Goldman Sachs

Fortnightly Thoughts

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The real consequences of artificial intelligence

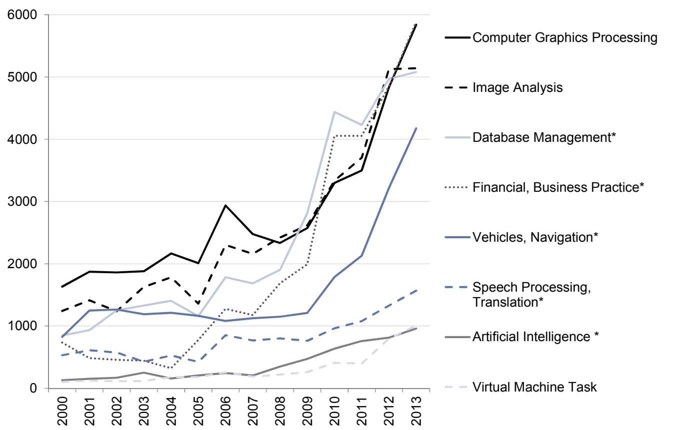
From the editor: In this edition we cogitate on the increasing transition of artificial intelligence into the mainstream, commercial world and its potentially disruptive implications and uses. We interview three experts on this subject and include our global analysts' views.

The substantial progress made over the last decade in the capabilities and cost of parallel computing, algorithms, big data and the move to the cloud is set to bring artificial intelligence out of labs and into the real, mainstream world. This has implications for information-intensive sectors as well as businesses that rely on highly skilled personnel. AI is already driving changes in advertising (programmatic ad buying), parts of retail (customised recommendations) and investing. With other sectors becoming increasingly data-intensive we see its tentacles reaching healthcare and manufacturing as well as logistics and energy consumption. The ability to think and learn enables AI-aided technologies to constantly improve and refine and when applied to decision making in businesses we believe this can lead to better cost and capital allocation, lower error rates and accelerated innovation. AI is aimed at augmenting human decision making, but in many areas it could replace humans or resolve the shortage of human skills (think collaborative robots in warehouses and hospitals).

AI can also instigate disruption in industries much like the advent of the internet did. While we do not foresee the indiscriminate demise of industry incumbents, we expect AI to act as a necessary stay-in-the-game cost to incumbents and also open the door to capital and labor-light new entrants. However AI can reinforce dominance in industry leaders that have a pre-existing edge in terms of access to proprietary data. Apart from them, we see opportunity in AI enablers such as NEC, Nidec, Verint and Criteo, as well as users of collaborative robots and AI like Amazon and Baidu.

The age of innovation

Total patent grants by the USPTO by field of technology



Note:all ''marked categories relate to data processing; Financial, Business Practice includes things like cost/price determination*

Source: USPTO.

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What's inside

The real consequences of AI

A broad way to define artificial intelligence or AI is that it is any intelligence exhibited by machines or software. By this we mean machines which can think, which are able to not just process data into information, but also derive knowledge from that information to augment human decision making or to act independently. It is difficult to draw a line between AI and a smart piece of code or smart connected devices, but the key difference here is that AI refers to technology that can be taught or is capable of self-learning and so can continually improve itself; capabilities once thought to be the forte of human beings. Take the case of Google search, which Nick Bostrom, Professor at Oxford University and a leading thinker in this area, highlights as the best example of AI to date in his book Superintelligence. What makes the original Google algorithm truly powerful is that it is capable of learning from millions of users searching, ignoring and clicking through results each day, teaching it to yield better results every time. AI can similarly be applied to continually refine decision making in any information-driven business model to streamline costs, enable more efficient allocation of resources, improve product quality and accelerate innovation. This means that AI can be deployed in sectors that rely on skilled employees (manufacturing, software, engineering), skilled intermediaries (doctors for pharma, mechanics for cars) or skilled users (autos, agriculture), and even in operations and processes that are simple and mundane. We see AI as the next leg of the technological revolution that digitises decision making and as a result threatens swathes of human expertise and pattern recognition skills, lowers entry barriers for new competitors and adds to the disinflationary forces in the world.

The stars are aligned

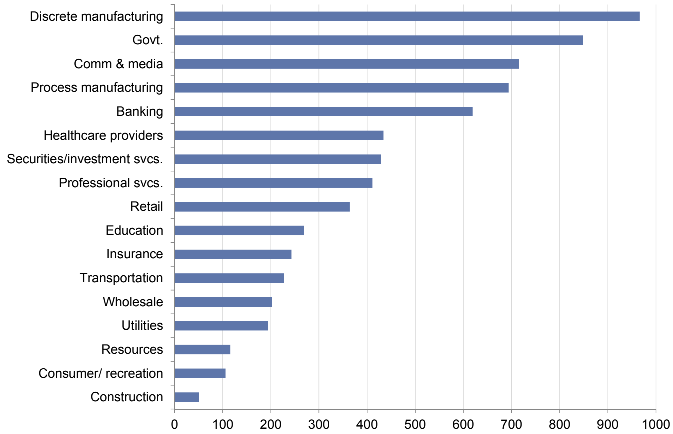
Artificial intelligence is by no means a new concept; however, even almost 60 years after the term was first coined it continues to conjure a perception that it is something that will be realised in the far future. This is the paradox of the AI effect – as soon as artificial intelligence achieves a commercial application, it ceases to be viewed as AI and is instead considered to be a really clever piece of code or a smart device. But in reality, AI is alive and kicking, and its influence is already evident in many industries, which we delve into in the next few paragraphs. However, we are writing about AI now because we think that it is on the cusp of a period of more rapid growth in its use and applications. The reasons are multi-pronged, but the improvements in the capability and economics of hardware is a good place to start. On one hand, many different device components such as sensors, cameras, radars, lasers etc. have become much cheaper in recent years thanks mostly to the smartphone revolution, which has driven innovation and economies of scale at an unprecedented pace. This has resulted in more connected devices and in turn, a lot more data being available for analysis. On the processing side, significant progress made in the field of neural networks and parallel computing in the last decade has meant that computers are now better able to understand even unstructured data, like oral conversations and pictures.

Deep mines

At the same time, the advent of deep learning, only about a decade old in its current form, has enabled faster and more accurate reasoning and processing algorithms in most of today's AI tools. Plus, as Manoj Saxena argues on page 15, the move to the cloud has meant that massive computing capacity and near infinite processing power is now available at very low prices and requires no upfront installation or capital spend, making AI more accessible to businesses than it has ever been. This should contribute to the network effect that accelerates the capability and adoption of AI – the more it is used, the better it becomes which should result in greater usage and so on. Taken together, the improved capability of machines to collate and comprehend more information and better optimise results is driving the broader and more significant potential for AI.

Stores of value

Stored data in the US by industry, petabytes



Source: IDC; BLS; McKinsey Global Institute analysis

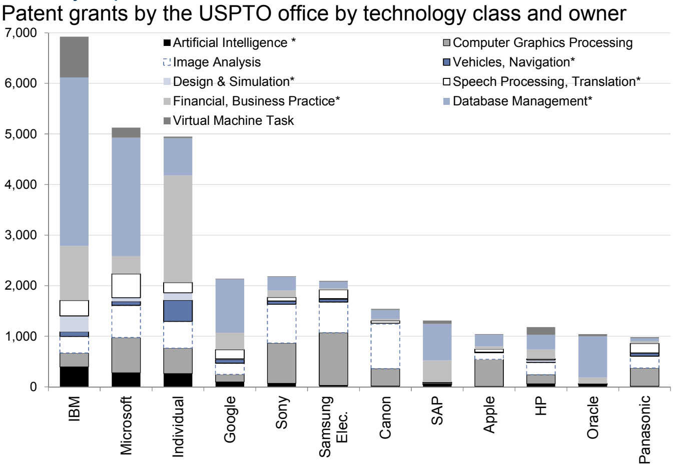
Where is AI now and where can it go?

AI going mainstream has broad implications, but it is currently most evident in data-heavy sectors. Algorithms behind Spotify, Netflix and Amazon are all aimed at driving greater customisation and user engagement. Retailers, both online and offline, are increasingly deploying AI to leverage their customer interaction data to boost revenue at lower selling costs. i.e. customised loyalty card-based promotions could become even more sophisticated. Smarter algorithms are also automating the process of buying and bidding for online ad space; programmatic ad buying, enabled by companies like Rocket Fuel, The Rubicon Project and Criteo, is reshaping digital advertising, driving cost efficiency for advertisers and publishers. And in the world of investing, algorithmic trading has been a force for the past few years, thanks mostly to its speed advantage. But more recent improvements in parallel computing technology have resulted in more powerful tools that are helping analysts digest reams of unstructured data, helping them replicate years of experience and acquired pattern recognition skills (see page 18 for Alex Blostein on robo-advisors). Private firm Kensho is an example here and so is BlackRock's Aladdin (on understanding investment risks).

Apple's Siri, Amazon's Alexa (inside Echo), Microsoft's Cortana and Google Now are also examples of AI-aided personal assistants on our devices. And this is perhaps one use case of AI which has grabbed the most mindshare of everyday consumers, by making that inconspicuous, but huge shift between text and voice commands and between reactive and pre-emptive search results and recommendations. This is the difference between searching for weather forecasts on smartphones versus them pre-emptively advising users to take an umbrella to their appointment. As they learn more and improve further, it is easy to imagine devices answering queries before they are asked. It is interesting to note here that last year, Amazon was granted a patent for 'anticipatory shipping', which aims to prepare a package for delivery before the customer actually makes the purchase, based on his or her browsing and purchasing behaviour.

Patently important

Patent grants by the USPTO office by technology class and owner

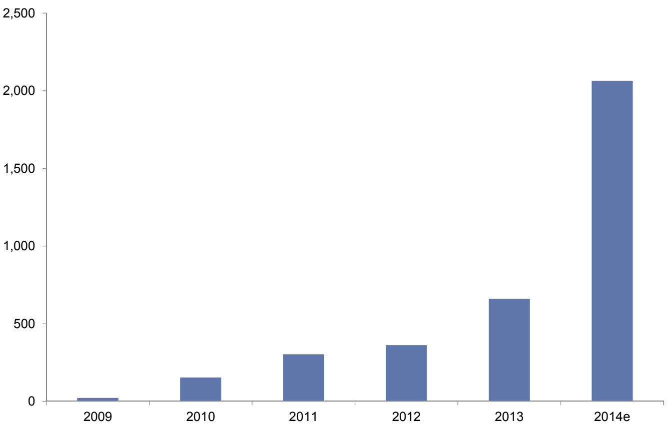


Note:all ''marked categories relate to data processing; Financial, Business Practice includes things like Cost/Price Determination*
Source: USPTO.

Which industries are becoming more information-intensive? Healthcare, and particularly pharmaceuticals, stands out here. One of the most well-known examples of cognitive computing of course is IBM's Watson, which won Jeopardy! in 2011. Its first commercial foray was in healthcare in 2013, helping doctors lower the error rate in cancer diagnoses. As a result of the significant progress made in gene sequencing over the past decade, healthcare providers now have access to a substantial and rapidly growing amount of genetic data; and given that the true value in genomics lies in the ability to digest and understand this information to translate it into more personalised and accurate treatment, this is another area where AI can play a huge role. Education, energy-consumption, logistics and manufacturing are all becoming more information-driven as well and hence present opportunities for AI deployment.

Automatic genomics

Data output measured by number of terabases



Source: The Broad Institute

AI can also lower the reliance on high-skilled personnel, especially in sectors that face a shortage of talent, thus helping companies counter wage inflation and make their product or service available to a wider audience. Again healthcare is an area where this is relevant; AI could go some way in resolving the shortage of care workers, nurses and physicians. Other sectors that are both labour-intensive (wages as a % of costs) and talent-intensive (wages per employee) include media, financial services and technology. All said, artificial intelligence should augment human intelligence and lead to better-informed decisions, and depending on the nature of the industry it is deployed in, it can be disruptive to incumbents or at the very least it can re-allocate industry profits among them.

It is useful here to draw parallels between AI and other technological waves – the use of plastic money, automation and even the advent of e-commerce. In the latter case, the investment opportunities were quite varied in the early years of online adoption. Whether it was in media, apparel or grocers, new entrants were disruptive to existing market shares, while amongst the incumbents, there was a marked difference in the performance of those who were willing and able to adapt early and those that were less capable of making the shift (especially those tied down by legacy fixed assets). Today, most large retailers have established an online presence and competition in some of these sectors is reverting back to the product quality, price or range ("old school" competition), rather than the convenience of the channel, but that has followed a costly and painful transition period. The longer the transition period, the more persistent the shifts in market share are (think online impact on food retail versus classifieds), even though the technology ultimately becomes part and parcel of the business. AI we think is headed in the same direction. In other words, AI can introduce new pure-play entrants and re-shape the revenue pool, until it is eventually adopted more broadly in the industry (much like Netflix vs. other cable companies adopting OTT, Tesla vs. other OEMs building EVs). It will become critical for competition but irrelevant for strategy, which means that the advantages of adopting AI are easily outweighed by the risks of not using it. And so, investment opportunities are more likely to be found by identifying AI tool providers, new entrants and incumbents who are best suited to adapt or respond.

Who provides the tools? Within industries which have been early adopters of AI, there are few listed companies that provide specific tools like advertising and programmatic ad tech vendors or financial analytics. Japan's NEC is dominant in face recognition and text analysis, which has broad applications in areas such as security and marketing. Tech firms that provide advanced data analytical and visualisation tools, like Verint Systems and Marketo are similarly exposed to this space (see longer list on page 6). In terms of general artificial intelligence, IBM's Watson remains one of the most prevalent providers of AI solutions. It now offers 13 different services including speech-to-text translation and trade-off analytics on Bluemix, its cloud platform for developers. IBM's CEO has previously mentioned that she hopes that the company will generate $10 bn in revenues from Watson in the next decade (versus $100 mn as of October 2014). Having said that, our analysts don't foresee a significant revenue contribution from Watson in the near-term. But apart from these, most solution providers remain private and relatively small, reflecting the nascent nature of this space. Greg Dunham has more on this on page 17.

Having said that, the list of AI start-ups that have been acquired by established companies in tech and other sectors has been growing rapidly in recent years. Google has been particularly acquisitive, buying deep learning, image recognition and neural network technologies. Yahoo, Microsoft, Intel, LinkedIn, Walmart, and Infosys have similarly invested in this field. This is of course one

M&A activities related to Artificial Intelligence

Acquirer	Target	Business description
Technology		
Google	DeepMind ($400m) - 2014	Deep learning to understand images, text and videos
	Dark Blue - 2014	Deep learning to understand natural language
	Vision Factory - 2014	Visual recognition using deep learning
	Jetpac - 2014	Image recognition and neural network technology
	DNNresearch - 2013	Deep neural networks, language processing
Yahoo	IQ Engines - 2013	Image recognition to tag and organise photos
	LookFlow - 2013	Enhanced image recognition
	SkyPhrase - 2013	Natural language processing technology
IBM	Kenexa ($1.3bn) - 2012	Data analysis to help recruit and retain workers
Microsoft	Equivio - 2015	Machine learning technology for info governance
	Revolution Analytics - 2015	Statistical computing, predictive analytics
Infosys	Panaya ($200m) - 2015	Automated cloud based quality management services
Dropbox	Anchovi Labs - 2012	Image classification using AI
Intel	Indisys - 2013	Natural language recognition
	Omek ($40m) - 2013	Maker of gesture-based interfaces
Stryker	MAKO Surgical ($1.65b) - 2013	Advance robotic assisted surgery in orthopedics
Monsanto	Climate Corp. ($930m) - 2013	Underwriting weather insurance in real-time

Acquirer	Target	Business description
Socia media		
Facebook	Wit.ai - 2015	Siri-like API voice interface
Twitter	Madbits - 2014	Image understanding using deep learning
Pinterest	VisualGraph - 2014	Machine vision, image recognition, visual search
LinkedIn	Bright ($120m) - 2014	AI and big data algorithims to connect users
E-commerce		
Ebay	Apptek - 2014	Hybrid machine translation using machine learning
Amazon	Evi Technology - 2013	Internet search and voice recognition
	Kiva ($775m) - 2012	Manufacturing mobile robotic fulfillment system
Deutsche Tel	Magisto - 2014	AI video story telling platform (partnership)
Retail		
Staples	Runa - 2013	Specialist in e-commerce personalization tech
Walmart	Luvocracy - 2014	Discovering recommendations by friends
	Inkiru Inc. - 2013	Predictive analytics applications
Home Depot	Black Locus - 2012	Data analytics innovation lab based in Austin TX
Capgoods		
GE	Pivotal ($100m+) - 2013	Develops data analytics offerings
Schneider	InStep Software - 2014	Real-time performance mgt, predictive analytics

Source: Goldman Sachs Global Investment Research

route that incumbents can take to adopt AI, the other being that they develop AI capabilities in-house (like social media companies for instance). But more broadly, incumbents that are best suited to respond to any AI-led disruption are likely to be those that have access to proprietary data. With AI, data is only set to become a stronger entry barrier. A large and growing population dataset allows the machine or the software to learn faster and deeper. In other words, more data can make a clever algorithm cleverer and so an early mover with a unique or large dataset can build a huge advantage. AI can thus reinforce dominance in industries where some existing players have a pre-existing data advantage, while for the others, it can prove to be quite disruptive.

Let's start something special

Artificial Intelligence start-up funding

Artificial Intelligence Start-up	Total raised ($m)	Start-up Description
Sentient Technologie	144	Data analysis through massively scaled AI
Rethink Robotics	127	Robots for production and research
Vicarious	72	Advanced image recognition
Modernizing Medicin	55	Cloud-based Electronic Medical Assistant
Context Relevant	44	Using machine learning to analyse big data
Narrative Science	32	Generate written naratives from data
Scaled Inference	27	Platform for general-purpose AI
Kensho	26	Automation of financial research
BuildingIQ	21	Energy management software platform
Expect Labs	15	Voice-activated discovery
Blue River Technolog	13	Lettuce thinning using machine learning
Nara Logics	13	Big data analysis
Tempo AI	13	Mobile productivity app organises user's day
Sentrian	12	Remote biosensors to prevent hospitalisation
PrecisionHawk	11	Aerial data analysis, AI software for UAVs
MetaMind	8	Natural language & image recognition

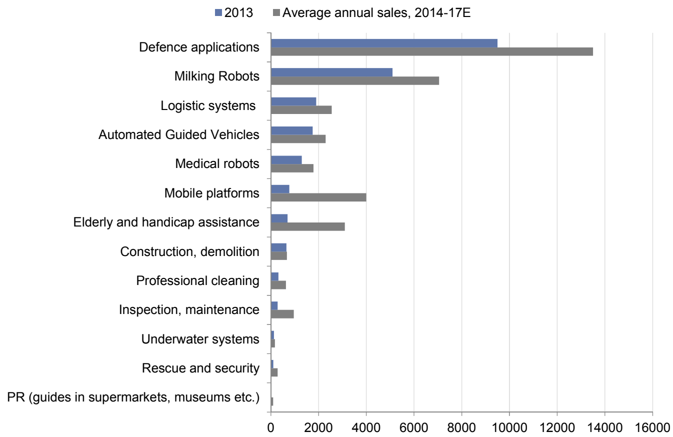
Source: Company data and News Sources

Baxter, is that you?

So far we haven't spent a lot of time on the hardware aspect of machine intelligence output because it is not paramount for AI. AI is the brain inside a robot, a robot is the container for AI and each can exist without the other. In previous issues of Fortnightly Thoughts, we have written at length about smart, flexible robots becoming more adept and expanding their scope beyond traditionally automated end-markets (like machine tool, auto manufacturing), into previously labour-intensive sectors like consumer electronics and food production. Robots equipped with AI can further negate the need for human instruction and intervention and, counter-intuitively, this is likely to have the greatest impact in tasks that are mundane, simple and time-consuming (like cleaning tools, moving waste and applying glue). On page 11, we interview Rodney Brooks of Rethink Robotics, which builds the Baxter robot and he notes that collaborative robots, which are smaller, mobile and often interactive, are better suited for small manufacturers with limited budgets, staff and space, rather than being disruptive to industrial robots that perform heavy and complex tasks. Another application for collaborative robotics is in logistics and warehouses; Amazon acquired Kiva Systems in 2013 which provides automation solutions in its fulfilment centres, using mobile robots and sophisticated control technology to identify and retrieve packages that have been ordered, allowing for faster cycle times, longer operational hours and reduced labour requirements. Again, these are simple, but cumbersome and tedious jobs.

At your service

Sale of service robots by type



Note: 2013 data not available for PR robots, only handicap assistance sales considered for 2013 in the elderly and handicap assistance category

Source: IFR World Robotics

Helping the age old problem

Outside of factories and warehouses, the potential for collaborative and service robots is perhaps highest in the field of healthcare – ageing demographics and a shortage of care workers is an emerging issue in many developed markets and particularly in Japan. This is one of the reasons that in 2013, Prime Minister Shinzo Abe's government announced subsidies to encourage companies to develop robotic care for the elderly (the government forecasts the nursing care robotic market to grow from $140 mn in 2015 to $3.4 bn by 2035). These are robots that can understand human conversations, avoid collisions, lift heavy objects (including people) and in general, make life incrementally easier for users.

Toyota and Panasonic are among the companies focused on building collaborative robots for hospitals and elderly care at home.

And smart machines do not necessarily have to be robots. Hearing aids, made by William Demant, Sonova and GN Store Nord, have increasingly become "more intelligent", with the devices now able to recognize what type of environment the user is in, i.e. a loud restaurant, an office, or in the car and listening to music. Upon distinguishing the environment, hearing aids automatically change the hearing program, and utilize processing algorithms which are best suited to that specific setting. For instance, the hearing aids may lower the volume of the background noise in the restaurant, and focus the microphones on the person sitting across the table, so that the user can hear the conversation clearly, but hears a lot less of the clinking plates and other conversations in the restaurant.

Look no hands

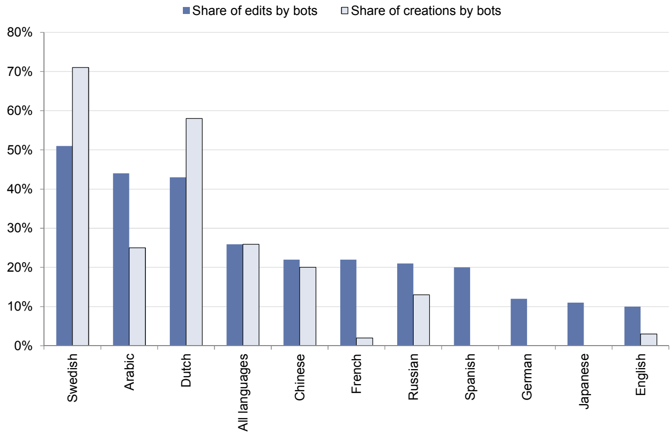
Another sector where machine intelligence has been attracting a lot of attention in recent times is automobiles. There is no denying that cars are becoming more tech-intensive, with connected cars gradually replacing the existing stock of vehicles (see Takafumi Hara on page 9 for more on this). But what about fully autonomous cars? We interview Prof. Raj Rajkumar from Carnegie Mellon on page 7, who expects the technology to become feasible by 2020, thanks to the falling costs of hardware components – actuators, sensors, cameras, scanners, etc., increasing connectivity and improving capacity of the software within these vehicles. Autonomous cars can make roads safer, reduce energy consumption, make the product more accessible (to older consumers, those who cannot drive), reduce the costs of ownership and eventually lower the aggregate demand, by optimising car usage. A car is a unique example of machine intelligence because it's one of the very few consumer goods that requires a license to operate, given that driving is one of the most dangerous and skill-intensive operations that most of us perform on a regular basis.

This brings us back to the question of skill and the relative economics of digital versus human labour. We have previously written about how the internet is disrupting businesses that rely on information asymmetry like travel agencies and real estate rentals. AI, we think, can take this further and bring about a step change in the economics of business models and professions that rely on knowledge asymmetry. What we are referring to here are industries where just the availability of information isn't sufficient, but expertise and knowledge are requisite (Google can provide a diagnosis based on our symptoms, but we would still prefer to see a doctor or we can refer to a recipe, but a chef can still prepare a dish better than an average cook). It is in these areas where AI could eventually make a big difference. IBM's Watson for instance has been deployed by lawyers to scrutinise thousands of legal statutes and documents to answer legal questions and soon it could do the same for consumers. That is a cheaper and faster alternative for paralegals or lawyers, with years of experience and know-how. Article writing is similarly getting automated for data-heavy news reporting. The company Automated Insights for example churned out more than 4000 corporate earnings stories per quarter for the Associated Press last year, up from 300 that AP could previously produce manually. AI can similarly be deployed in augmenting human talent in a broad range of industries; like assist parking, assist diagnosing, assist investing, and assist piloting, etc.

So at the same time that collaborative robots are becoming more economically viable for low-skill intensive, tedious jobs, AI is likely to prove equally if not more disruptive to skilled labour.

Ifs and bots

Share of article edits and creations by bots on Wikipedia



Note: Only registered bots have been included. Only article namespace(s) have been counted.
Source: Wikipedia

So, what is everybody going to do?

We have asked this question many, many times before. And we keep coming back to this because each year the capability and reach of technology seems to increase substantially, strengthening the advantage of digital labour versus human labour, both in terms of cost and capability. Machines already provide the advantage of speed, precision and endurance (they don't need to go to sleep, they don't get stressed or tired). With AI, if we can combine these advantages with breadth and expertise, including pattern recognition and a better contextual understanding for decision making (crucial in the arsenal of skilled professionals), then machines can compete against human labour in a wider range of jobs. Most AI applications being developed today are aimed at augmenting, rather than replacing, human skill. But that still means that AI is increasing the supply of expertise, thus reducing its value in people.

Of course there are counter arguments to this; many experts argue that artificial intelligence is still no match for natural stupidity. While machines have been able to replicate human tasks that require thinking, many have failed to perform simpler jobs that don't require much thought. And AI could also be limited by regulation that seeks to save jobs or protect privacy; if companies are restricted from collecting or using some of their data, AI-based business models are harder to imagine. It is also not difficult to imagine consumer reluctance to completely trust machines to drive their cars or prescribe medical treatments. So it is unlikely that machines will replace human expertise and labour drastically in the near future, but we do expect this to continue to weigh on wages.

All said, we find AI both gloomy and exciting in equal measure. It is the next phase of the data and tech revolution, as the world becomes more tech-intensive and machines become even more capable. More specifically, AI is the digitisation of decision making and that can lead to varied consequences in different sectors. Below, we have a list of companies from our global coverage exposed to the broad field of AI and machine intelligence, and there is one final observation we'd like to make before we leave you. The table includes AI enablers, both in the software and hardware, as well as users of AI and it is dominated by Japanese and American firms. The lack of many European stocks to play this theme may change in the future, but at the moment it is reflective, we think, of Europe falling behind in the innovation race, especially within the tech sector. Europe's notable absence amongst the bigger companies isn't due to a paucity of start-ups, but it has yet to nurture them beyond adolescence. Further learning it seems is required.

How to invest in this

Company	Sector	Country	Rating	Market Cap ($mn)	Last Price	Target Price	Upside Potential	Rationale
Imparting intelligence to hardware and physical objects								
NEC	Integrated Electricals	Japan	Buy*	7,468	¥342	¥435	27%	No.1 in facial recognition (finds target face in image regardless of changes over time and in expressions) and text meaning analysis (considers sentence structure and importance of words to recognize meaning of sentences); also has proprietary invariant analysis tech
Nidec	Electronic Components	Japan	Buy*	18,696	¥8176	¥9000	10%	Its R&D Research Center remains targeted on the IoT opportunity; active in Advanced Driver Assistance Systems (ADAS) and autonomous delivery robots
Mobileye	Technology	Nether.	Neutral	8,657	$36.07	$50	39%	c.65% share of the front-facing camera-based ADAS market (interpretting visual field, anticipating collisions to warn driver); our analyst expect semi-autonomous driving to contribute c.25% of group sales growth out to 2020E
Nippon Ceramic	Electronic Components	Japan	Buy	313	¥1578	¥2150	36%	No. 1 global share in infrared/ultrasonic sensor (used for automobile parking assistance); the start of autonomous emergency braking assessments (from 2016) and broader auto safety assessment programs should further catalyse the spread of ultrasonic sensors
Pacific Industrial	Electronic Components	Japan	Buy	449	¥1002	¥1170	17%	No. 1 in Japan and No. 2 globally in Tire Pressure Monitoring Systems (installation of TPMS already mandatory in the US and Europe, and greater/mandatory installation in Japan and China remain catalysts)
Using artificial intelligence to boost revenues, increase customer stickiness								
Baidu	Internet	China	Buy	73,334	$207.15	$241	16%	Has developed a speech recognition system Deep Speech which provides accurate results c. 81% of the time even in noisy environments; investments in deep learning, language processing should enhance the relevance between search results and ad display
Amazon	Internet	US	Buy*	176,892	$373.37	$430	15%	Acquisition of Kiva Systems (warehousing automation) helps it improve delivery cycle time; its unique system integrates recommendations throughout the purchasing process from product discovery (product suggestions) to checkout (often bought together)
Twitter	Internet	US	Buy	33,506	$47.82	$62	30%	Enhancing its algorithms to improve recommendations of users to follow and organizing content around world events (like world cup) better remain top product priorities and focus areas for the company
Enablers and champions of data analytics								
WPP	Media	UK	Buy*	28,683	1482p	1717p	16%	Well placed to capture volume benefits within programmatic advertising having invested early to build proprietary offering in the field of programmatic buying
Criteo	Internet	France	Buy	3,048	$43.43	$50	15%	Programmatic-ad platform that allows marketers to circumvent agencies and buy digital media in-house; highly scaled, retargeting software player with a differentiated market position through its Criteo engine, first party data and direct publisher relationships
Verint Systems	Software	US	Buy	3,537	$57.52	$70	22%	Efficiently aggregates, processes and provides insights on large-scale, unstructured datasets (voice, video, text) in high volume and speed use cases; leader in Actionable Intelligence (analyses multi-sourced Big Data for insights around workforce optimization, CRM etc.)
Opower	Software	US	Buy	726	$13.65	$25	83%	Leading cloud-based analytics provider for utilities; reduces energy consumption by analysing over 130 Terabytes of utility customer data (eg:historical usage, billing, weather) to inform consumers of their usage patterns and making recommendations for efficiency
Marketo	Software	US	Buy	1,293	$27.02	$42	55%	Provides segmentation and campaign management solutions; has one of the broadest marketing automation capabilities as per management- offers real-time personalization tech (obtained through Insightera acquisition), Calendar Planning applications etc.

*Source: Datastream, Goldman Sachs Global Investment Research. *On the relevant regional Conviction List. Prices as of the close of February 17, 2015.*

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Interview with Raj Rajkumar

Raj Rajkumar is a professor in the Department of Electrical and Computer Engineering and Co-director of the General Motors-Carnegie Mellon Autonomous Driving Collaborative Research Lab. He is the President and CEO of Ottomatika, Inc., was a primary Co-Founder or TimeSys Corporation, and has served as a research staff member at IBM T.J. Watson Research Labs.

When do you expect to see completely autonomous vehicles on roads? What are the key milestones between now and then?

I expect completely driverless cars to be feasible only in the 2020s, and even then it will first be offered in some developed countries, where the infrastructure is more advanced and traffic rules are generally obeyed. Autonomous vehicles will take longer to appear in developing economies because: (a) their driving etiquette tends to be very aggressive with very thin error margins, and (b) higher costs will initially be a deterrent. These issues will likely continue in the 2020's too. We can also expect that some rich, developed city-states or small countries like Singapore or Qatar, which are forward-looking in terms of adapting cutting-edge technologies, to become earlier adopters.

In terms of milestones, there are two very different ongoing paradigms. The first is the so-called "Holy Grail" approach exemplified currently by companies like Google, which has been experimenting on fully autonomous vehicles. Here the milestone is really one capability - the vehicle will be able to drive to its destination all by itself. But, another approach is the paradigm of incremental automation adopted by today's carmakers. Most if not all car companies expect a human to be part of the driving process for quite some time to come. Even if the human is not necessarily driving, manufacturers expect a human driver to be present in the driver's seat, engage and take over control from the self-driving mode as and when necessary. That is still an advance from cruise control, where right now, the driver gives up control over the accelerator pedal, but still operates the brake and steering wheel. Most importantly, the driver has the responsibility of cancelling cruise control and taking back full control when there is a vehicle driving at a lower speed ahead.

So, in this second paradigm, the first milestone - and it's very imminent - is an autopilot capability on the highway, allowing drivers to engage in a driving mode where the vehicle steers, brakes and accelerates in the current lane. The next development is a highway pilot capability with lane changes, where the vehicle can also change lanes to pass a slow-moving vehicle in its lane. Another milestone is a self-parking feature, with yet another being traffic jam assist (TJA) capability where the vehicle drives itself while in a traffic jam. When the traffic jam clears the human needs to take back control. Production cars available for purchase will reach these milestones in the next three to five years. My belief is that by the time vehicles become completely autonomous, people would hardly notice it because they would have slowly, but steadily, given up control for most of the driving functions before that final step.

Does transportation infrastructure like roads and traffic lights need to change to facilitate the development of this technology?

It is very unlikely that infrastructure will change broadly enough to accommodate this technology in the foreseeable future. As such, autonomous vehicles are being built on the assumption that there will be no special infrastructure for driverless cars. That being said, infrastructural enhancements would be extremely beneficial for self-driving cars.

A wireless communication device which can be added to traffic lights can transmit the location and current status of the traffic light to a receiver implanted in a vehicle, allowing a self-driving car to react appropriately. Similarly, this wireless system can also facilitate vehicle-to-vehicle (V2V) and other vehicle-to-infrastructure (V2I) communications. For example, a car can communicate to the traffic light about where it is going, so that the traffic light can adjust its timing, turn green and let a car pass when there is no traffic in other directions. This should significantly reduce delays and pollution. Furthermore, such technologies will become available on smartphones to enable vehicle-to-pedestrian (V2P) communications, automatically alerting vehicles and pedestrians, when a pedestrian is crossing the street. It must be borne in mind that the cost of upgrading traffic lights involves significant inertia.

Fortunately, these communication technologies exist today, and cars will be able to dynamically plan routes and co-ordinate with other vehicles. However, changes in infrastructure will only happen incrementally. We are beginning to see mandates in the US, in Europe and in Japan to implement the wireless technology. Starting in about 2017 or 2018, the US government is expected to require that all newly manufactured vehicles to carry this technology. But even so, given the whopping 250 million cars that can operate in the US and assuming that roughly 15 million new cars are sold every year, it would take 16 to 17 years to replace the current fleet of cars. So, it will take time.

What are the societal and economic benefits of self-driving vehicles?

Every year an estimated 1.2 million people die and hundreds of millions of people get injured due to automotive accidents, taking a huge toll on society, both emotionally and economically. Imagine the potential benefits if we could take human error, which accounts for more than 90 percent of these accidents, out of the equation. Unlike people who are prone to distraction, computers are not and they will be able to drive a lot safer. Another value-add of autonomous vehicles would be an improvement in productivity. You'd agree that being stuck in traffic is a very common urban phenomenon. In the US, the normal person commutes about 51 minutes per day to and from work, and that's unproductive time. Over time, when the technology has proven itself, if the vehicle was driving itself, that time could be used to catch up on email, texts, or doing something more productive including taking nap! I believe that would have a global impact on economic productivity in time – it is no longer a question of if, but when. Thirdly, people lose their driving ability and license when they age. If older people are living all by themselves, they would have lost some of their independence, self-esteem and their quality of life would be declining dramatically too. In this case, autonomous vehicles would help them regain their mobility and could drastically improve their living standards. This is true for the disabled too.

What are the highest value-add components in an autonomous car?

An autonomous car comprises four sub-systems. The first one is a set of sensors, things like cameras, laser scanners and radars. These act as the eyes and ears of the car. The second subsystem is actuators, which operate the steering wheel, the accelerator, the brake, and transmission; so, basically they act as our hands and feet. Thirdly, there is a set of computers that process all the information gathered by the sensors and then generate commands to the actuators; in other words, this is the brain of the vehicle. And fourth is a communication system that is similar to the human nervous system; this receives sensory inputs from sensors and also communicates the commands from the brain to the actuators.

Now, actuators are becoming cheaper and my view is that by about 2020, they will be broadly available and affordable. In terms of the sensors, cameras have already become very cheap and radars are rapidly getting there, however lasers and scanners won't be as affordable for consumers for a few more years. Essentially, the costs of a car's hardware components are subject to the same downward trend that is also evident in the computer and smartphone industry. They are constantly becoming cheaper, faster and smaller. So the key to autonomous technology is really in the software which controls all these four subsystems. Driving is one of the most complex activities that human beings engage in on a daily basis and so, any firms that become leaders in developing software for it will play a big role in deploying this technology, and that is where the bulk of the value will lie. And this situation is similar to the Windows OS in PCs or Android in smartphones. There is also a major role for someone who can vertically and smoothly integrate the different function and capabilities of technology. So, looking again at smartphones, Apple obviously does this very well in terms of integrating hardware (design), software and brining together other related products, like the iPod and iPad. One can imagine something similar evolving in the autonomous car space as well.

What happens when autonomous cars come across a new scenario on the road? Are they capable of adapting or have they begun to self-learn and improvise in new situations?

In pretty much every project that is working towards autonomous cars around the world today, there is always a person in the driver's seat when the car is being tested on public roads, to act as the final authority and take over control if needed. The number of scenarios that one needs to test is very extensive. And multiply each individual scenario with different conditions in terms of weather, lighting, quality of roads, traffic, crowd densities and special situations like a fire truck or an ambulance going by or a heavy truck right behind you. Driving really is a very complex activity for humans, but even more so for machines when they encounter unusual or unique scenarios. Someone has to teach these self-driving vehicles the right action to take, and in that sense they are not yet self-adapting or self-learning. Think about it this way - when we were young, we did learn by ourselves, but we were taught a lot more by our parents, our families and teachers. Eventually, because our brains are structured that way, we were able to learn things ourselves just by observing what was happening around us, based of the underlying principles that we were taught. My view is that it will be a long time before self-driving vehicle technology can get to the position where it is able to teach itself what to do in different scenarios. We are still in the teaching phase.

What regulatory challenges to autonomous car adoption do you foresee?

A lot of progress has been made on all these fronts. In the US, regulations have been implemented at the central (federal) level; there is a very clear awareness at the federal level that this technology is progressing rapidly, and the government wants to facilitate this work, but ensure that it is safe. A few states in the US are also issuing their own rules to facilitate the testing and deployment of automated vehicles. In fact, these states are competing with each other to be perceived as the leader in this technology by being very receptive to companies that want to build and test self-driving vehicles. In return, they expect those companies to set up businesses, proliferate their tech environment and bring more jobs to their states. So competition has been a catalysing force and that is a very good thing.

There are also very interesting developments occurring on the insurance front. As we previously mentioned, the rate of automotive accidents, injuries and fatalities would go down with this technology, which means that pay-outs for insurance claims would drop. Subsequently, this would lead to lower premiums in a competitive landspace. So, of course, insurance companies have to worry about the reliability of self-driving technologies, while being aware that the overall revenue and the market size could shrink significantly. If that happens, only the most nimble and forward-looking companies are likely to survive or thrive.

How do you see the use cases for wireless cars developing? And what does that mean for aggregate car demand?

Interestingly, Uber recently announced a strategic relationship with us here at Carnegie Mellon University, to build self-driving cars for the car- and taxi-sharing market. And, almost immediately, Google responded saying it was looking into the ride-sharing market independently. The fact that two forward-looking giants are eyeing this space can be an important catalyst to realise this driverless car technology, and I expect it to advance very rapidly. Of course, we don't know yet when exactly we'll start to see self-driving cars as taxis, but I believe that other players will quickly join the game too, and this on the whole will accelerate this technology.

A long-term impact of this sharing paradigm perhaps is in the ownership model of cars. A common observation is that an average car sits idle for more than 80% of the day, representing a big chunk of dead investment. Instead, if there is a smaller subset of self-driving cars which can simply be fetched or summoned by a smartphone for a task, which, when finished, then drives away to service the next person, then resources would be utilised much more efficiently. This in fact would have a major impact on the demand for cars, and could dramatically change the industry as we know it now. Substantially fewer cars could be sold every year but they may be replaced much more often due to the additional wear and tear incurred. Subsequently, fewer cars and better efficiency should have a meaningful impact on total resource and energy demand. And given a completely different user paradigm, car designs would evolve as well. More streamlined, efficient cars would contribute to greater energy savings. So, these are truly exciting times for self-driving vehicle technology. Only a few years back, people still perceived it as a long-term development i.e. that it is 20-25 years away. Now, we are talking about what is going to be available to consumers in the next five years. And that has been because multiple milestones have been achieved in the past three years, and more companies are jumping into the fray. Remarkable advances happened recently not just in terms of the technology, but also social awareness, social acceptance, insurance and the legislative sides.

The road to automation

Takafumi Hara, our Japan Electronic Components analyst, on the future of automated vehicles

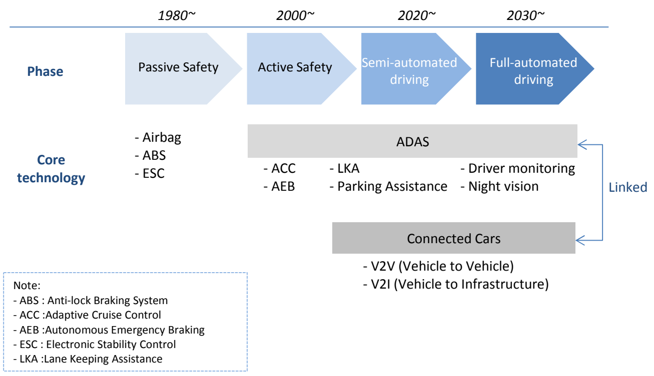
On the cusp of an automated driving era

The development of the automobile is nearing a major transformation point. The automated driving era is fast approaching, and the commercialization of related auto technologies is advancing at a rapid pace. We believe self-driving vehicles will change lifestyles and create winners and losers in the technology sector (auto electronic parts).

From a safety perspective, the development of automated driving can be divided into the following phases: (1) Passive safety: airbags and anti-lock braking systems (ABS); (2) Active safety: advanced driver assistance systems (ADAS), mainly automatic braking, lane-keeping assistance (LKA), and automated parking; (3) Semi-automated driving: enhanced ADAS and connected car technologies (vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I)); and (4) Automated driving: enhanced V2V/V2I. We are currently in the active safety stage. ADAS is the core active safety technology and main ADAS functions include adaptive cruise control (ACC), LKA, and automatic braking. These systems are already found in vehicles and we expect the installation rate will increase quickly. In addition to the initiatives of OEMs, non-auto makers like Google and Japanese venture-company ZMP are actively conducting self-drive related R&D. The roadmap to fully automated driving is filled with uncertainty and we do not expect this stage of development to be reached until 2030 at the earliest. However, foundation technologies for semi-automated driving have already been developed. We believe technologies like automatic braking, LKA, and ACC will make automated driving on highways a reality by around 2020.

ADAS and connected cars will open the door to the automated driving era

Automated driving development roadmap and changes in core technologies



Source: Goldman Sachs Global Investment Research.

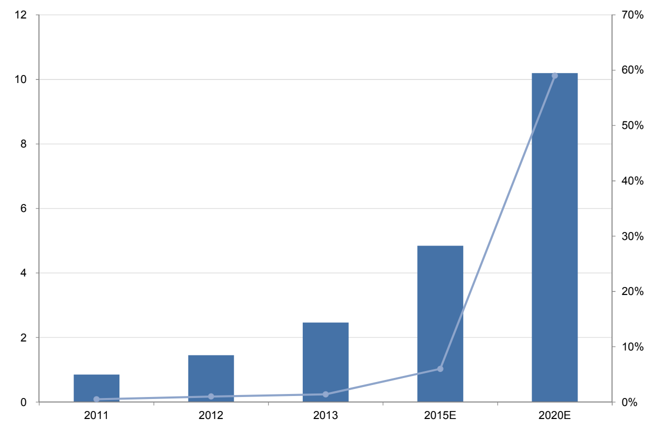
Advance of ADAS/connected cars to turn technology companies into auto-tech companies

ADAS penetration is starting to gain real momentum in the current active safety era. Awareness of ADAS products is increasing and in Europe and Japan the installation rate for automated braking is high even for mass-market cars. With ACC and LKA also becoming increasingly common in luxury cars, our impression is that the framework for semi-automated driving is gradually being put in place. Amid the shift from active safety to semi-automated driving, we expect the connected car penetration rate to increase rapidly and the volume of tech products installed per vehicle (content value per vehicle) to rise at a much higher speed.

We forecast the market for ADAS sensing devices (millimeter wave radars, light detection and ranging (LIDAR) devices, cameras, and ultrasonic wave sensors used in automatic braking systems) will grow quickly to US$10 bn in the next five years. This should be a major tailwind for companies that make these products and the electronic components used in them. We estimate auto electronic parts will become a pillar of tech company profits comparable with components for smartphones and other consumer electronics. Companies with a high exposure to this field are likely to evolve into auto tech companies.

The spread of connected cars should drive the market for ADAS sensors to US$10 bn

Connected car global penetration rate and ADAS sensor market size ($US bn)

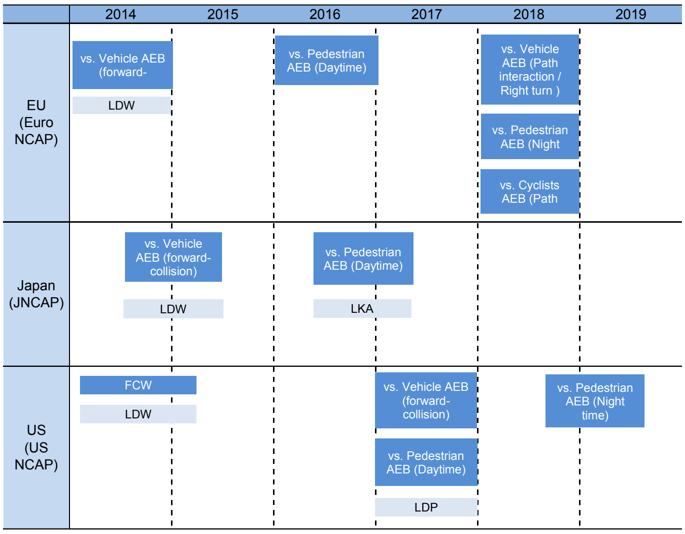


Source: Goldman Sachs Global Investment Research, Japan Patent Office.

The automation of driving and consumer pull demand are important factors behind ADAS diffusion. However, we believe the most important driver of all is changes to safety regulations and safety assessments conducted by third parties. In Japan and Europe, automatic braking has been or will be added to the New Car Assessment Program (versus vehicles in 2014 and versus pedestrians in 2016). In the US, meanwhile, rear cameras will become compulsory from 2018 under the Kids and Transportation Safety Act. Changes to the regulatory environment reflect rising consumer safety awareness.

Increasing importance of automated braking in vehicle safety assessments is promoting ADAS penetration

NCAP roadmap in Japan, the US, and Europe



Source: Denso, Goldman Sachs Global Investment Research.

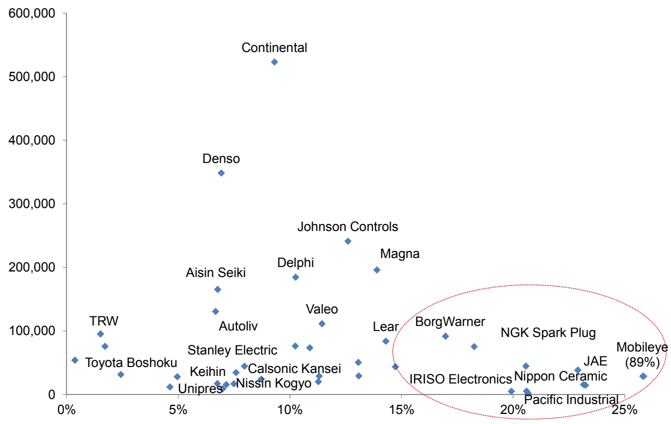
Winners from this trend: Unveil hidden gems

We expect Tier 1 makers and automotive semiconductor and electronic component makers to be the main beneficiaries of rapid auto tech market expansion. For example, Tier 1 names Bosch, Denso, and Continental; automotive semiconductor makers Infineon, Renesas Electronics, and STMicroelectronics; and automotive electronic component makers Nidec, Murata Mfg., and TE Connectivity. These companies have leading global market shares in their respective fields. Compared with consumer electronics, the barriers to entry for auto tech products are high because (1) it takes a long time to obtain spec verification and (2) manufacturers must meet extremely stringent defective product ratio standards. This bodes well in our view for large companies that had already established automotive products as core businesses before ADAS penetration.

But when considering investment in the auto tech industry, is it wise to only invest in these top companies? As these companies tend to have broad product line-ups, we believe auto tech growth could be diluted to some extent. From the perspective of earnings growth rates, we highlight first-class specialists that have already scaled the high barriers to entry. In particular, we highlight companies with high market shares in technologies that ADAS/connected cars are likely to create new demand. As examples, we cite the following companies in our coverage: Mobileye (UK), the No.1 maker of mono-camera chips; Nippon Ceramic (Japan), the No.1 maker of ultrasonic sensors for parking assistance; and Pacific Industrial (Japan), the No. 2 maker of tire pressure monitoring systems (TPMS). While these companies only have small sales, they have already secured the top global market share in their product categories.

Top specialists very attractive from the perspective of earning growth rates

Comparison of 2013-16E operating profit CAGR: global auto parts and auto tech (JYP mn)



Source: Goldman Sachs Global Investment Research.

Automated driving technologies are increasing the IT product content of automobiles. In other words, we expect the auto industry to converge with the tech industry in many fields. Rather than bringing traditional auto companies and traditional tech companies into opposition, we think this trend will create new value for them through reciprocal technology fusion.

Takafumi Hara

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Interview with…Rodney Brooks

Rodney Brooks is the founder, chairman and CTO of Rethink Robotics. Previously, he co-founded iRobot in 1990, where he served variously as CTO, Chairman and board member until 2011. He also served as a Professor of Robotics at MIT from 1984 to 2010 and was the founding Director of the Institute's Computer Science and Artificial Intelligence Laboratory. He has been elected to the National Academy of Engineering and as a Fellow of the American Academy of Arts and Sciences, the Association of Computing Machinery and the Association for the Advancement of Artificial Intelligence, among others.

Baxter is an industrial robot built by Rethink Robotics and was introduced in September 2012. It is a 3-foot tall, two-armed robot with an animated face that is designed to perform simple tasks on a production line.

What are the changes occurring in the industrial robotics space and why do you see an opportunity for collaborative robots?

Industrial robots are very adept in situations that involve repetitive motions in a fixed co-ordinate system, but they haven't evolved much in the past 50 years. Back then those robots didn't have sensors and computers connected to them, and today they still don't have built-in sensors so they are not very safe to be around. Therefore, industrial robots need to be put in cage-like enclosures to keep them away from people during the operating process.

Collaborative robots on the other hand use low-cost chips and sensors that enable them to impart a level of intelligence which they use for basic perception and reasoning. They are safe to be around and so can be employed in factories to work in close proximity with employees, instead of having a separate area dedicated to them. Another important feature that distinguishes collaborative robots like Baxter is that ordinary people can use these robots and teach them new, different tasks. They are extremely intuitive and flexible and integrate seamlessly with other automation technologies. They are also relatively affordable and do not require specialists to operate them on a routine basis, and this is what makes them useful, particularly in smaller manufacturing facilities where processes and requirements change on a day to day basis.

What is driving the improvement in economics for collaborative robots?

Improvements in capability and a persistent reduction in the cost of hardware technologies, thanks to the smartphone revolution, have driven a lot of progress in the field of collaborative robots. Rapid growth for electronics in the last 20 years has helped bring down the cost of cameras, sensors, accelerometers and other related technologies, and this has enabled the cost of collaborative robots to come down, because these robots use processors and sensors that are the same as the ones embedded in smartphones and other electronic goods.

The other important development of course has been the increasing role of software in robotics; software reduces the time and cost of installing, maintaining and modifying robots. It also makes the robot more flexible, enabling it to impart an intuitive user interface and helps the robot improve over time, thanks to regular updates.

The latest upgrade of the software that powers Baxter, for instance, helps users to re-deploy the robot quicker and more easily, after common plant-floor variations occur, such as tables being bumped, fixtures being moved etc. These individual upgrades aren't necessarily breakthrough, but they matter a lot to the improving capability of robots.

What kind of end-markets are you targeting for Baxter?

Currently, only about 10%, according to the Boston Consulting Group, of manufacturing facilities and factories employ any sort of industrial robots and they tend to be very high end; these are not the areas that hold a lot of potential for collaborative robots. Baxter is not going to compete in sectors where industrial robots make sense because they are already partitioned into distinct human and robot areas. Collaborative robots won't disrupt industrial robots used in automotive manufacturing for instance. What we aim for instead is to help put robots in places where automation was previously not possible – the incredible range of simple activities that current robots are just not economical for.

Unlike traditional robots, which tend to be very expensive, particularly when we consider the programming, installation and integration costs, collaborative robots like Baxter are a lot cheaper to deploy. If we compare their cost and output against that of employing human labour in the US for instance, it takes less than a year to recoup investment. Further, these robots do not require specialized engineers to integrate them for carrying out a single task and can be reprogrammed easily, which helps maximize ROI as the same robot can be utilized across multiple lines in a plant. This is why these robots make an ideal fit for small manufacturers with limited budgets, space and staff.

What are the constraints that have hindered greater adoption of collaborative robots so far?

Collaborative robots are still quite new as a category and the lack of understanding of what they do, how to use them and how they differ from other industrial robots has been one of the key bottlenecks that we have faced. It took us a while to get people to understand how these robots work and why mapping their capabilities with existing industrial robots doesn't work. But adoption is now picking up.

We have also improved the software inside our robots dramatically in recent months. For Baxter for instance, upgrades from last July have made the robot even more capable and productive than it used to be. It is able to do the kind of tasks that people want it to do more and more and that should help boost penetration further. We are continually expanding the capabilities of the robot and I think we will see demand get way out in front of our supply this year as we ramp up production.

How do you see software usage in collaborative robots evolving?

It is software that adds new capabilities to the robot. And so, with Baxter we are aiming to merge our software programs into one package and make it open to third-party developers, at every level, in 2016. This will allow lots of people to build new capabilities for the robot, which could then be sold by third parties or remain in an open source format.

Hundreds of people are already developing software for Baxter in universities. And while all of the new developments may not be useful to our broader customer base, there will surely be some good ideas that will emerge as so many different smart people work on improving the capabilities of the robot.

What is the competitive intensity like in this category of robots?

While collaborative robots did not exist as a category until as recently as a year and a half ago, the big four robot manufacturers, i.e. Fanuc and Yaskawa from Japan and Kuka and ABB from Europe, and smaller companies like Universal Robots, have all already offered or are in the process of developing some sort of collaborative robot or the other. Some of them are making advances, but currently they are at a much higher cost compared to Baxter. We also have a lot of patent protection, which will make it difficult for other players to do exactly what we're doing. But we are glad that big companies are foraying into this domain. It not only validates us and what we do, but also opens up more possibilities for the field of collaborative robots.

In which segments and geographies are your customers concentrated?

Our customers come from a variety of sectors, from small plastics manufacturers to third-party logistics. Areas like machine tending (putting sheet metal in press brakes), which is both boring and dangerous in nature, also represents a growing market for us and we believe robots can be perfect substitutes for risky and dull jobs like these that people are not keen on doing.

Apart from this, I believe that elderly care will be one of the biggest drivers of robotics over the next 30 years. The demographic inversion in Japan, North America, Europe, Australia and even China simply necessitates greater adoption of collaborative robots. Now, while Baxter has some capabilities that the previous robots did not have, it is still not in the perfect form needed for elderly care. And this is why it is great that Baxter is being used in universities and that a lot of people are trying to work towards developing elder care applications with Baxter.

In terms of geography, we are mostly located in the US and Canada currently, but we plan to expand internationally later this year. But production should still be limited to the US, where we design and build Baxter today – simply because while designing the robot, we worked alongside 19 different custom parts suppliers to figure out where their low-cost sweet spot was to optimize Baxter’s production, and fed that information into the design process. And they are all in the US and Canada. I don’t think we could have done that in China without going through an extremely long and expensive process and even if we did, I don’t think we could have built our robots as cheaply in China as we build them here in the US.

You've refuted the concerns around the potential dangers of artificial intelligence and negative impact on jobs...

Yes. Things like deep learning have made significant progress in the last five years; very surprising progress, and this has made many outsiders to the field overestimate the capabilities of the computer programs that are now able to do some of the things that human beings do. But while programs can now label images based on their content, for instance, they do not understand what the image really means. So, if a collection of randomly organized pictures of a doll’s parts are fed into a computer program, it might just label the image as ‘a doll’ without understanding the concept of a doll. A person, on the other hand, will be able to say that the image is not that of a doll, but a collection of doll parts. So I believe people outside the field over-generalize the capabilities of what turn out to be very commercially useful programs, but where the adjacencies don't generalize in the same way they would if a person was doing that task. It is extremely hard to assert what the capabilities of artificial intelligence will be like 100 years from now, but from a 30- to 50-year perspective, I do believe there is a gross overestimation of the capabilities of artificial intelligence which is leading to worries and doomsday scenarios. Also, while there will be some disruptions in the labor markets as artificial intelligence becomes more capable, that has always been the case with technological progress. Overall, the progress being made in this field is likely to help people do their jobs better rather than replacing them completely.

How accommodative are regulations for collaborative robots?

The current industrial robots are not safe to be deployed in proximity to humans and the safety standards established for them do a good job at maintaining distance. But a robot like Baxter does not need to be separated from people on the factory floor. And this is what we are trying to explain to all the standard setting bodies in this field. It has been easier to do that in some geographies and harder in others.

There are also many incumbents, especially in the safety industry, which are trying to invoke regulation on safety grounds, but again, this isn’t the first time that innovation is faced with regulatory hurdles. Historically, train companies tried to use regulations to stop people from using automobiles in Great Britain in the 19th century, and we are seeing similar oppositions being hurled at Uber currently. So, like many other innovations, there will be a process involved and it will take some time to straighten regulations for collaborative robots, but eventually, I don’t think regulation will stand against progress being made in the field.

How do you feel about the prospects of innovation more broadly?

Some of the biggest problems in the world require a little longer-term development of not just the software but also the hardware coupled with it. And so, while a lot of software-based platforms have seen valuations rocket and in turn led to a situation where many VCs are focused on shorter-term hits, we need longer-term investments to come up with genuine innovations that can help solve the world’s constraints.

The start of the collaboration era

We asked Yuichiro Isayama, our Japan Machinery analyst, how collaborative robots are changing the Machinery industry

Japan's machinery industry is home to many leading suppliers of machinery and equipment that fall under the category of Factory Automation (Discrete Automation). Through a process of trial and error, Japanese machinery makers have been pioneering the development of robotics/the automation industry. The majority of companies in Japan’s machinery sector are focused on cementing their position as “suppliers”, rather than actual “makers” of core technologies of artificial intelligence or controlling systems of those smart machines.

The robot is probably the best example of a machine that features both collaborative and learning intelligence functions. In recent years, Fanuc, the top global industrial robot manufacturer, has unveiled a prototype collaborative robot that has attracted considerable attention, while also much talked about is the Nextage collaborative robot, co-developed by automated machine manufacturer THK and Kawada Technologies, a supplier of helicopters and equipment for defense applications. Below, we use these two examples to discuss the features, current themes, and outlook for collaborative robots.

Fanuc produced and demoed a prototype collaborative robot in 2014 following the relaxation of ISO regulations (allowing the removal of safety fencing surrounding robots with a power output of less than 80kW). Ensuring the safety of peripheral workers is the biggest precaution in human/robot collaborative processes. Many touch and vision sensors usually need to be fitted to prevent any accidental contact between human and robot. With its collaborative system, however, Fanuc has slowed the movement of the vertically articulated robot to a fraction of the regular speed and covered the robot with a green sponge and installed a sensor to shut down the robot's operation upon human contact. By doing so, Fanuc has minimized the actual impact on the human operator from contact with the robot. The only additions to a standard vertically articulated robot are the sponge, the sensor and the reduction in speed. Since the function of the robot is little changed, Fanuc has successfully kept down its price vs. complicated collaborative robots.

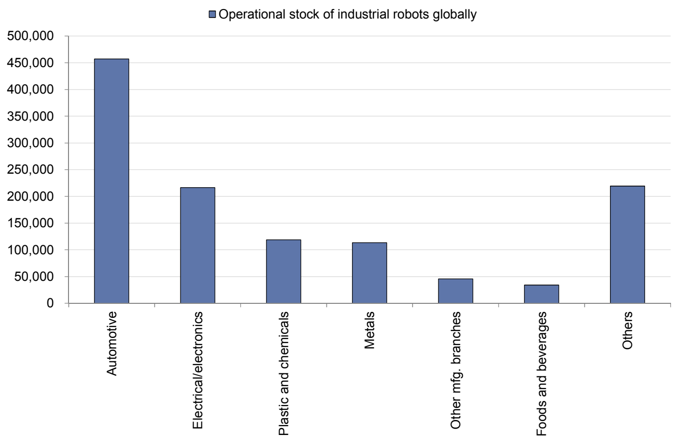
It seems potential users of Fanuc's collaborative robot are mainly automotive and electronics clients that already employ vertically articulated robots in significant numbers. Nearly all robots used in manufacturing at present are not self-organizing, but instead require humans to teach them process patterns. For a company considering introducing industrial robots in general, the key determinant for opting to automate a process is whether or not it has sufficient experience in using robots already. We believe this is why the main potential users of collaborative robots are yet concentrated in the auto and electronics industries, and why we still see considerable room for growth in robot penetration chiefly in general industry, as shown in the next exhibit.

Machinery manufacturers are seeking to capture various growth opportunities in an effort to alter this trend. A good example is the Nextage robot produced by Kawada Technologies. This robot is able to directly replace a human operator for light and small tasks. Equipped with vision sensors in the head and arm sections, the Nextage robot can complete simple, light and small assembly processes instead of a human operator. With Nextage retailing at just over ¥10 mn including system costs, the price has come down to a level that allows potential users to give serious consideration to replacing human tasks with robots. Based on announcements, it seems that both Japanese and foreign companies such as Glory and Airbus have introduced Nextage, which is steadily building up a track record already.

Kawada Technologies assembles Nextage robots and developed its control system, while THK supplies the components. THK also provides the required teaching and integration services when a client chooses to install Nextage. We believe this offers major clues as to how the leading automation players in Japan's machinery industry plan to approach the AI and Smart Machine space.

THK's CEO Akihiro Teramachi explained in an analyst meeting last September that he saw little value-added in assembly per se. This seems reasonable to us given that automation-related equipment and component suppliers like THK maintain higher margins than manufacturers involved only in robots and other assembly processes. Also having a major impact, in our opinion, is that the standardization/establishment of control systems is the most difficult area for Japanese companies to rival their US/European counterparts.

Global operational stock of robot by industry



Source: Goldman Sachs Global Investment Research.

Our interviews with companies operating in new automation/robot fields indicate to us that Japanese manufacturers' chances of success are low in the both the self-organizing space, typified by AI, and the control function space, as these areas require the sort of aggressive strategy with which they have generally struggled historically. First, both spaces are software based, and international standardization is unfamiliar territory for Japanese manufacturers. Second, fundamental to Japanese manufacturing industry as a whole is an ethos of offsetting deficiencies in software functions with hardware. Third, Japanese companies do not have the financial wherewithal to rival major US/European IT players where large-scale investment is required from the development stage.

Although Japan sits on specification committees for IoT standardization (Industrie 4.0 in Germany, Industrial Internet in the US, etc.), we confirmed via interviews with Japan's Ministry of Economy, Trade and Industry and other parties that there is no growing momentum to create specifications unique to Japan.

We believe a similar situation is occurring in the self-organizing space, and this is why most Japanese machinery manufacturers have not stepped up their own development of software but prefer to play a role as equipment/component suppliers. In the new era of robots and automation, Japan's machinery sector looks likely to retain its position as key supplier.

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Interview with…Manoj Saxena

Manoj Saxena is a founding General Partner of The Entrepreneur's Fund, where he focuses on identifying, investing in, and scaling cloud-centric software companies in the Cognitive Computing space that also complement the IBM Watson Cloud ecosystem. He is a Special Advisor to IBM senior leadership, where he focuses on operationalizing IBM's $100 mn Watson Cloud Ecosystem Fund and making side-by-side investments with the TEF IV fund. Prior to joining TEF, Saxena was General Manager, IBM Watson, where his team built the world's first cognitive systems in Healthcare, Financial Services and Retail. Prior to IBM, Mr. Saxena successfully founded, scaled, and sold two venture-backed software companies within a five-year span.

How have cognitive computing and artificial intelligence evolved in the last few decades? And how do you see them developing in the future?

Cognitive computing, as an incredibly useful and transformative technology, has reached the tipping point, in my opinion. The technologies that enable cognitive computing at scale have been around for at least one, if not two or more decades. And right now, these multiple technologies are converging in a perfect storm, creating tremendous opportunities for businesses.

Firstly, cloud technology has meant that massive computing capacity and near infinite processing power is now available at very low prices and requires no upfront installation or capital spend. Secondly, new machine learning technology and its applications to different functions, like natural language processing, are maturing. Take Apple's Siri, Nuance, IBM's Watson, Microsoft's Cortana and Google's efforts in this direction, for instance. Thirdly, there has been rapid proliferation of mobile devices and the emergence of a new class of users, which together are creating a new distribution mechanism. And last but not least, we are also seeing substantial amounts of data being generated from both social devices and the Internet of Things, in a form that traditional computers cannot process and extract intelligence from. This data is known as "dark data." It contains critical insights and makes up more than 80% of data today, yet it often goes uncollected or neglected. One of our portfolio companies, Cognitive Scale, is able to extract insights from dark data to help customers improve decision-making, personalize consumer experiences, and create more profitable relationships.

Also, we now have an entirely new set of workers and consumers, millennials, who are starting to use these technologies, which are converging to enable the endless capabilities that cognitive computing represents. I believe, along with IT industry analysts at IDC, that cognitive computing is creating the third big platform in IT. It is following the first two, which are marked by mainframes and personal computers and followed by the World Wide Web. There will be very exciting opportunities in the next few years, as the cognitive computing platform leverages the convergence of cloud, mobile and big data and I expect this trend to last for the next couple of decades.

The rate at which cognitive computing can accelerate in the future will depend on three major factors. Firstly, platforms will need to implement these technologies and deliver results more quickly, perhaps in a matter of weeks, rather than the current period of nine months to a year. So basically, there should be specialized platforms to create and process cognitive applications speedily. Secondly, as businesses start to see initial pilots pay off, they will invest heavily in many more projects, just like they did with the internet. The moment these businesses recognize the breakthrough value of cognitive computing, they will implement this technology in all of their applications and processes, a phenomenon that we have begun to see today. And lastly, there will be an evolution of how people understand and embrace cognitive systems, as well as the development of new tools and methods. Inevitably, IT and business people alike will start looking at the new paradigm for creating value, while recognizing cognitive computing not just as a way to accelerate a company's investments in Big Data, but as a fundamentally new platform that will provide exciting opportunities.

Which industries have begun adopting cognitive computing and where else do you see potential in the future?

Cognitive computing has the potential to become omnipresent in every industry that we know of, but there are some industries that are, naturally, adopting this technology sooner than others. These are information-intensive industries, where access to data is creating a tremendous number of opportunities. This includes industries like healthcare, insurance, telecoms, financial services, and travel. Within these industries, there are the early movers that are already adopting cognitive computing. And to my surprise, this shift is happening faster than I had anticipated.

We're also seeing cognitive clouds being adopted across organizations. Specifically, across horizontal business processes such as procurement, customer care, HR, sales, manufacturing, and marketing. For these functions, cognitive insights enable companies to better understand the thousands, if not millions, of business processes transacted throughout their companies every day. This insight transforms business processes, which boosts productivity, improves customer satisfaction, and results in cost savings.

Across sectors, there are mainly three selling points for AI or cognitive computing – a greater ability to provide highly personalised insights and experiences to customers, enabling better decision-making in a timely manner, and lastly, creating more profitable relationships with customers and suppliers. Cognitive computing is going to cause a big shift in enterprise and consumer applications; in other words, every application will have analytics woven into it. So, instead of just laying out the processes without taking into account any context, in the future these applications will start integrating intelligence from third-party data. For example, when you are using an application to process someone's mortgage, with the cognitive platform you can go beyond looking at the information provided to you on the form and very easily look at the applicant's social profile, the kinds of activities that they are involved in or the likelihood of flooding in the area of the house being underwritten for mortgage, or even claims on properties getting vandalised from police reports. Such third-party data facilitates smarter business processes because the analytics-woven applications are able to understand unstructured data, as well as text and images altogether.

This point can be illustrated by an example of Cognitive Scale application in a children's hospital. In large cities, care providers are looking after tens of thousands of kids for diseases like paediatric asthma and the key aim is to prevent the condition from getting worse for those afflicted with it. Currently, this is done by going through different touch points: from personal records to lab reports and then following up with parents and the kids to get them treated. All these, however, only take physical data into account, without considering lifestyle, socio-economic factors, weather data and so on. Cognitive Scale can overcome this problem by connecting the process to third-party data like US census, weather.com, pollen.com, Google Maps, and ZocDoc – which shows which doctors are available and how highly they are rated. So for instance, when pollen.com predicts a ragweed outbreak in a particular zip code, the cognitive application can quickly identify the number of children in that area who have an allergy to ragweed. Then based on the US census map, the application can start dividing the people into those who have socio-economic issues and where access to transportation is a problem. Finally, it can suggest a few solutions, such as getting the children to a nearer clinic, shipping them an inhaler or calling the nurses at their school to keep the kids inside, away from the ragweed outbreak. This example demonstrated how intelligence from third-party data can be woven into a business process, which traditionally was not possible, to guide a knowledge worker in making better decisions and to improve relationships with their patients. Cognitive systems are going to transform every business process that we know and create myriad opportunities.

Can we expect one ultimate dominant cognitive system or is the market still fairly open? What are the barriers to entry for cognitive computing?

It is still too early to tell as we are probably in the third year of a seven-to-ten year cycle of growth and maturity. If we refer to the lessons we learnt from the early days of the previous two tech platforms, we can expect dozens of new companies to come about and change the industry in the following four dimensions: At first, there will be many point-to-solution vendors who provide just deep learning algorithms; many of these are going to struggle and some of them will fall by the wayside. Then we will see the emergence of large companies bringing out platforms to start creating cognitive applications. Subsequently, specialized vendors will start providing platforms and applications that are optimized to specific industries, giving inch-wide and mile-deep solutions to really address hard-core business problems. And finally, system integrators will start providing consulting and deployment services around cognitive clouds and cognitive solutions.

Cognitive Scale is a very interesting case in this context, because large platforms often fail to provide highly focused and pinpointed solutions that deliver quick value. This is perhaps due to three problems with the cognitive systems – it is expensive to put everything together as a technology stack, once they put it together they need to deal with the fact that the technology is still changing, and last, but not least, there is insufficient skilled labour to build a solution on top of it. As a result, we will see the emergence of many smaller competitors who will address narrow and core problems. As these new competitors create their own niches, they will expand fairly quickly if the big companies don't respond. The industry saw this when Documentum created a document-centred database and when Logic created a platform for internet application. Overall, I think this space is just getting going and it's not anywhere near overcrowded.

Of course, we should keep in mind the major constraints in adoption of cognitive systems. Beside the availability of platforms that can create rapid applications, the availability of data to feed into these systems also plays an important role. This role includes third-party and fourth-party data. Then there is also a barrier from the lack of skilled labour to build out these applications and the need for a new governance model to embrace this technology. Last but not least, the markets have to learn and understand the myriad possibilities that this technology can bring. These things are creating obstacles to adoption, but are currently being tackled by various players.

Who do you think will benefit from this technology and who will be the losers?

Cognitive computing is definitely going to create a massive shift in productivity, efficiency and innovation. Productivity wise, hundreds of these systems are going to raise the proficiency of every worker in different businesses to the level of the best knowledge worker in his or her field, and beyond. In essence, they allow democratization of best practices, thus enhancing the efficiency and capability of each worker. Furthermore, this should also foster the emergence of new innovative business models. Just understanding the outcome of the reward-sharing models could lead to the creation of new, different and customized customer offers, for instance. Take the mortgage example from earlier; a traditional procedure to process a mortgage would be more labor-based and involve document translation, application checking and filling and so on. If cognitive intelligence is woven in, not only would the application process mortgages, but it would also help the customer reduce liquidity requirements, thanks to a better understanding of risk.

In that context, providers of old technology will lose out if they are unable to come up with new innovative solutions fast enough. Without intelligence woven into their solutions, these last-generation technologies are at massive risk of getting disintermediated by a new class of vendors like Cognitive Scale or Spark Cognition, just like the shift to cloud has disrupted revenue streams and pricing models for many giant tech companies, thus reshaping the entire landscape. In general, cognitive computing can be disruptive, not just for software vendors but for software infrastructure vendors as well. In addition, companies that are slow to adopt cognitive computing will lose their competitive advantage because their competitors can improve the experience of their end users, make better decisions and improve profitable relationships.

And if cognitive computing can help knowledge workers make better decisions, when do you think they will replace workers altogether?

I think that we are still very far away from that, at least 20 or 30 years. The concerns about job losses have been somewhat overdone, as has been the case with every shift in technology. Consider the forecasts versus reality when the telegraph came out, then the telephone and the internet. What is more important is how cognitive computing will augment human cognition and decision-making, rather than replacing human beings. In other words, it will be more about man and machine, not man versus machine. In the end, what is probably not known is the scale of disruption and the opportunities brought along with cognitive computing. We are entering an era that mirrors the advent of the internet in the mid-to-late 1990s, when people moved from client server-based systems, and the markets grew exponentially with companies worth billions being created, and new vendors and new leaders emerging. The same thing is going to happen here, and it is occurring even faster than I had anticipated. My advice would be to keep an eye on the smaller players, because they are more agile and innovative, and they are learning at the cost of big players, which are still opening up the school bus.

AI – is this time different?

Our software analyst Greg Dunham stresses that Big Data technologies can bring in a new set of Artificial Intelligence Applications

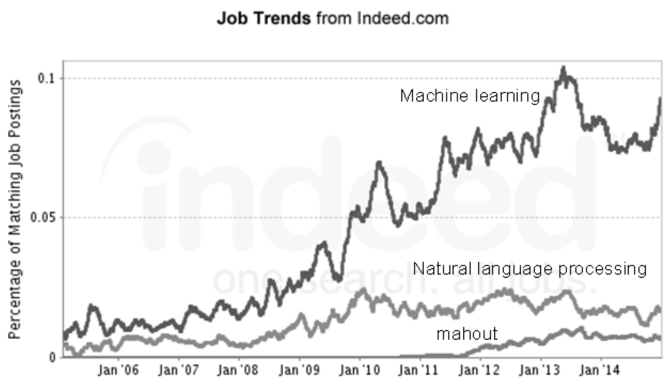
While the emergence of Artificial Intelligence (i.e., thinking machines) dates back decades, new cloud models in conjunction with the advancements in processing and big data technologies have enabled use cases to expand. Tech industry heavyweights such as Google (Google Now), Microsoft (Cortana), and Apple (Siri) are all investing aggressively in the areas of Machine Learning and Natural Language Processing to bring to life "intelligent virtual assistants" which leverage the broadening set of data (voice, location, web, etc.) with personal history to understand how to serve the consumer best.

Awareness has also grown as speech recognition, from companies like Nuance, is increasingly embedded in consumer electronics (i.e., smartTVs) and cars, and consumers have now seen how a computer (i.e., IBM's Watson) can win the TV gameshow Jeopardy!

Perhaps more interesting is the emergence of hundreds of start-ups which are leveraging new open source technologies (i.e., Hadoop, Mahout, Spark), often with cloud models, to create a broad array of recommendation engines, enable programmatic bidding within advertising, reduce fraud, optimize a manufacturing process, and even help detect prostate cancer.

Start-ups like Scaled Inference and Sentient have raised tens of millions of dollars in VC funding to better bring to market solutions which deliver real business value, something which has historically been elusive in AI business models.

Percentage of Indeed job postings by keyword since 2005



Source: Indeed.com.

Artificial Intelligence (AI): Generally refers to software that can interact with humans in a way that makes it appear as if the software has a human-like ability to reason. Two major components of Artificial Intelligence are Natural Language Processing and Machine Learning.

Natural Language Processing (NLP): Analysis of interactions between human language (natural language) and computers or other machines. The goal of natural language processing is to allow computers to fully understand normal spoken and written language, without the need to adjust that language to fit computer or software language rules.

Machine Learning: Generally refers to algorithms that run on large data sets and create a model of inputs that can then be used to predict or suggest outcomes given a set of variables. These models are dynamic, and change as new data enters the data set, as opposed to traditional static programming instructions.

Optical Character Recognition: Generally refers to software that analyzes printed documents or scanned images of documents, and generates machine-encoded text from the source material. This technology simulates the human ability to read and internalize printed text.

Semantic Network/Semantic Net: A virtual structure that links concepts with related concepts, and words with related words. Semantic nets are often used in natural language processing in order to allow algorithms to determine context for queries and improve responses.

Hadoop: An open source framework that uses low-cost commodity hardware to process and store large data sets. Core Hadoop consists of several open source components including Hadoop Distributed File System (HDFS), YARN, and MapReduce.

Mahout: Open source, machine learning library of algorithms designed to run on very large, scalable, distributed systems, especially Hadoop.

Watson: Computer system developed by IBM that uses machine learning and natural language processing to generate answers to common-language queries. Famously, Watson competed on the TV gameshow Jeopardy! against previous champions and consistently outperformed its human opponents.

Virtual assistants: Software programs that use natural language processing, and machine learning to simulate an actual person when interacting with humans. Typical applications include automated customer service, and voice-activated modules such as Apple's Siri. Also referred to as automated assistants, automated online assistants, or digital personal assistants.

Spark: Open source framework designed to perform high-speed, repetitive queries on data stored in-memory. Highly scalable technology, as it is leverages cluster computing. Spark can function with several other open source frameworks, including Hadoop (HDFS), Cassandra, and others.

Private companies, and public investments in artificial intelligence

Investments by tech companies	
Google acquires DNNresearch and DeepMind	
Yahoo! Acquires IQ Engines, LookFlow, and SkyPhrase	
Pinterest acquires Visual Graph	
Dropbox acquires Anchovi Labs	
Facebook acquires Wit.ai	
Digital Personal Assitants from Google (Now), Apple (Siri), and Microsoft	
Private companies	
Sentient Technologies	Vicarious
Scaled Inference	Narrative Science
Expect Labs	Kensho
MetaMind	Nara Logics
Tempo AI	

Source: gigaom, geekwire, Goldman Sachs Global Investment Research

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The age of "robo" advisors

Alex Blostein, our US Capital Markets & Exchanges analyst, discusses the potential and challenges for automated investing

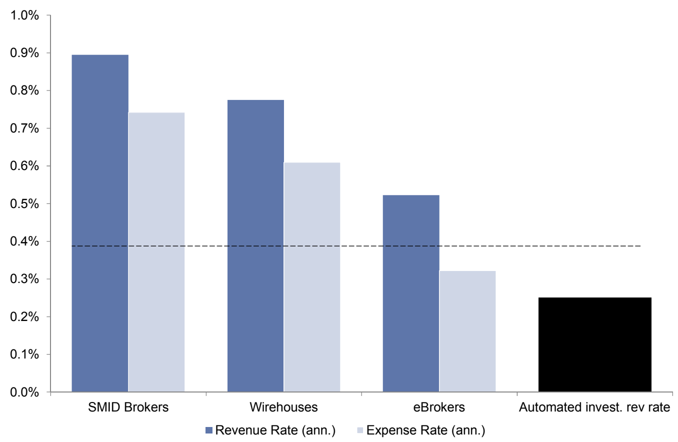
Automated Investing Solutions – a fad or a real game changer in wealth management?

Over the last two decades, innovation in Financial Services led to a wide range of benefits, including greater transparency, lower cost and improved speed of transacting business. For retail investors, the frontier has largely focused on two elements – lowering cost and enabling self-directed investing, with the use of technology. The origins of this trend date back to the mid-1990s, when electronic brokers such as E*Trade, Ameritrade, Charles Schwab, and Fidelity made trading more convenient and less costly by displacing voice brokers and moving the process online. Coupled with evolution of the asset management product and growth of passive investing (index funds and ETFs now comprise over 30% of equity assets in the US), end-user fees continue to decline and switching costs become lower.

The next area where we might see innovative disruption appears to be in automated investing ("robo" advisors) – a form of algorithmic, software-driven financial advice that cuts human advisors out of the equation. By improving the scalability of advice with technology, and thereby significantly reducing the cost to end clients, automated investing can engage a whole new segment of the population that traditional managers have never touched: largely younger, small account-holders.

While we think that in the near term, the potential disruption will be limited as automated advisors gather assets mainly from clients that are "too small" for a traditional model, longer term, automated investing has the potential to gain share as the transfer of wealth from baby boomers to the next generation puts tech-minded Millennials in the driver's seat. That said, the "robo" advisor solution is not without its challenges, as these models are yet to be tested by a market downturn, barriers to entry are low, scale of larger competitors could keep profitability for new participants under pressure, and the missing "human" element could be too difficult to overcome as someone's wealth grows.

Fee rates of different types of brokers



Note: "Wirehouses" include: BAC, MS, UBS, WFC; "SMID Brokers" include RJF, SF, LPLA, AMP, "eBrokers" include: ETFC, SCHW, AMTD
Source: Goldman Sachs Global Investment Research.

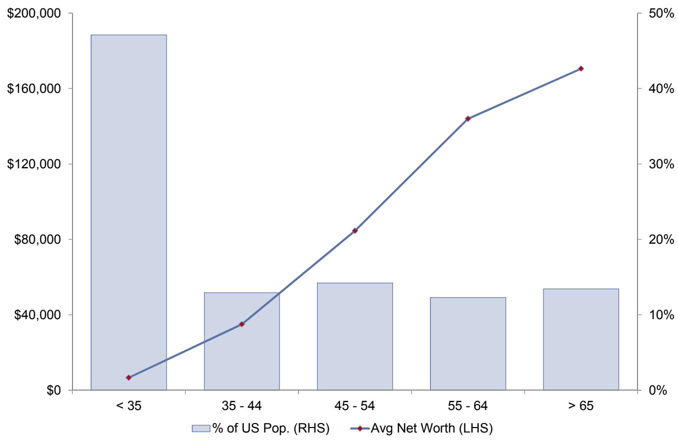
What is automated investing?

Automated investing (dubbed by the press as "robo advisors") offers a low-cost, 100% web-based portfolio allocation solution to the client by using software to make investment and rebalancing decisions. The platform creates a portfolio based on a client's age, risk preference, and income that consists entirely of low-cost ETFs across asset classes (US Stocks, Foreign Stocks, Emerging Market, etc.). The portfolio is automatically rebalanced using algos, keeping behavioral bias aside. These platforms also provide other services such as tax loss harvesting and single stock diversification.

Since their launch in 2010-11, automated investing firms have garnered over $15 bn in AuM in the US – still a rounding error compared to the $12 tn of total assets under management. Some of the larger players in the space include Betterment and Wealthfront, but Schwab has also recently announced the launch of automated advisory solutions (Intelligent Portfolios). The former charge about 25 bp on a client's AUM as an all-in fee, while Schwab is providing the service for free.

The average account size at these firms is notably smaller than traditional wealth managers, averaging ~$90K. Moreover, clients are significantly skewed toward younger generations, with 90% of account holders being under 50, and 50% under 35.

US household demographic



Source: US Bureau of Labor; 2010 Census; Goldman Sachs Global Investment Research.

Merits of the offering:

- **Advice at a lower cost:** Technologically enabled low cost to end-user is a clear advantage of the automated investing offering. Without the traditional wealth managers' brick and mortar offices, the all-in fee of just 25 bp (and free at Schwab) is on average 50 bp lower than the fee rate that incumbents charge. More importantly, the 25 bp fee rate is also 30 bp lower than the cost basis (expenses/client assets) at incumbent firms.
- **The Millennial factor:** Millennials (born between the 1980s and 2000s) are the primary client targets of the "robo advisory" industry. This group tends to be more conservative and more focused on achieving personal finance goals vs. beating the market. Moreover, a Cerulli survey suggests that a greater proportion of Millennials value online advice (27% vs. 12%) and goal planning (20% vs. 10%) than older generations. At an estimated 80 mn (or ~25% of the US population), the group is bound to eventually control a meaningful portion of wealth. While currently, nearly 70% of the total net worth in the US is held by the baby boomers (age 55 or older, 25% of the US population), according to Accenture over $30 tn in wealth is

expected to be transferred from the Boomers to younger generations. Thus, if automated investment advisors are successful in retaining their younger clientele today, there could be a meaningful threat to the traditional model 20-30 years from now.

- **A sweet spot of engaging the "under the radar" assets:** Today, only 30% of those under 30 in the US receive regular financial advice. However, about 2/3 of that population said they need more financial advice and 81% said they want to be more involved in the daily management of their portfolios, per Cerulli. This segment represents an attractive opportunity for automated investment firms to go after given its low-cost approach, as this group is unprofitable for most traditional models where costs are higher.

Potential challenges:

- **Low barriers to entry:** We think the barriers to entry in the automated advice space are low. To that extent, we have already seen similar solutions being developed in-house, such as Charles Schwab's Intelligent Portfolios (provided free of charge). While there are nuanced differences between each offering, the core of the product is fairly similar – automatic rebalancing, tax efficacies, etc. and is already being offered by others. Moreover, a Cerulli survey shows that beyond the 30% of traditional wealth advisors who have already announced plans to launch an automated investment management tool, about 64% have indicated interest in developing such tools.
- **Limited track record:** Because automated investment firms were established in 2010-11, and we have not experienced a full economic cycle since then, there is no historical record on how the algorithms used by automated investment firms will react under drastic market conditions. Thus, it may be difficult for automated investment firms to convince potential clients that the returns on their portfolios can hold up in a down market.
- **The "trust" factor:** Despite the cost benefits of using technology, the generations that carry the most wealth (i.e. baby boomers) today tend to prefer human advisors over software and algorithms. Thus, the ability for automated wealth advisors to gain share from traditional wealth mangers and tech-assisted advisors might be constrained in the near term. Moreover, traditional wealth advisors often offer a more holistic spectrum of services throughout the client's life cycle (Trust and Estate planning, financial planning around specific liquidity needs and life events, etc.), that algorithms may not be able to perform.

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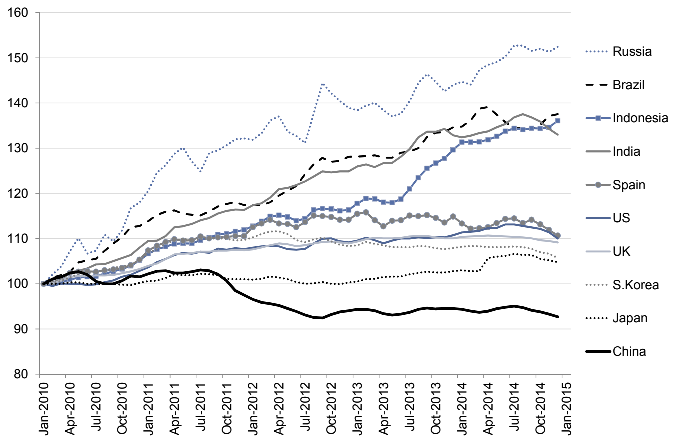
Six of the best – our favourite charts

In our six of the best section, we pull together a pot pourri of charts that we hope you will find interesting. They will be different in each edition but hopefully always of note.

Summer 2014 things started getting cheaper

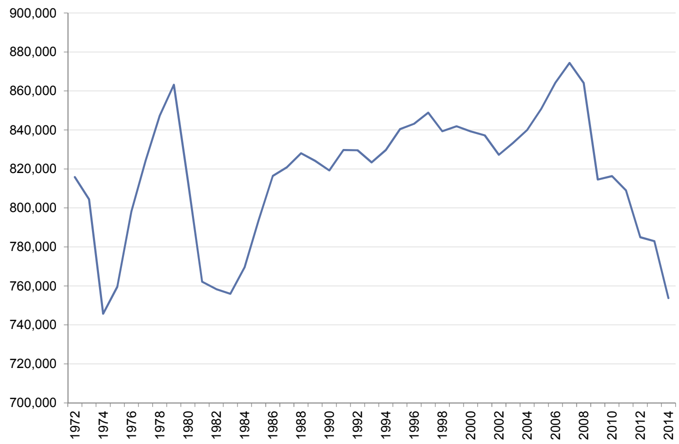
Producer Price Index for selected countries, Jan 2010 = 100



Source: Datastream

Energy demand, blowing away

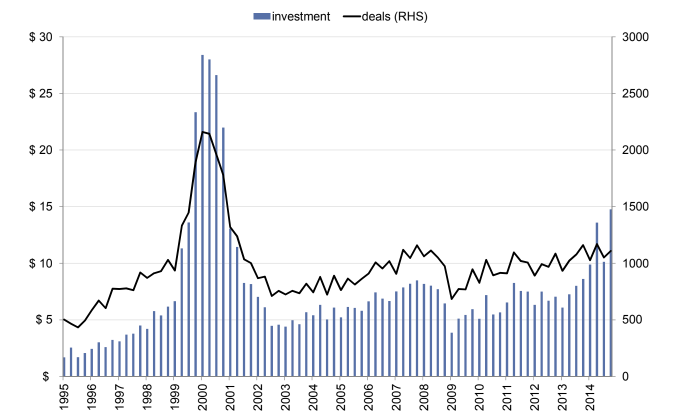
Danish gross energy consumption, 1972-2014 (TJ fuel equivalent)



Source: Danish Energy Agency

Decade highs, not all-time highs

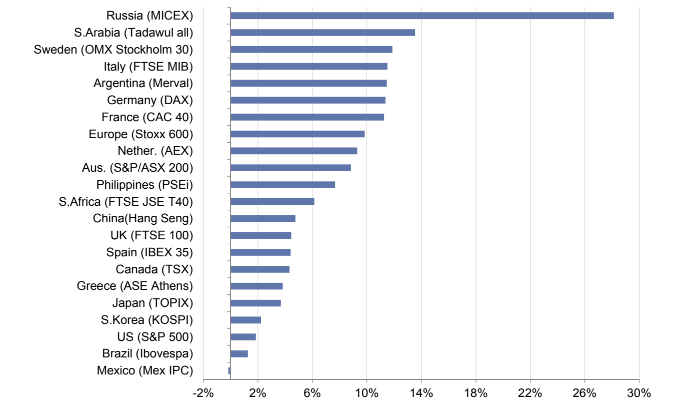
Aggregate funding to US start-ups ($ billions) and number of deals



Source: PricewaterhouseCoopers LLP/National Venture Capital Association MoneyTree Report; data by Thomson Reuters

Russian twists

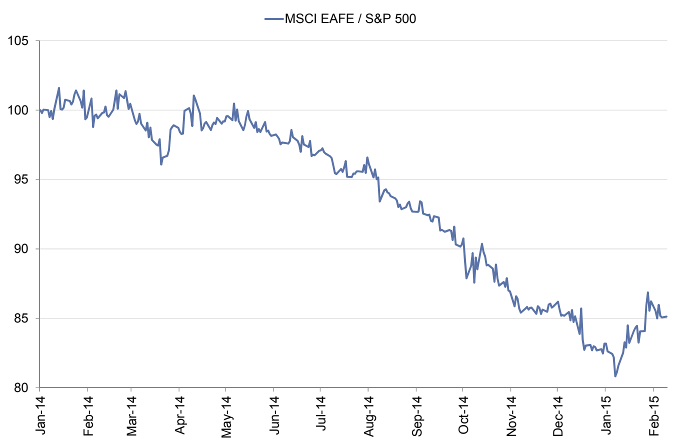
YTD performance in USD, as of February 16, 2015



Source: Bloomberg

Murmurings in Europe

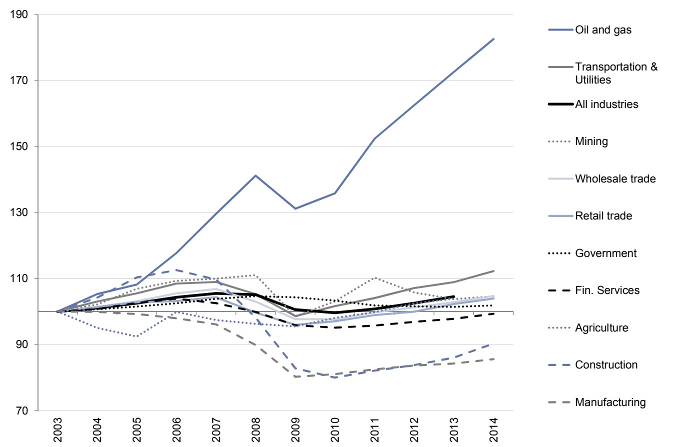
MSCI EAFE index relative to S&P 500, Jan 2014 = 100



Source: Datastream (EAFE - 'Europe, Australasia, Far East')

Spot the odd one out

Employees in the US by industry, 2003 indexed to 100



Source: BLS, BEA

Disclosure Appendix

Reg AC

We, Hugo Scott-Gall, Sumana Manohar, Alex Blostein, Greg Dunham, Yuichiro Isayama and Takafumi Hara, hereby certify that all of the views expressed in this report accurately reflect our personal views about the subject company or companies and its or their securities. We also certify that no part of our compensation was, is, or will be, directly or indirectly, related to the specific recommendations or views expressed in this report.

Unless otherwise stated, the individuals listed on the cover page of this report are analysts in Goldman Sachs' Global Investment Research division.

Investment Profile

The Goldman Sachs Investment Profile provides investment context for a security by comparing key attributes of that security to its peer group and market. The four key attributes depicted are: growth, returns, multiple and volatility. Growth, returns and multiple are indexed based on composites of several methodologies to determine the stocks percentile ranking within the region's coverage universe.

The precise calculation of each metric may vary depending on the fiscal year, industry and region but the standard approach is as follows:

Growth is a composite of next year's estimate over current year's estimate, e.g. EPS, EBITDA, Revenue. **Return** is a year one prospective aggregate of various return on capital measures, e.g. CROCI, ROACE, and ROE. **Multiple** is a composite of one-year forward valuation ratios, e.g. P/E, dividend yield, EV/FCF, EV/EBITDA, EV/DACF, Price/Book. **Volatility** is measured as trailing twelve-month volatility adjusted for dividends.

Quantum

Quantum is Goldman Sachs' proprietary database providing access to detailed financial statement histories, forecasts and ratios. It can be used for in-depth analysis of a single company, or to make comparisons between companies in different sectors and markets.

GS SUSTAIN

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Disclosure Appendix

Coverage group(s) of stocks by primary analyst(s)

There are no coverage groups associated with the analyst(s).

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Goldman Sachs Investment Research global coverage universe

	Rating distribution			Investment Banking Relationships		
	Buy	Hold	Sell	Buy	Hold	Sell
Global	33%	54%	13%	44%	38%	32%

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Price target and rating history chart(s)

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