh (The Walt Disney Company; Burbank, California) have been investigating room-scale wireless-charging systems. The scientists used quasistatic cavity resonance (QSCR) to turn a 16-by-16-by-7.5-foot room with aluminum walls, floor, and ceiling into a wireless-charging area. Currents flow up and down a copper pipe at the center of the room. Disney Research Pittsburgh associate research scientist Matt Chabalko explains, "Those currents travel through the ceiling, down through the walls, and back down to the floor, where they again flow up through the pole. It's those currents that generate magnetic fields that circulate around the pole." Special orthogonal receivers enable devices in the room to charge wirelessly at any orientation. Including windows and doors in the room's design will not significantly affect the system's efficacy. The scientists believe they could use modular metal panels or even conductive paint to achieve room-scale wireless charging, enabling them to retrofit buildings with QSCR.

Rather than retrofitting infrastructure, mobile-telecommunications provider EE (BT Group; London, England) plans to use mobile blimps and drones to provide emergency mobile-phone coverage. The company claims its technology could see use to help people and first responders stay connected during emergency situations and after floods and other natural disasters. The technology could also see use to improve mobile-phone reception in rural areas and at large events such as concerts.

Signals of Change related to the topic:
SoC929 — Rural Connectivity
SoC913 — …Urban Environments…
SoC630 — …Demand on Networks

Patterns related to the topic:
P0995 — Advances in Telecommunications
P0989 — Connected Objects
P0932 — Improve Thy Connectivity

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Viewpoints

User Interfaces

By Sean R. Barulich (sbarulich@sbi-i.com)

The Expanding VR Ecosystem

Why is this topic significant? New VR headsets and applications are creating a competitive and accessible ecosystem of VR devices.

Description

Although various virtual-reality (VR) headsets are already on the market (for example, HTC Vive, Oculus Rift, and PlayStation VR) new headsets and software continue to arrive, increasing competition. Microsoft recently revealed a long list of partners—including Acer, HP, Dell, and Lenovo—releasing mixed-reality (MR) headsets running on Windows 10. Some of the offerings improve on the technology of competitive devices—including Oculus Rift and HTC Vive—by providing better displays and software integration. Microsoft is also providing Windows Mixed Reality Controllers with the headsets. The Windows-based headsets provide an affordable VR entry point for consumers.

During Apple's WWDC (Worldwide Developers Conference) 2017, Apple did not present a headset-based mixed-reality system but did reveal two applications for VR: Metal 2 and ARKit. Metal 2 adds support for VR—including for games development—on macOS. ARKit is an iOS 11 application that provides mixed-reality

capabilities to iPhone and iOS. Although Apple did not provide a headset, the company's interest in VR and mixed reality is clearly growing.

Sony—which produces PlayStation VR, one of the most affordable VR systems next to Acer's and HP's upcoming systems—is expanding its gaming library with a series of games and downloadable content from various publishers. PlayStation VR has performed fairly well, selling over a million units since launch in 2016.

Implications

Even though Oculus, HTC, and Sony are providing competent devices for VR, their products remain niche. Microsoft is looking to provide an affordable and technologically competitive VR option.

Microsoft is perhaps targeting enterprise customers with their partner-built headsets by placing emphasis on Windows 10 integration. The Windows OS integration provides users with a large software library for enterprise applications—though also for gaming. Apple seems to be exploring mixed-reality content for iOS by taking advantage

of its strong developer base as well as the large population of iOS users. Sony is continuing to improve PlayStation VR and still provides the most affordable entry to VR gaming for consumers who use the PlayStation 4 console.

Impacts/Disruptions

Although some new VR and MR offerings are promising, drawbacks exist in comparison with offerings from the current competition. Microsoft and its partners presented devices with better displays at a lower price point, but they lack VR game libraries such as the HTC Vive has with Steam, Valve's game-distribution platform.

Another disadvantage of Microsoft's devices is that the controllers require that they remain in field of view to operate. If Microsoft can integrate Steam, its VR headsets will be able to compete directly with the HTC Vive.

Another challenge for Microsoft is to provide a wireless headset option. Oculus and HTC are currently working on providing stand-alone VR devices that do not require connectivity to a PC. Although new products will face challenging competition, opportunities exist for new, affordable, products that will appeal to consumers looking to experience VR.

Scale of Impact	Low	Medium	**High**

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

Opportunities in the following industry areas:
Consumer electronics, software development, enterprise, entertainment, gaming

Relevant to the following Explorer Technology Areas:
• User Interfaces • Collaboration Tools • Electronic Displays • Pervasive Computing

Explorer provides up-to-date evaluations and analysis of business opportunities arising from technology commercialization. Explorer filters information, provides perspectives on developments, and allows users to focus on what they need to help their decision processes. For more information about Explorer, visit our website at www.strategicbusinessinsights.com/explorer , or email: info@sbi-i.com.

P1081

Cyber(in)security

By Peter Batty (Send us feedback.)

As cyberattacks increase in frequency, new opportunities will emerge for players capable of mitigating threats.

Abstracts in this Pattern:
SC-2017-06-07-091 on start-ups
SC-2017-06-07-013 on Project Shield

SC-2017-06-07-040 on car apps

The increasing volume, severity, and complexity of cyberattacks is leading to record investment in cybersecurity start-ups. According to CB Insights (New York, New York), investors distributed $3.1 billion among 279 new cybersecurity firms in 2016.

Cybercrime journalist Brian Krebs works to uncover actors behind high-profile cyberattacks; in doing so, he faces retribution in the form of distributed-denial-of-service (DDoS) attacks on his website (https://krebsonsecurity.com). Jigsaw (Alphabet; Mountain View, California) recently added Krebs's website to its Project Shield (https://projectshield.withgoogle.com/public) program in an attempt to mitigate the DDoS attacks. DDoS attacks on Krebs's website had increased to such a large volume that the website's previous security provider had to stop supporting it. Ultimately, Alphabet's goal is to minimize downtime for its products and services. Proactively seeking out the largest and most powerful threats enables Alphabet's security engineers to find weaknesses in their own systems and develop new methods for mitigating attacks.

The quickest way for an attacker to gain control of a system is to take advantage of security vulnerabilities, and cars that have connectivity features are creating new opportunities for hackers. For example, Kaspersky Lab (Moscow, Russia) researchers Victor Chebyshev and Mikhail Kuzin found that seven Android smartphone apps for connected cars had vulnerabilities to malware and lacked security features such as data encryption (for example, some of the apps did not encrypt user credentials). In addition, none of the apps performed integrity checks or detected root permissions to app data and events, enabling hackers to create malware versions of the apps with relative ease. The researchers suggest that hackers could use a variety of methods to trick people into installing such malware versions of the apps on their smartphones. Because these Android apps enable users to unlock and sometimes even start their car, a malicious actor could take advantage of the apps' security vulnerabilities to steal cars. Such vulnerabilities will create opportunities not only for software designers and third-party security companies but also for insurance companies and liability mediators.

Signals of Change related to the topic:
SoC946 — Diffusion of Hacking…
SoC933 — Snooping Technologies
SoC930 — Trust(ed) Systems

Patterns related to the topic:
P1086 — Suspicion Plagues…Data
P1064 — Data and Privacy…
P1036 — Hacking's Reach Expands

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Viewpoints

July 2017

Artificial Intelligence

By Sean R. Barulich and Michael Gold (mgold@sbi-i.com)
Barulich is a research analyst with Strategic Business Insights.

Neuromorphic Chips

> **Why is this topic significant?** Suppliers that want to advance the status of AI might need to use neuroscience insights to help design chips.

Description

Neuroscience has inspired much artificial-intelligence (AI) software and some AI hardware. A few neuromorphic chips are available and are mostly for researchers and hobbyists. Adafruit sells mini circuit boards containing Intel's Curie chips. Each chip contains 128 interconnected artificial neurons, with each neuron containing tightly integrated processing and memory—attributes common to natural neurons. Intel licensed the design from start-up General Vision. Another start-up—Knowm—has reportedly delivered chips having arrays of neurons whose processors integrate with memristors. Such nonvolatile memory devices have programmable electrical resistance; brain cells have somewhat similar properties.

Perhaps the best-known neuromorphic chips are TrueNorth (developed by IBM with funding from the US Defense Advanced Research Projects Agency's SyNAPSE and Switzerland's Blue Brain projects) and SpiNNaker (developed by the University of Manchester with funding from Blue Brain and the European Union's

Human Brain Project). In 2016, the Human Brain Project commissioned a six-rack SpiNNaker system containing 500,000 interconnected ARM cores. Natural neurons have similarly abundant interconnections. Recently, the Air Force Research Lab contracted IBM to build a unit that will contain 64 TrueNorth chips—reportedly, enough processing resources to simulate 64 million neurons while consuming only 10 watts. Power requirements are major obstacles to high-performance computing efforts; TrueNorth aims to make progress toward achieving brain-like energy efficiency by using voltage spikes for signaling (as natural neurons do) rather than steady-state ones and zeros (as most computers use).

Much additional early-stage research is under way. Belgium's IMEC research institute recently developed a prototype chip that uses oxide-based resistive memory; the chip can find patterns in audio and create music. The Massachusetts Institute of Technology recently reported on development of a chip that uses light and lenses rather than electricity and wires in an effort to build artificial neurons

having brain-like speeds. Other organizations that are developing chips having various neuromorphic attributes include Hangzhou Dianzi University; HRL Laboratories; Oak Ridge National Laboratories; Stanford University; the University of Heidelberg; the University of California, Santa Barbara; the University of Tennessee; and Zhejiang University.

Implications

Insights from neuroscience research inspired the invention of artificial-neural-network software, including deep-neural networks. Now, hopes are high for hardware that might make use of neuroscience insights to enable an AI breakthrough. Attempts to use such insights are what distinguish neuromorphic hardware from other AI chips, which typically serve to accelerate specific categories of artificial-neural-network software algorithms.

Neuromorphic chips are largely unproved for practical applications. They remain too immature for use in applications—such as web-

services data centers, driverless cars, drones, and augmented-reality eyewear—that could benefit from accelerated AI operations. In order to commercialize neuromorphic chips, researchers will need to determine what aspects of the human brain are important and possible to model in hardware. When and if hardware appears having brain-like processing capability, developers will need further breakthroughs to produce software that can make effective use of such hardware.

Impacts/Disruptions

Use of spiking models promises rich possibilities for controlling how and when neurons fire, emulating how biological systems activate and inhibit neural activity. Spikes also help brains achieve superior energy efficiency; hardware that uses spikes instead of steps could therefore support greatly increased use of parallel processes. Implementation of spiking and other attributes of brains could become critical for realizing breakthroughs in image recognition, natural-language processing, and other AI goals.

Scale of Impact	Low	Medium	**High**

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

Opportunities in the following industry areas:
Artificial intelligence, machine learning, electronics manufacturing, software engineering

Relevant to the following Explorer Technology Areas:
• Artificial Intelligence • Mobile Communications • Nanoelectronics • Pervasive Computing • Portable Electronic Devices • User Interfaces

P1085

Right to Repair

By Rob Edmonds (Send us feedback.)

Connected products are transforming maintenance and repair, but some product owners are rebelling.

Abstracts in this Pattern:
SC-2017-06-07-096 on predictive maintenance   SC-2017-06-07-035 on legislation
SC-2017-06-07-101 on license agreements

For years, smartphone manufacturers have tried to discourage consumers from repairing their own phones and using unauthorized repair shops. As the Internet of Things develops, more products than ever before include software, and the repair and maintenance markets are changing. Manufacturers are issuing product licenses that place restrictions on repairs, arguing that they need to protect their intellectual property and device security and safety. Manufacturers also believe that new data services could transform maintenance.

Predictive-maintenance services use equipment data to optimize maintenance and predict failures. For example, Caterpillar's (Peoria, Illinois) marine division offers predictive-maintenance and optimization services for the shipping industry. For one client, Caterpillar's software analyzed shipboard-sensor data to deliver an optimized hull-cleaning schedule capable of saving $400,000 per ship in an eight-ship fleet. And General Electric (Boston, Massachusetts) operates a cloud platform to optimize the operation of its industrial machines.

Some product owners are resistant to embedded and cloud software that ties product repair and maintenance to a particular manufacturer and its authorized partners. In

October 2016, owners of John Deere (Deere & Company; Moline, Illinois) equipment had to sign a license agreement that forbids equipment repairs and modifications by entities other than John Deere dealerships and authorized repair centers. Some farmers are ignoring their license agreements with John Deere and using the black market to purchase modified firmware for use in repairing and modifying their farming equipment.

Some legislators are concerned that the repair market for electronic products is uncompetitive and have made efforts to enact so-called right-to-repair laws. Such laws would require companies to "make their service manuals, diagnostic tools, and parts available to consumers and repair shops—and not just select suppliers." In Nebraska, senators recently debated a bill that would establish the Fair Repair Act; however, lobbying from bill opponents such as Apple (Cupertino, California) and John Deere has been strong, and senators did not move the bill forward. In Minnesota, lobbying efforts contributed to a similar bill's failing to reach a hearing. Several other states are considering similar legislation, and some right-to-repair proponents expect to see the introduction of another version of the Nebraska bill in 2018.

Signals of Change related to the topic:
SoC935 — 5G and Connected Devices
SoC918 — The Road to Industry 4.0
SoC860 — 3D Technology and Tinkering

Patterns related to the topic:
P1041 — New Technologies and Liabilities
P0920 — Sustainable Thoughts
P0801 — Makers' Dream, SOHO's Promise

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P1074

Drones' 1,001 Uses

By Peter Batty (Send us feedback.)

The decreasing size and expanding capabilities of drones are enabling an increasingly wide range of applications.

Abstracts in this Pattern:
SC-2017-05-03-022 on conservation
SC-2017-05-03-086 on pollination
SC-2017-05-03-026 on military

SC-2017-05-03-083 on industrial use
SC-2017-05-03-075 on flight time

A project by Resolve's (Washington, DC) Biodiversity and Wildlife Solutions Program, the Tanzania Wildlife Research Institute (Arusha, Tanzania), and the Mara Elephant Project (Nairobi, Kenya) has had success in using drones to prevent conflicts between humans and elephants in communities close to the Tarangire and Serengeti National Parks in Tanzania. Data from 51 field trials show that drones can reliably drive wild elephants away from contested areas, thereby protecting them from humans. And in an effort to address concerns about dwindling bee populations, researchers at the National Institute of Advanced Industrial Science and Technology (Tokyo, Japan) have created a prototype insect-size drone capable of pollinating plants.

Decreases in the cost and size of drones have increased military interest in drone technology. The US Department of Defense (Arlington County, Virginia) recently tested a swarm of 104 electric microdrones, dispersing the drones from three jets above the Naval Air Weapons Station China Lake in California. The Perdix drones—originally developed during a student project at the Massachusetts Institute of Technology (MIT; Cambridge, Massachusetts)—have been modified for military use by researchers

at the MIT Lincoln Laboratory. During the test, the Perdix drones demonstrated autonomous swarming capabilities such as "self-healing communications, self-adapting formation flying, and collective decision-making." And industrial use of drones can prevent human workers from experiencing deadly accidents such as falls from power lines and electrocutions. Power utility AES Corporation (Arlington, Virginia) is working with Measure (Washington, DC), which develops software that turns drones into service machines, to create fleets of inspection drones that can perform hazardous inspections and maintenance work. AES is making increasing use of drones that take close-up video of power lines and electrical equipment that human inspectors can view on a computer monitor.

Most small electric rotor-driven drones suffer from short flight times because of the shortcomings of the batteries they use. H3 Dynamics (Singapore, Singapore) recently unveiled a fuel-cell-powered multirotor drone that weighs only 7 kilograms and can fly for ten hours without refueling, which gives it a flight distance of 500 kilometers. Such capabilities could one day enable a broad array of new drone applications.

Signals of Change related to the topic:
SoC866 — A Flock…of Drones
SoC796 — Drone Update
SoC677 — The Sky's the Limit for UAVs

Patterns related to the topic:
P0998 — Drones on Top of the Hype Cycle
P0942 — Drones: Ability to Save…
P0911 — Drones' Capabilities Expand

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P1079

Computer Modeling as an Enabler

By Guy Garrud (Send us feedback.)

Advanced computer modeling can benefit an increasingly wide range of applications.

Abstracts in this Pattern:

SC-2017-05-03-014 on Vanguard Moto   SC-2017-05-03-049 on MIT
SC-2017-05-03-012 on Fraunhofer   SC-2017-05-03-061 on Harvard

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Start-up motorcycle company Vanguard Moto (New York, New York) is using computer modeling as an integral part of its design process. Computers enable engineers not only to iterate a design rapidly but also to use computer-aided engineering and simulation systems to test components and vehicle designs without making a physical product. Vanguard is also taking advantage of advances in computer design to simulate production methods, enabling it to enter a usually capital-intensive industry.

New computer-modeling approaches can even provide detailed analyses of entire urban environments. Researchers at the Fraunhofer Institute for High-Speed Dynamics, Ernst-Mach-Institut (Fraunhofer Society for the Advancement of Applied Research; Munich, Germany) have developed VITRUV—software that drastically simplifies the structural-risk-analysis process by supporting city planners during all phases of their work: "In the concept phase, a rapid assessment of the safety-related topics is performed. In the planning phase, the tool provides insights into vulnerability, weaknesses and specific areas of risk. Finally, in the detail planning, it develops concrete solutions to minimize risks."

Computer modeling is playing a significant role in cutting-edge research. For example,

researchers from the Massachusetts Institute of Technology (MIT; Cambridge, Massachusetts) used atomistic computer modeling in their efforts to fuse and compress two-dimensional graphene flakes into strong, lightweight three-dimensional structures. The researchers discovered that the geometric arrangement of the flakes following a treatment of heat and pressure forms a very strong structure. Using a 3D printer, the researchers printed large versions of these microscopic structures for mechanical testing. "Their mechanical response under loading was simulated using the team's theoretical models. The results from the experiments and simulations matched accurately." And researchers from Harvard University (Cambridge Massachusetts) used computer modeling to devise a general framework for the design of *metamaterials*—materials with functions determined by the materials' structure rather than by their bulk properties—that are reconfigurable. The researchers discovered that "assemblies of polyhedra can be used as a template to design extruded reconfigurable thin-walled structures." In principle, the Harvard researchers' design method is scale independent, which means it can see use in small applications such as nanoscale systems and large applications such as architectural structures.

Signals of Change related to the topic:

SoC910 — Origami-Inspired Design…
SoC905 — …Future Urban Environments
SoC870 — …Nanoscale Manufacturing's Science

Patterns related to the topic:

P0990 — Medical Origami
P0955 — Algorithmic Guidance
P0835 — Visualization for…Engineering

Viewpoints

June 2017

User Interfaces

By Sean R. Barulich (sbarulich@sbi-i.com)

Eye-Tracking Interfaces Update

> **Why is this topic significant?** Eye-tracking technology may create effective controls for VR gaming and entertainment and enable hyperaccurate marketing that tracks users' attention.

Description

Efforts to develop eye-tracking software and hardware have increased with the growth of virtual-reality (VR) and augmented-reality technologies. Developers are working on eye-tracking technologies to create hands-free controllers and attention trackers.

Tobii, one of the leaders in eye-tracking technology, offers multiple stand-alone eye-tracking devices and supplies product makers with eye-tracking modules and components (for example, for some current VR devices, laptops, and PC monitors with built-in eye tracking).

Google and Oculus VR are interested in improving the capabilities of their VR devices and have, respectively, acquired eye-tracking start-ups Eyefluence and The Eye Tribe. Eyefluence's technology primarily used distinct eye gestures as a method of navigating menus and making selections. Before acquisition, The Eye Tribe was also advancing user interfaces by implementing eye-controlled navigation for software.

Other vendors also see benefit in eye tracking for VR. For example, HTC recently revealed an eye-tracking upgrade—aGlass—for the Vive VR headset. Chinese start-up 7invensun supplied the eye-tracking module. Other companies developing eye-tracking technology include SMI, iMotions, EyeLink, and Fove.

Implications

Eye-tracking devices and sensors may enable advanced navigation and control for devices and applications. In addition, the technology could provide marketers and advertisers with useful feedback about consumer responses.

In entertainment and VR gaming, eye tracking can increase the immersive experience for users by using foveated rendering—a technique that prioritizes graphics performance on areas where users are looking and can add depth-of-field effects to simulate human vision better. This efficient method of rendering can provide 4K graphics while maintaining a high and smooth frame rate for viewers.

In marketing and advertising analytics, software can use data from eye-tracking monitors or headsets to gain a detailed understanding of advertising effectiveness. By tracking users' attention and focus, advertisers can tailor and improve their messages based on the likely interest and attention of viewers.

Eye-tracking devices also serve medical applications. For example, the devices can provide communication interfaces, assist in rehabilitation, and potentially aid diagnostic testing.

Impacts/Disruptions

Although eye-tracking technology is developing rapidly, it is unlikely to play a significant role as a primary interface anytime soon. Touch and gesture controls may remain more effective than eye-tracking technology until manufacturers can integrate the latter into mobile displays.

Another concern for eye-tracking technology is data privacy—especially for marketing and analytics applications. Users may be unwilling to share eye-tracking data without some sort of compensation. In addition, integration of eye tracking into TV displays, although ideal for cable companies and advertisers, would at this time seem to provide minimal if any benefit to viewers.

Scale of Impact	Low	**Medium**	High

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

Opportunities in the following industry areas:
Electronics manufacturing, sensors, software development, augmented reality, virtual reality

Relevant to the following Explorer Technology Areas:
• User Interfaces • Collaboration Tools • Connected Cars • Mobile Communications • Pervasive Computing • Portable Electronic Devices

Viewpoints

June 2017

User Interfaces

By Sean R. Barulich (sbarulich@sbi-i.com)

Ultrasound Touchless Interfaces

> **Why is this topic significant?** Ultrasound touchless interfaces may provide advanced gesture control for various virtual- and augmented-reality devices and for software applications.

Description

Some touchless interfaces use ultrasound to receive inputs and, in some cases, provide feedback to users. Most current touchless interfaces, including Microsoft's Kinect, use depth cameras. Cameras are challenged by bright light and transparent objects and cannot provide feedback to the user. Although ultrasound interfaces are still in development, promising examples of the technology exist.

- Google's Soli interaction sensor chip uses the reflection of electromagnetic waves off objects to determine the characteristics of the object by analyzing the varying properties of the reflected waves. The sensor and associated software are effective enough to detect subtle gestures that can simulate physical tools for specific interactions such as turning a key or pushing a button.

- Ultrahaptics is developing a touchless interface device that integrates a gesture-tracking sensor coupled with a microprocessor and field-programmable gate array. By using ultrasound waves, the device may provide haptic feedback

for users as well as accurate gesture detection, simulating in air the actual feeling of switches and buttons.

- Chirp Microsystems' low-power ultrasonic sensor uses transducers and reflects sound waves off objects to measure depth and motion.

- Elliptic Labs' ultrasound technology uses the existing audio hardware in phones to emit ultrasound waves and record reflection via microphone to recognize gestures.

Implications

Touchless interfaces provide potentially intuitive and simple controls for devices and applications. If they integrate with PCs or virtual- and augmented-reality devices, touchless gesture interfaces may replace some peripheral devices and controllers. For example, virtual keyboards coupled with haptic feedback could enable navigation through software applications and the web with augmented-reality headsets.

Because of the small form factor of some touchless sensor systems, integration into mobile devices may be possible, adding advanced gestures to touch-screen interfaces. Elliptic Labs' technology even requires no new hardware.

Impacts/Disruptions

Although ultrasound interfaces have some advantages over camera-based approaches, the outcome for ultrasound interfaces is uncertain.

As manufacturers of touchless gesture systems search for applications, computer vision and cameras may end up providing advanced gesture recognition to consumers more easily than ultrasound approaches can. This possibility becomes more plausible because cameras already integrate into many devices and are constantly improving along with computer-vision software. For example, some computer manufacturers already integrate depth cameras—including Intel RealSense—into their devices. Facial recognition is another benefit to using cameras as a touchless interface. Touchless gesture interfaces using ultrasound will need applications—such as haptic feedback or robust outdoor operation—that computer vision cannot effectively compete against. If both interfaces continue development, a chance exists of a symbiotic relationship between the technologies that ultimately provide a combined interface.

Scale of Impact	Low	**Medium**	High

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

Opportunities in the following industry areas:
Sensors, electronics manufacturing, computer vision, wearables

Relevant to the following Explorer Technology Areas:
• User Interfaces • Connected Cars • MEMS/Micromachining • Mobile Communications • Pervasive Computing • Portable Electronic Devices

Viewpoints

July 2017

User Interfaces

By Sean R. Barulich (sbarulich@sbi-i.com)

Voice-Assistant Devices: Update

Why is this topic significant? New voice-assistant devices are introducing new applications and capabilities and increasing competition among manufacturers.

Description

As Amazon.com and Google race to add third-party integrations and new capabilities to their voice-assistant devices, other new devices are arriving that provide new uses to consumers.

Microsoft and Apple recently introduced their voice-assistant speaker devices. Microsoft and Harmon Kardon have presented the Invoke speaker that integrates with the Cortana artificial intelligence (AI). The Invoke speaker has base functions including music streaming and query response, and the device can make and receive Skype voice calls. Apple revealed the HomePod at its WWDC (Worldwide Developers Conference) 2017 and placed emphasis on the high-fidelity audio capabilities of the device. Although Apple's speaker integrates with Siri and can interact with some mobile apps on iOS, it lacks the capability of assistants in established devices including Amazon Echo models and Google Home.

Although Google has not responded with any new voice-assistant devices, Amazon has introduced two new products. First, Amazon's Echo Look is an Alexa-enabled camera that can provide fashion advice and catalog outfits in the Echo Look mobile app. Second, the Echo Show is another smart speaker like the Echo but with a touch-screen display. The display provides visual answers to queries and can also play videos and enable voice and video calls in combination with the Amazon Alexa app.

Implications

A growing voice-assistant ecosystem will probably be good for consumers as manufacturers and third parties improve quality and add functionality to voice-assistant devices in their bid to compete for consumers.

Apple's HomePod could end up a popular product even if creating an intelligent hi-fi speaker with an audio focus has implied the immaturity of Siri as a voice assistant. Keen Apple customers may want to maintain their Apple-device ecosystem and place their bets on Apple's Siri's growing into a more competent AI than it is today.

Other consumers may opt for Echo devices. Amazon is looking to grow its foothold with Alexa not only by adding functions but by introducing a new interface (via touch display) that still keeps the device hands free but provides more informative feedback to users than voice alone provides.

Impacts/Disruptions

Although new products have expanded the voice-assistant ecosystem, many of the new devices do not provide significant or unique capabilities.

The HomePod's cost is Apple's primary obstacle, because the device is the most expensive smart speaker available, costing $349. Without a competitive amount of Siri functions and app integrations, consumers may not find the high cost justifiable for a hi-fi audio smart speaker. With other devices upgrading capabilities to make calls and identify multiple users, Apple will most likely need to do more to distinguish the HomePod.

Amazon's Echo Show offers unique benefits to users by providing a touch interface, but—for now—the Echo Look appears to offer consumers little beyond niche use cases in fashion recommendations and outfit logging.

With a more populated ecosystem of voice assistants, manufacturers will need to distinguish their devices and ultimately offer better AIs to encourage sales.

Scale of Impact	Low	**Medium**	High

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

Opportunities in the following industry areas:
Artificial intelligence, cloud computing, natural-language processing, software services

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

Viewpoints

June 2017

Artificial Intelligence

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

Fast Inference Algorithms

Why is this topic significant? As some developers focus on improved chips for AI, others focus on achieving similar benefits by developing improved algorithms.

Description

Start-ups Aipoly, Scorchai, and Xnor.ai are developing software that accelerates execution of image-recognition applications on smartphones and other devices. Developers use deep-learning methods to pretrain the software, for example by using cloud resources or multiple graphics processor units in rack-mounted computers. Afterwards, battery-powered devices can efficiently recognize objects in video images. Ordinary general-purpose microprocessors—not graphics-processing chips or other special-purpose hardware—execute the software. The inference software runs on the device, not in the cloud.

Similar software could accelerate many kinds of applications that exploit deep learning, but developers of fast inference algorithms have focused on image recognition. Aipoly and Xnor.ai have published video demonstrations of smartphones that seem to identify multiple objects, people, and animals instantly. Xnor.ai has also implemented its software on a Raspberry Pi platform (which can

be smaller than a phone). Scorchai has expressed intention to support smartphones, wearable cameras, augmented-reality headsets, and drones.

Instead of expressing inference procedures in conventional computer languages, Xnor.ai developers reduce algorithms to microprocessor-friendly binary operations. Further gains arise from extensive use of reduced-precision calculations. The developers are not simply being sloppy; they monitor the effects of reduced precision to understand when such mathematical shortcuts are harmless and do not degrade performance. Aipoly indicates that it uses a related approach; Scorchai has disclosed little about its methods.

Implications

Experts lack consensus about the merits of recent developments toward fast inference algorithms. And Android smartphones have performed non-cloud-based speech recognition for some years. So what is new? Increased efficiency promises to reduce battery drain during continuous operations. And

systematic work flows promise to reduce the effort needed to produce a broad range of deep-learning applications for embedded devices.

Many applications would benefit from battery-operated systems that can interpret video scenes with no need for a network connection and no need for additional chips. A basic smartphone app that identifies flowers, plants, and trees might inspire initial interest from nature lovers and gardeners. Aipoly demonstrated food recognition, which might eventually prove useful for apps that estimate how many calories a person on a diet is consuming.

Other battery-powered platforms including drones, robots, and augmented-reality headsets also face design constraints and could benefit from image recognition technologies that add little to no weight, size, or hardware costs to designs. With or without image recognition, general-purpose microprocessors and video cameras are required for many such products; fast inference algorithms might run with minimal revisions to hardware.

Drones and robots might benefit from fast image recognition to aid maneuvers and avoid collisions. AR headsets will need fast image recognition to help render video labels for real-world objects and correct perspectives of superimposed virtual objects.

Impacts/Disruptions

Makers of automotive systems could see disruptions. Ambarella, MediaTek, Mobileye, Nvidia Corporation, and Renesas Electronics Corporation are among the companies wagering on needs for special hardware in autonomous and semiautonomous vehicles. In an ideal case, cars will not need special chips for AI. Alternatively, developers of driverless vehicles might need to use every trick in the book to achieve safety and affordability goals, combining special hardware and accelerated inference algorithms—possibly, algorithms and chips that are different from those currently under development.

Scale of Impact	Low	Medium	**High**

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

Opportunities in the following industry areas:
Smartphone application development, augmented reality, drones, robots, vehicle manufacturing

Relevant to the following Explorer Technology Areas:
• Artificial Intelligence • Big Data • Connected Cars • Portable Electronic Devices • Robotics • User Interfaces

Viewpoints

June 2017

Artificial Intelligence

By Sean R. Barulich and Michael Gold (mgold@sbi-i.com)
Barulich is a research analyst with Strategic Business Insights.

Update on Emotionally Intelligent Computing

Why is this topic significant? Emotional recognition can advance the contextual understanding of AI and expand the capabilities of computer-vision systems.

Description

"Emotion Recognition via Machine Vision" in the October 2013 Viewpoints describes progress made in commercializing "affective computing" to evaluate human responses visually. Some of the companies mentioned, including Affectiva and nViso, as well as others, are providing new products toward eventual development of emotionally intelligent AI by means of computer vision.

At its Build 2017 conference, Microsoft revealed a new portfolio of Microsoft Cognitive Services. One service, Emotion API, first detects a face in a photo or video by invoking Microsoft's Face API. Emotion API then estimates and establishes confidence levels in the face's resemblances to faces in many training images that people previously labeled with particular emotions. Computer vision systems can call the API for use in various applications.

Eyeris, with its EmoVu software, uses deep learning and convolutional neural networks to track faces and detect emotions in video. The company claims it has implemented "continuous learning" and that accuracy improves as EmoVu analyzes features and aggregates data.

The annual Emotion Recognition in the Wild challenge that concluded in November 2016 demonstrated efforts from seven winning research teams in both video and group-based emotion recognition using computer vision.

Implications

Emotion recognition may endow computer-vision, voice-assistant, and other AI-based systems with some important capabilities through the large number of APIs provided to developers. For example, ultra-high-definition security camera systems and body cameras may be able to supply

systems with information needed to detect signs of ill intent and to prioritize people of interest for effective and efficient surveillance.

Emotion analytics also has potential roles in cars, determining when drivers are not at full attention or are inebriated. But much of the commercial utility would likely be in marketing analytics applications for infotainment purposes, especially as autonomous driving progresses.

Generally, computer-vision systems using emotion recognition also have promising applications in advertising and marketing, tracking consumers' emotional responses to ads, products, and brands, and designing more effective campaigns. In psychological research and therapy applications, emotion recognition can also potentially help in diagnosis of mental illness, assist therapists in addressing patients' issues, or log dialogue and emotion for deeper analysis.

Impacts/Disruptions

Although there has been some progress in visual, audio, and text-based emotion recognition, AI still struggles with the recognition and interpretation of irony, sarcasm, slang, and references to popular culture. Companies such as Lexalytics, Aylien, and Clarabridge are attempting to address the challenges of sentiment analysis. Until better understanding of context is integrated into audio and text-based emotion recognition, AI systems may continue to struggle with reliable interpretation.

Beyond the challenges of accurately interpreting data, there also may be obstacles regarding data privacy and trust in emotion-recognition systems. Many commercial applications require divulgence of personal user data, which presents ethical concerns in implementation. The commercial value of emotion-recognition systems depends strongly on people's willingness to cooperate with and contribute data to the systems.

Scale of Impact	Low	Medium	High

Time of Impact	Now	5 Years	10 Years	15 Years

Opportunities in the following industry areas:
Computer vision, high definition cameras, advertising analytics, software development

Relevant to the following Explorer Technology Areas:
• Artificial Intelligence • Big Data • Connected Cars • Connected Homes • Mobile Communications
• Portable Electronic Devices • User Interfaces

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Artificial Intelligence

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

Neuromorphic Software

> **Why is this topic significant?** In ideal cases, software that simulates how a brain works would mimic the brain's behaviors. With or without special chips, software will be key to using neuroscience to advance artificial intelligence.

Description

Some software makes use of insights from neuroscience and operates on commercially available processor hardware. Like neuromorphic chips, such software is inspired by biology; it does not simulate brains in detail. Brain Corporation is a key player in commercialization of neuromorphic software. In a 2016 report, the company describes how it applied insights from neuroscience in the design of its computer-vision software, "without implying a physiological correspondence" to real brains.

Software exhibits various degrees of fidelity to nature. Artificial neural networks (ANNs) use thoroughly artificial learning methods, but they were first inspired by neuroscience during the 1940s and saw robust software implementations by the 1970s. During recent years, findings about layers of neurons in brains helped to inspire development of deep-learning systems. One class of deep-learning ANN, a long short-term memory (LSTM) network, shares attributes of brains that many other ANNs lack—namely, feedback loops and rewriteable memory. Google uses LSTM networks for speech recognition and language-translation services; Amazon.com uses them to synthesize Alexa's voice. Many software-development tools are available for developing LSTM networks, including tools for the popular Python programming language.

Some neuromorphic software is exclusively for research and experimentation. Numenta's software tools reportedly support "rewiring" of ANNs—analogous to the natural process of neuroplasticity. Canada's University of Waterloo publishes Nengo, a tool that implements models of neural signals in the form of voltage spikes instead of direct-current analogues. For software developers, spiking models promise rich possibilities for controlling how and when artificial neurons fire, based on insights about how natural neurons behave.

Implications

Neuro-inspired software has a long road map toward improvements and innovations. Many established findings about brains have seen limited

use in research and no commercial applications. For example, future software tools might model two-way communications—as occurs across gap junctions in real brains. New research findings are likely to emerge to inspire software that emulates the structure, function, and roles of various kinds of neurons; how they connect; and ways that synapses modulate neuron behaviors.

Impacts/Disruptions

Monitoring of large natural neural nets will not be feasible for years. Meanwhile, software simulations might yield insights about how brains work. According to *Wired*, a team led by the controversial brain scientist Henry Markram is now conducting a yearlong simulation on a supercomputer at Argonne National Laboratory as part of a quest to see if the exotic field of algebraic topology can explain odd behaviors that large collections of simulated neurons exhibit. Whether the team is investigating natural or invented phenomena will remain a mystery for some time—but unusual projects have inspired previous ANNs that saw success. Markram's research implies that enterprises that want to exploit the latest findings in neuroscience to "build a brain" may need to learn higher math, not just hire engineers and scientists.

DeepMind cofounder Demis Hassabis has several independent careers—as a deep-learning software developer, as a game developer, and as a contributor to several peer-reviewed reports in neuroscience and cognitive-science journals. Apparently, his neuroscience research remains quite distinct from his software developments. His unique skill set might sooner or later have the effect of disrupting road maps for neuromorphic software.

Scale of Impact	Low	Medium	**High**

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

Opportunities in the following industry areas:
Neuroscience, mathematics, software development, advanced research, independent research

Relevant to the following Explorer Technology Areas:
• Artificial Intelligence • Connected Cars • Robotics • User Interfaces