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Intelligent shoe making

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The intriguing relationship between manufacturing and AI (artificial intelligence), is considered here with the purpose of providing some basic insights into this fascinating science and of suggesting what its applications might be in the world of footwear. There is no need to stress how popular the topic of AI is also becoming among non-specialists as we see more and more comments and articles stating how impactful in general its applications will be on our lives, stressing the good things it can bring and warning about the risks and threats that its misuse can pose to our true existence. Governments from all over the world are investing huge amounts of money in basic research on the various domains of AI, with China and the United States the leaders in terms of money poured into research activities and Europe unfortunately lagging behind. Many commentators see this as one of the main challenges in gaining technological leadership in the years to come.

WHAT IS AI?

But what does AI mean exactly? 'AI' is a general term that refers to hardware or software (or a combination of the two) that exhibits behaviour that appears intelligent. Basic AI has in fact been in existence since the 1950s via rules-based programs that display

rudimentary intelligence in limited contexts. Early forms of it included 'expert systems' designed to mimic human specialists. Rules-based systems are nonetheless limited. Many real-world challenges, from making medical diagnoses to recognising objects in images, are too complex or subtle to be solved by programs that follow sets of rules written by people.

Excitement regarding modern AI relates to a set of techniques called machine learning, where advances have been rapid and significant. Machine learning is a sub-set of AI. All machine learning is AI, whereas not all AI is machine learning. The latter enables programs to learn through training instead of being programmed with rules. By processing training data, machine learning systems provide results that improve with experience. Machine learning can be applied to a wide variety of prediction and optimisation challenges, from determining the probability of a credit card transaction being fraudulent to predicting when an industrial asset is likely to fail. Try to imagine a new generation of electronic shoe making machines that are capable of gathering data about their status and working conditions while they operate, data that can be used to predict when a failure might occur to pre-emptively take the necessary actions in order to prevent such a failure. This can have a

tremendously positive impact on reducing down times and on the overall efficiency of the process these machines are part of.

There are many approaches to machine learning. Popular methodologies have exotic names such as 'random forests', 'Bayesian networks' and 'support vector machines'. Deep learning is a subset of machine learning that is delivering breakthrough results in fields that include computer vision and language. It emulates the way animals' brains learn subtle tasks by modelling the brain, not the world. Networks of artificial neurons process input data to extract features and optimise variables relevant to a problem, with results improving through training. After seven false dawns since its inception in 1956, AI technology has come of age. The capabilities of AI systems have now reached a tipping point due to the confluence of several factors; new algorithms, the availability of training data, specialised hardware, cloud AI services, open source software resources, greater investment and increased interest. Together, these developments have transformed results while reducing the difficulty, time and cost of developing and deploying AI. A virtuous cycle has developed and progress in it is attracting investment, entrepreneurship and interest. These, in turn, are accelerating progress.

A TURNING POINT

Recently, MMC and Barclays, two UK based venture capital firms, published an interesting study titled 'The state of AI 2019: Divergence', meaning that 2019 represented a kind of turning point in the general, widespread adoption of AI. In their study they show that its spread has in fact tripled in 12 months with one in seven large companies adopting it. In 24 months from now, two thirds of large companies will have live AI initiatives. It may be the fastest paradigm shift in technology history. In the course of three years, the proportion of enterprises with AI initiatives will have grown from one in 25 to one in three. Adoption has been enabled by the prior paradigm shift to cloud computing, the availability of plug-and-play AI services from global technology vendors such as Amazon and Google, and a thriving ecosystem of AI-led software suppliers.

This fast growth is supported by rapid progresses in hardware and software technologies. Leading hardware manufacturers are creating new classes of computer processor designed from inception for AI. Custom silicon offers transformational performance and greater versatility. Custom silicon is also taking AI to the 'edge' of the internet, to IoT devices, sensors and vehicles. New processors engineered for edge computing (the portion of computing in an Internet of Things scenario that happens close to the machines themselves) combine high performance with low power consumption and small size. And finally, when quantum computing, the new generation of computing machines matures, it will create profound opportunities for progress in AI and enable humanity to address previously intractable problems, from personalised medicine to climate change. While nascent, quantum computing is advancing rapidly, researchers have also developed functioning neural networks on quantum computers.

On the software side, new approaches are appearing that will push the ability of AI even further. One of them is a methodology called 'Reinforced Learning' and is an alternative approach to developing AI that enables a problem to be solved without knowledge of the domain. Instead of learning from training data,



Reinforced learning enables robots to learn from past experience in order to improve their skills. CREDIT: ARKHIPOV ALEKSEY / SHUTTERSTOCK.COM

RL systems reward and reinforce progress towards a specified goal. AlphaGo Zero, an RL system developed by DeepMind to play the board game Go, developed unrivalled ability after just 40 days of operation. Another one is called 'Transfer Learning' which enables programmers to apply elements learned from previous challenges to related problems. TL can deliver stronger initial performance, more rapid improvement and better long-term results. Interest in it has grown rapidly and is enabling a new generation of systems with greater adaptability. All these aspects constitute the landscape that surrounds the possible adoption of AI in the footwear world.

PRESCRIPTIVE MAINTENANCE

Let us start with manufacturing. We have already mentioned a first possible application of AI in a domain called 'predictive maintenance' which could bring great benefits in terms of improving the overall efficiency of the manufacturing process by reducing (or totally eliminating) the risk that a machine could break down, causing the work in progress to slow down or come to a complete stop with the kind of consequences that can be easily imagined. The traditional approaches to somehow contain the problem include keeping a set of critical spare parts in stock in order to rapidly fix the machine when it occurs or relying on external

repair and maintenance teams that can intervene within hours to minimise the down time.

A better way to deal with the problem would be to adopt so called 'prescriptive maintenance', which means estimating the typical time between failure of each critical machine component and to send alerts to the user so they can take the necessary maintenance actions when the time comes. If the first approach can be called reactive, this second one is prescriptive and, when well established maintenance plans exist and are carefully applied, can certainly be beneficial. Nevertheless, neither of the two is able to anticipate the possible failure and to call the user to pre-emptively adopt the necessary measures. This is what predictive maintenance aims at doing and the way to accomplish this is to capture a huge amount of data about machine operations over time and analyse them in order to identify patterns in the data that could signify an incipient possible failure long before it occurs. A promising way to identify such patterns is using machine learning approaches that can build knowledge from earlier happenings and use that to understand when it is time to request a pre-emptive action.

ROBOTS AND COBOTS

Staying on the shop floor, we now focus on robots, which provide another interesting potential area of application of AI. As we have stated on several

occasions in previous articles, robots are becoming more and more popular in footwear factories and from all the indications that we are gathering, we will see even more of them in future. Although major progress has been made in the past few years in regard to making their deployment easier and faster, and in simplifying the way they are programmed, particularly in relation to the appearance of the new families of collaborative robots (cobots), their programming is still far from being 'intelligent'. At present, an operator must teach them each and every step of the mission they have to accomplish or, worse, to program them through writing an endless number of lines of code.

What if a robot could instead 'learn' by itself the task it is asked to execute? In this ideal scenario there would be no need to program the machine and teaching would be reduced to showing our mechanical servants how to execute a given task and to let them learn by themselves, reinforcing their learning at each single execution of the task, adjusting to changes in the surrounding environment and coping with unforeseen or even unpredictable situations. This interaction between robotics and AI is seen as one of the high potential, new technological domains in the forthcoming future up to the point that someone has already referred to this evolution as Industry 5.0, the next stage in the progress of our manufacturing paradigms.

One challenge of this kind that has already been taken on is in an area called 'collision avoidance', in particular the avoidance of collisions between robots and human workers. In an interesting research performed by Prof. Marco Piastra of the University of Pavia in Italy, a RL (reinforced learning) approach was used to develop, in a typical industrial robot, a capability to learn how a worker moves in the area around it and to combine vision and RL to avoid collisions even in the absence of any other safety provision; it is a good example of how robots can truly become more 'intelligent'. But other than this, there are many topics in manufacturing that are being tackled more and more using AI methodologies, from dynamic process reconfiguration to flexible job scheduling and from smart, intelligent grippers to routing of mobile robots on the shop floor.



Research at the University of Pavia has shown that reinforced learning also enables robots to learn to avoid humans working close to them. CREDIT: BIG BLUE STUDIO / SHUTTERSTOCK.COM

IoT AND IoM

Another very promising area of crossing different technologies is found in the combination of IoT/IoM (Internet of Things/Internet of Machines), big data analysis, cloud computing and ML/AI. We are progressively entering the new Internet, which will connect more and more devices of every kind rather than just computers, from smartphones to smart sensors, from house appliances to cars, to manufacturing machines. Several billions of them will soon be connected to this super inflated version of the Internet that we all know and forecasts say that in no more than five years from now the number of connected devices will surpass the number of human beings on earth.

Each device generates data that can be transmitted, stored in the cloud and analysed to produce a wealth of knowledge that only a short time ago was unimaginable. AI/ML methodologies are the perfect tools to extract real knowledge from an otherwise chaotic mass of digital data. Returning to the manufacturing domain, predictive maintenance is a good example of what can be (and is already) done and we can think of other interesting outcomes such as machine or process performance improvement, pre-emptive stock replenishment and supply chain optimisation.

OTHER POSSIBILITIES

Moving from manufacturing to other segments of the shoe value chain, we can identify other promising areas of application for AI. In the design phase, for instance, it could be used to capture trends by observing and learning from consumers' choices and habits and to turn this learning into design directives that can anticipate what consumers might choose tomorrow. Similarly, AI can drive generative design algorithms that can quickly iterate through different design options selecting among them the most promising ones. When we find ourselves on the verge of a true technological revolution, the limit is only our own imagination and ingenuity.

But, despite how rosy this future may look, there are warnings to be observed. AI can be overused, misused or simply not fully understood as examples over the past few years have taught us and that could lead to negative rather than positive outcomes. There are some who say that AI could actually change our very human nature, leading to our evolution into augmented or super humans. These extreme positions are to be expected when we are confronted with such a disruptive technology as AI promises to be. The message here, therefore, is to maintain control over our emotions and to manage this technology shift with great attention. In essence, 'AI handle with care'. 🧠