LEADING EDGE FORUM

Position Paper

There is Now a Formula for Machine Intelligence Innovation

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"What a piece of work is a man! How noble in reason, how infinite in faculty! In form and moving how express and admirable! In action how like an angel! In apprehension how like a god! The beauty of the world …" – Hamlet II. ii

As Shakespeare understood more than four centuries ago, much of human identity, thought and culture has been rooted in the idea that we are unique. Although novelists, film-makers and technologists have often imagined advanced inter-galactic civilizations and super-capable futuristic machines, such thinking has always been the realm of science fiction.

But the belief in our uniqueness is now becoming its own fiction. While Human Intelligence (HI) is wondrous and remains deeply mysterious, it is not magic. Similar capabilities exist all around us, and many skills once seen as exclusively human can now be done better by machines that are infinitely replicable. There is also mounting evidence that life on other planets is even more likely than the sheer size of the universe always suggested.

These realizations are expanding our understanding of intelligence. While this paper will focus on Machine Intelligence (MI), society's understanding of Animal Intelligence (for which we use the abbreviation AI) is also improving rapidly. Of course, we have always known that animals often see, smell, hear and navigate far better than we do, but we now know that they also have complex memories, emotions, identities, languages, problem-solving skills and social relationships. Jennifer Ackerman's recent book, *The Genius of Birds*, makes these points about birds, but similar evidence has been amassed for wolves, whales, dolphins, octopuses, apes, elephants and many other species, especially by Frans de Waal.

From an MI perspective, animal capabilities are also *not magic*, and science is beginning to figure out how these talents might someday be *engineered*, greatly expanding our sense of the extraordinary skills that robots and other machines could eventually have. Imagine a machine with the night vision of an owl, or the scent-tracking of a hound. Looking ahead, we will increasingly need to think about intelligence in an integrated HI, AI and MI context.

(Terminology note: we prefer the term 'machine intelligence' to 'artificial intelligence' because there is nothing artificial about it. For example, we don't refer to industrial machines as 'artificial strength'. Using AI to mean 'animal intelligence' provides an additional useful twist.)

But why all the fuss about machine intelligence right now?

Sceptics might concede that all of the above is theoretically true, but they would also point out that there have been many previous predictions – going at least as far back as the 1960s – of an imminent machine intelligence era, which look silly in retrospect. And since there are still significant MI obstacles that must be overcome in basic areas such as Natural Language Processing, it is fair to ask why we think that this time will be different. Based on our research, we believe that, although the tipping point has not yet been reached, the code for MI innovation has been cracked. It has three main components:

1) **Big Data.** It has now been convincingly demonstrated that large unstructured data sets can be used to develop powerful machine intelligence capabilities, without specific subject matter expertise, or even human intervention. Many of the most important MI initiatives today – such as language translation and image, facial, activity and emotion recognition – are based on *predictive analytics* that get more accurate as the data behind them gets richer, and the internet is making larger and more relevant data sets more available than ever before. In these MI applications, human subject matter experts such as professional translators and psychologists are not only not necessary, they often get in the way of purely algorithmic approaches.

   An influential example of this has been the image recognition project, ImageNet, which has created a database of some 14 million labelled images that can now be used to train machines to recognize just about any *thing*. In 2015, Microsoft demonstrated how *deep learning* (see below) could be used to enable computers to recognize these images as well

as or better than humans. Similarly, Facebook enjoys a huge head start in facial recognition because it can already match our names and faces, just as Google has important advantages in machine translation because it has aggregated the best set of multilingual documents.

Looking ahead, new and established MI companies will use millions of internet images, videos and podcasts of people smiling, laughing, frowning, talking, arguing, holding hands, walking, playing football and so on as the basis for unprecedented Emotion and Activity Recognition capabilities. MI is now clearly among the most important Big Data applications.

2) **Software and hardware advances.** For decades, machine intelligence researchers have predicted that neural networks and parallel processing would be important MI development tools because they more closely resemble the way the human brain works and because they enable machines to *learn*. However, until the last few years, progress in both areas was slower than in many computer science fields. Happily, this is now changing, with the emergence of new software and hardware architectures that are particularly good in MI applications.

While deep learning is one of today's hottest IT buzzwords, its meaning is often poorly understood. Deep learning is basically the latest generation of neural network design. It is called *deep* because there are more *layers* of processing than in the past. Although this is a highly technical and mathematical field, the basic idea is that the use of additional layers of abstraction enables tasks to be broken down more finely, and this enables a greater capacity for detailed analysis and *self-improvement*. This multi-layer approach was used in the recent triumph of Google's AlphaGo program over Lee Sedol, one of the world's best Go players.

Both neural networks and deep learning are computation-intensive, and real MI applications can overwhelm traditional systems. Fortunately, new hardware designs have emerged at both the individual system and cloud level. Many MI developers now use hardware that includes Nvidia's GPUs (Graphical Processing Units) which can greatly accelerate neural processing speeds. And when even more computational capacity is required, the almost unlimited cloud resources of Amazon, Microsoft, Google and others are available at affordable prices. Taken together, deep learning software and parallel processing hardware now provide a powerful MI platform.

3) **Cloud business models.** The ability to leverage Big Data and the availability of much more capable hardware and software mark major steps forward in the MI journey. But as important as these computer science advances are, the emergence of powerful MI business models is arguably the single biggest reason that the MI field is so energized today.

We are essentially seeing the merger of machine intelligence with *cloud economics*. This merger will prove fundamental to the innovations of the future, but it is still not sufficiently recognized. Before the cloud, most AI work was isolated and relatively high cost. However, as shown in the figure below, MI advances can now take advantage of the full panoply of cloud capability – including 24x7 availability, rapid global deployment, variable costs, continuous improvement, real-time data, effectively zero marginal cost, easy integration with supporting web services, venture capital funding, and winner-take-all market tendencies.

Figure 1 – The cloud and MI are merging

This means that MI capabilities such as recognizing faces or translating languages will soon be no different from everyday web services such as using Shazam to identify a song or Googling a search term (both of which are actually highly complex MI activities). As MI enthusiasts have long observed, once an advanced new application becomes ubiquitous, people no longer see it as MI – it becomes just another cool service. Consider the way speech translation capabilities are now being bundled into Skype.

Looking ahead, virtually every capability listed in Figure 1 (and many more) has the potential to be used by billions of people and thus may well be worth billions of dollars. It is this realization that is triggering both the explosion of highly specialized MI start-ups as well as the major MI pushes at Google, Facebook, Microsoft, Apple, IBM and their various global rivals. Arguably for the first time, MI is seen as a potentially huge business opportunity. Microsoft paid $250 million for the tiny UK keystroke anticipation firm SwiftKey because every little piece of the MI/cloud can be extremely valuable; and there are hundreds, perhaps thousands, of such pieces.

Taken together, these three developments – ever-richer data sets/algorithms, improved MI computing platforms, and powerful cloud-based economics – have triggered a new Silicon Valley gold rush. While the timing is still uncertain, the formula for rapid innovation and deployment is now in place. Providing clients with a first-hand sense of these developments is the goal of this year's LEF Machine Intelligence Study Tour (26-30 September 2016).

A brief history of market code-cracking

No one can say for sure how quickly MI will progress, but if history is any guide, once the formula for success is in place, market advances tend to be rapid. Consider these growth markets of the past, each of which had its own three-part formula:

- The personal computer market took off when there was a combination of 16-bit microprocessors, inexpensive hard disk drives, and highly useful word processing, spreadsheet and graphics applications

- The internet took off thanks to its ability to provide universal email, link pages across diverse systems, and support a user-friendly graphical browser interface (Mosaic)

- Smart phones took off thanks to the shift to touch-screen displays, the emergence of app stores, and strong telco support to provide the required 2G/3G bandwidth

Will we some day add MI to this list, with its big three – Big Data availability, Deep Learning architectures, and cloud-based business models? Or will the growth of MI be more like today's much slower *internet of things* roll-out? Our guess is that it will be somewhere in between. But it isn't hard to imagine MI eventually pushing PCs, the web and smart phones into the background, as ubiquitous MI and clever software agents become our dominant user interfaces. Clients should increasingly think in terms of the following equation:

Big Data Availability + Deep Learning Architectures + Cloud Economics = MI Innovation

From top-down to bottom-up MI

This formula for innovation is exciting news in Silicon Valley and other technology capitals, but what does it mean to the typical large firm? We think it mostly means an important expansion in perspective, adding a *bottom-up and outside-in* approach to traditional *top-down and inside-out* machine intelligence activities.

As shown in Figure 2 overleaf, from an enterprise perspective, MI has traditionally been primarily a top-down process, focusing on sophisticated *expert systems* that meet the needs of particular industries or firms. Such systems now perform mission-critical services in just about every industry sector, in areas as diverse as stock trading, reservation pricing, tracking pharmaceutical side effects and air traffic control. Important work continues in all of these areas and more, as exemplified by the use of IBM's Watson in healthcare and other industries.

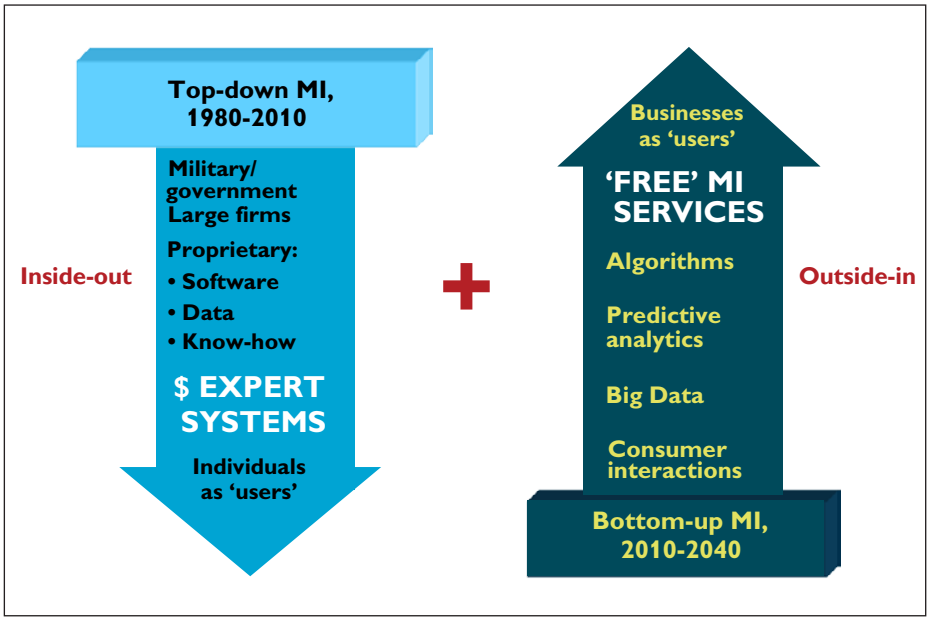

Figure 2 – Top-down and bottom-up MI

While most expert systems are application-specific and highly proprietary in nature, many of today's most important MI efforts are aimed at the broadly applicable functional capabilities shown in Figure 1; these are services that virtually any firm and individual might use, often available free of charge. Increasingly, they stem from consumer-driven companies such as Google, Facebook et al, which is why MI is becoming much more bottom-up and *consumerized*.

Leveraging these advances requires an outside-in mindset because firms must embrace innovations outside of their traditional industry space. As MI innovation migrates to the cloud, the pace of external digital innovation will continue to outstrip what firms can do for themselves. Importantly, the next generation of expert systems will likely require a mix of specific internal know-how and general-purpose, cloud-based MI services. Self-driving cars, robo-investing, digital healthcare and advanced robotics are all likely to follow this hybrid path, as cloud and proprietary MI systems start to combine in novel and useful ways.

How far will MI go?

Like many debates, public discussions about the impact of MI tend be overly bi-polar. There are many naysayers who argue that computers will never be intelligent because all they do is follow human instructions. Others see MI as one of the greatest threats to humanity, a destroyer of jobs, preparing to become our master, not our servant.

Neither of these extremes reflect the situation today. The sceptics' case looks weaker every day, while the doomsayers are, at this stage, mostly being speculative. But at least the doomsayers understand the extraordinary technology capabilities that lie ahead, and in the long term many of their concerns may well emerge. It is certainly possible that computers will not just enhance human capabilities but vastly exceed them, and if this happens many people may, rightly or wrongly, turn against technology in the same way many are now turning against global trade. At some point, the social contract may well have to be revisited.

But today, we are in an unsettled middle ground, where both sides can still make their arguments. There are serious doubts about how reliable many MI systems – such as driverless cars – will be in the real world, just as there are valid concerns regarding the future impact of many MI systems in an economic environment where jobs are already scarce, wages often stagnant, and inequality generally on the rise. This situation is summarized in Figure 3 overleaf.

High risk	Medium risk	Low risk
• Flying	• Diagnosing	• Navigating
• Driving	• Investing	• Learning
• Surgery	• Essay grading	• Reporting
• Policing	• Forecasting	• Matchmaking
• Spying	• Accounting	• Entertaining
• Killing	• Complying	• Caring/supporting
• Inventing	• Lawyering	• Companionship

Figure 3 – What will you trust machine automation for?

These three groupings suggest that society will be more willing to experiment with MI in low-risk areas such as those on the right, but perhaps less so in areas to the left. For example, will parents and students accept the idea of school essays being graded by machine? Right now, most do not, just as we don't accept having pilotless airplanes. On the other hand, if a computer can effectively write about (say) a sporting event just by analyzing the detailed data of the game, who – other than sports reporters – would seriously object? Looking ahead, levels of societal acceptance, confidence and comfort will likely vary widely, both within each column in the figure, and especially among countries.

Overall, the 21 items listed above provide an applications framework for tracking the real world progress and impact of MI, and we would be the first to say that there are a great many unknowns. We are particularly interested in MI's effect on the professions – doctors, lawyers, professors, accountants, architects – as well as the new forms of insurance/assurance that will be required. These will both be important areas of future LEF research. However, in the long run we expect MI to drive profound changes in virtually all of the above areas.

What to do?

While the overall formula for MI has been cracked, the market is not yet at its tipping point, and many of the changes above may not be dramatic in the near term. Given this, how should clients prepare for MI? We would start with the following agenda:

1. Visibly embrace the idea that Machine Intelligence will matter to your organization
2. Identify which forms of MI could be most important to your firm
3. Take an *outside-in* view of relevant start-ups and other global MI developments
4. Understand which parts of your firm could be safely run by algorithms
5. Determine which internal and external data sets have the most MI potential
6. Assess the extent to which your firm's key *professional expertise* can be automated
7. *Experience* Deep Learning, Neural Computing and other MI technologies
8. *Map* the relevant MI services and technologies to your firm's value chain
9. Develop and empower a strong set of MI leaders within your firm
10. Factor likely MI advances into your firm's overall strategic planning process

Conclusion

As we noted at the outset, our sense of what it means to be intelligent is expanding. Just as there are multiple forms of human intelligence, so will there be at least as many forms of machine – and animal – capability. Science is in the process of unlocking the secrets of all three domains in what will be one of the greatest technical and cultural accomplishments of this or any era. We know that MI can augment, extend and improve human capabilities, but we can now easily imagine that it will also automate, obsolete, greatly exceed or even merge with them. Either way, intelligence will be all around us. It is not just for humans.

We are now in the early stages of this journey, during which market competition will force companies to leverage emerging MI capabilities as best they can, lest some other firm gains an edge. For the next few years, these dynamics will surely help us deliver better products and all kinds of cool new services, and that's what businesses need to do now. If the negative MI possibilities eventually start to assert themselves, we will have to deal with them then. Right now, it is full speed ahead.

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