Editorial

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Artificial intelligence and smart cities

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In their book *The Race Against the Machine*, Brynjolfsson and McAfee (2011) raise the prospect that contemporary society will no longer be able to maintain anything like full employment due to ever-increasing automation from rapid advances in artificial intelligence (AI) and machine learning. Certainly since the beginning of the industrial revolution, automation has not led to widespread unemployment despite a succession of predictions to the contrary but this time, it may be different. How many times has this been said, yet the picture that Brynjolfsson and McAfee paint is rather convincing in that they suggest that our abilities to devise the appropriate organizational structures – business models if you like – are woefully inadequate when it comes to innovating strategies to deal with rapid automation. One has only to examine the terrible user interfaces that are continually foisted upon us to enable us to interact with new digital technologies to realize that developing ways of interacting with new technologies constitutes a major challenge. Arguably the decline in productivity that now seems to plague western developed countries might be due to the ever-increasing amount of time we are spending interacting with machines that are supposed to increase our productivity. Apparently American teenagers and young adults look at their smart phones an average of 75 times a day (Eadicicco, 2015). What this is doing for our productivity and our wider learning abilities is anybody's guess. In fact, Brynjolfsson and McAfee's argument is that rather than a race 'against' the machine, we need to develop appropriate responses to a race 'with' the machine, and the challenge that they identify is not that we are incapable of this but that the rate of change in AI is such that we have very little time left to develop the right responses.

Lest this appear to be scaremongering, I will repeat a famous example of exponential growth that was used by Kurzweil (2005), amongst others to argue that we will soon be overcome by such growth. The example is also repeated in Brynjolfsson and McAfee's book. Starting with Moore's Law, for the last 50 years, the average speed of computation has been doubling every 18 months with costs of production halving on the same cycle. This shows little sign of slowing down, despite physical limits which are now being bypassed by better design. To see the rate of change, one only needs to examine the annual improvements in smart phones over the last five years, in terms of memory, speed of access, user interface design, availability of Apps and so on. Improvements are being made all the time, largely dependent on the increases in speed and decreases in cost that come from advances in raw computation. Using Kurzweil's example, this kind of growth can be pictured in the following way. He tells the story of the sage who invented the game of chess and then introduced the game to his King. The ruler was so fascinated by the invention that he told the inventor to name his reward. The inventor asked the King to place a grain of rice on the first square of the chessboard and then double this on the next, doubling it again on the third square and so on until the chessboard was covered in rice. This pile of rice would be his reward. The King readily consented to this as he considered it to be a small reward for his subject, and called his granary for the delivery of the rice. He placed 1 grain on the first square, 2 on the second, 4 on the third, 8 on the fourth and so on. It is easy to see what happens. By the time, he had reached the 64th square, the pile on that square had reached nearly a quadrillion (a thousand trillion) grains, more than the size of Mount Everest, according to Kurweil.

You get the message. This is the same old problem of period doubling which dominates every exponential. But it is not the ultimate number of grains of rice that is the punch line. When you cover half the chess board, there are about 2 billion grains of rice and although this is a big number, it is not that big, in terms of the current definitions of big data in our digital age. What Brynjolfsson and McAfee argue is that in terms of Moore's Law and the current increases in raw computational speeds and memory, we are just about to enter the second half of the chessboard. In short, it is from now on that very disruptive exponential growth will really begin: that we will begin to see very dramatic changes in computational power, and the real race against the machine will kick in. This is why we need new organizational structures to cope with these changes, to begin to tame AI and to establish the right kinds of regulatory structure, to invoke serious ethical principles and to ensure that the increasing polarizing effects of information technologies are dealt with appropriately. All these questions are organizational not technological, but they must dominate how we deal with future automation.

The notion of the smart city of course conjures up these images of such an automated future. Much of our thinking about this future, certainly in the more popular press, is about everything ranging from the latest App on our smart phones to driverless cars while somewhat deeper concerns are about efficiency gains due to the automation of services ranging from transit to the delivery of energy. There is no doubt that routine and repetitive processes – algorithms if you like – are improving at an exponential rate in terms of the data they can process and the speed of execution, faithfully following Moore's Law. Pattern recognition techniques that lie at the basis of machine learning are highly routinized iterative schemes where the pattern in question – be it a signature, a face, the environment around a driverless car and so on – is computed as an elaborate averaging procedure which takes a series of elements of the pattern and weights them in such a way that the pattern can be reproduced perfectly by the combinations of elements of the original pattern and the weights. This is in essence the way neural networks work. When one says that they 'learn' and that the current focus is on 'deep learning', all that is meant is that with complex patterns and environments, many layers of neurons (elements of the pattern) are defined and the iterative procedures are run until there is a convergence with the pattern that is to be explained. Such processes are iterative, additive and not much more than sophisticated averaging but using machines that can operate virtually at the speed of light and thus process vast volumes of big data. When these kinds of algorithm can be run in real time and many already can be, then there is the prospect of many kinds of routine behaviour being displaced. It is in this sense that AI might herald in an era of truly disruptive processes. This according to Brynjolfsson and McAfee is beginning to happen as we reach the second half of the chess board.

The real issue in terms of AI involves problems that are peculiarly human. Much of our work is highly routinized and many of our daily actions and decisions are based on relatively straightforward patterns of stimulus and response. The big questions involve the extent to which those of our behaviours which are not straightforward can be automated. In fact, although machines are able to beat human players in many board games and there is now the prospect of machines beating the very machines that were originally designed to play against humans, the real power of AI may well come from collaboratives of man and machine, working together, rather than ever more powerful machines working by themselves. In the last 10 years, some of my editorials have tracked what is happening in the real-time city – the smart city as it is popularly called – which has become key to many new initiatives in cities. In fact, cities – particularly big cities, world cities – have become the flavour of the month but the focus has not been on their long-term evolution but on how we use them on a minute by minute to week by week basis. Many of the patterns that define the smart city on these short-term cycles can be predicted using AI largely because they are highly routinized but even for highly routine patterns, there are limits on the extent to which we can explain them and reproduce them. Much advancement in AI within the smart city will come from automation of the routine, such as the use of energy, the delivery of location-based services, transit using information being fed to operators and travellers in real time and so on. I think we will see some quite impressive advances in these areas in the next decade and beyond. But the key issue in urban planning is not just this short term but the long term and it is here that the prospects for AI are more problematic.

Urban planning since the 19th century has been based on attempting to organize the city in such a way that the quality of life for all is increased in terms of how the city functions economically and how the city is organized in terms of social equity. There are some hard choices involved in producing any plan for the long-term development of the city to meet these kinds of goal and it is difficult to see the kind of design and decision-making involved in such planning being replaced by an AI. The sheer range of factors and the uncertainties involved cannot be automated using any available AI technology although it is possible that some limited types of AI might be generated that deal with uncertainties in such a way that the intelligence is superior to that produced by human design. Plan design is very different from the search for good models of routine behaviour and this is reflected in the fact that even in routine processes such as in the development of driverless cars, it is the non-routine, the unexpected that cannot be anticipated by an AI. Such unexpected events define human behaviour and when these events occur, they are sometimes even unpredictable to the very person generating that same behaviour.

Doubtless, the development of AI in the form of machine learning will be useful in extending our understanding of how the high-frequency, real-time city actually functions but it is difficult to see how such methods will ever dominate plan-making and design except in the very short term. What is likely is that AI will inform the plan-making process in much the same way computer tools of many kinds lie at the basis of planning support systems. In terms of urban planning, there are hardly any tools that have been developed demonstrating how AI can be used to advance the state of our art. Years ago we had a flirtation with expert systems but these fell into disrepute as being too simplistic and obvious notwithstanding that we now take for granted some of the tools that are now in every day use that emerged from these developments (Yeh and Batty, 1991). In fact, in my editorial a couple of issues ago introducing the 21st anniversary of the Geocomputation conference, I noted Stan Openshaw's quest for thinking of cities in terms of models that embodied AI in their construction but these ideas were premature (Batty, 2017; Openshaw and Openshaw, 1997). What we need now and this journal is well placed to act in the vanguard of this, is a real push for demonstrating how AI can be used in urban analysis and city science, in urban planning and design. In this quest, we need a concerted effort to explore the limits of AI in our understanding of cities, in how we can invent new ways of automating functions within cities, and within the wider context of their urban planning.

Michael Batty

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