

Digital Water and Climate and its relation with AI

Key water management tools for the climate adaptation

By Vladan Babovic

Over the last decade almost every aspect of our lives has become digital - from the way in which we deal with finances to the way in which we are being entertained. Pervasive availability of powerful and interconnected technologies, including the Cloud and Artificial Intelligence (AI), are leading many business and governmental organisations on a digital transformation journey.

Although disruption in general has been long present in many sectors, the rise of digital technologies has accelerated the pace of change in virtually every industry, creating immense ambiguity and unease. In addition to this, uncertainty continues to accelerate in the broader business environment as the rate at which new technologies emerge increases exponentially.

These changes are also creating immense opportunities. The possibilities for new products, services and business models promise to substantially impact almost every sector of the economy - not least the water sector.

Fields of hydraulics, hydrology and hydro-environment in general are concerned with natural phenomena described through deterministic equations derived from our best understanding of conservation laws and other underlying water-physics, chemistry and biology. Initially, there was a limited interest in the scientific and communities of practice, even a degree of skepticism about AI. However, now and on the heels of the successes of artificial intelligence over the last two decades, there is a growing interest and accelerating adoption by the

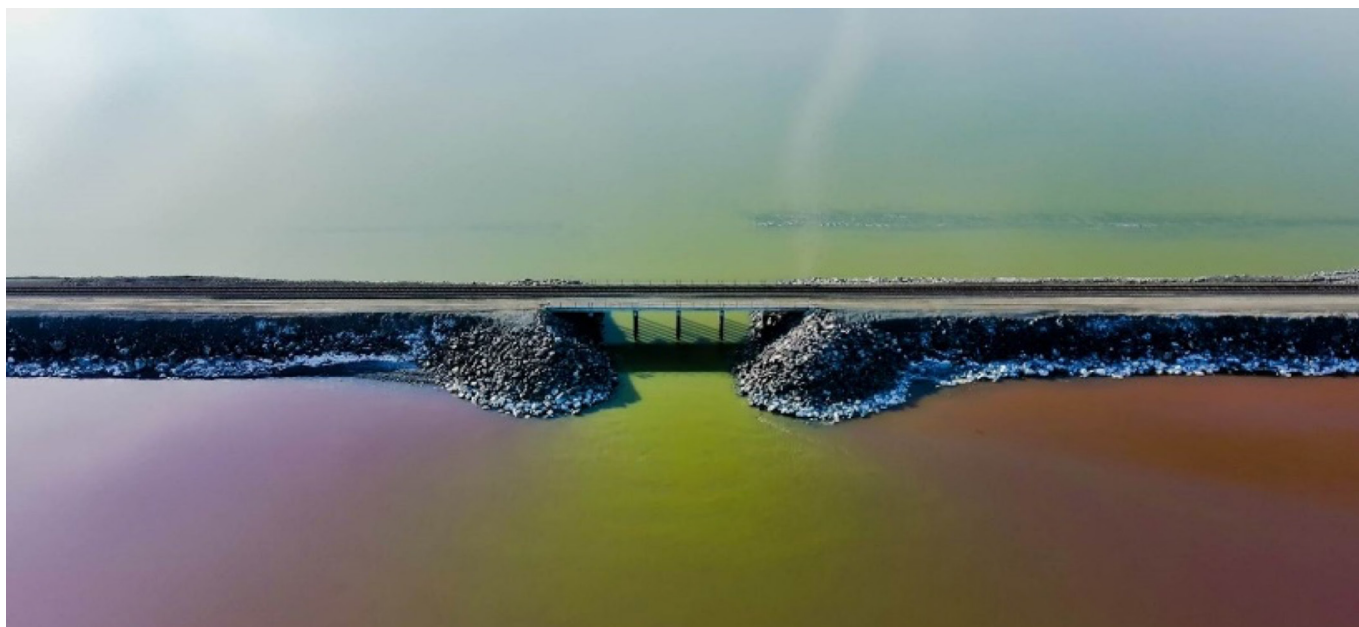
water community of state-of-the-art AI techniques originated in computer science into the water community.

How and why is this happening? In which direction is this transformation taking our community?

Perhaps a historical perspective as an overture could help appreciate the developments.

The manure parable¹

The main form of transport in big cities in the late 19th Century relied heavily on horses. With horses came manure, somewhere between 10-15 kg of manure per horse per day. Clearly this evolved into a massive problem, and policymakers did not know what to do about it. Fortunately, around the 1870 the first internal combustion engine was built and in 1880 installed in an automobile. Soon afterwards Ford's Model T was introduced and by 1912 New York City had more cars than horses, and only five years later the last four horse-drawn carts were decommissioned⁵.



¹ This subtitle is inspired by Elizabeth Kolbert's piece of The New Yorker, November 2009 issue in which she referred to the challenge as a "Parable of Horseshit"⁵.

The advent of technologies

The Industrial Revolution or what many people refer to as the First Machine Age (Muntone, 2013) enabled humans to dispose physical power by steam engines, internal combustion engines, and electricity, all to complement human labour. The sheer ability to create and control physical power resulted in phenomenal economic advantages, albeit not entirely without social resistance. For example, English textile workers called the Luddites protested against the introduction of spinning frames and power looms, fearing that the machines would leave them without jobs. Ever since, new technological advancements brought with them waves of concern about a possible displacement of labour. The debate about the implications of technology on work and jobs is as old as the industrial era.

The second machine age

I am borrowing this subtitle too, in this case from a book by Erik Brynjolfsson and Andrew McAfee².

At present we find ourselves in the second machine age surrounded by computers that are much better than we are in manipulating numbers for all kinds of practical purposes. Brynjolfsson and McAfee refer to this as a creation of mental power and discuss it as an enhancement of our own mental capabilities. This process of "enhancement" has been going on for quite some time now, starting with the first computers of early 60s till today. Throughout this period, according to Moore's Law, the speed and capability of computers doubled every year leading to an exponential growth in computational power. This is truly extraordinary. $2^{60} = 1.15 \times 10^{18}$ is a very large number indeed. The computers of today are more than one quintillion time faster than their predecessors of 60 years ago!

The second aspect of the second machine age is related to volume and capabilities of connected devices. Having 100 billion connected devices means that we now also have 100 billion data points that relate to each other. If we combine these two aspects – the sheer computation power and data availability – we have vastly new possibilities.

And also today, similar to the Luddites, 30% of the people fear that technology is actually threatening their jobs. An often-used term is 'technological unemployment'. Obviously, this is

not the first time it happens. It happened many times in history but – fortunately – never really materialized.

What do these developments mean for us in the field of water?

Growing volumes of data and accelerating computing power

The capabilities of digital devices will continue to increase, and Internet of Things (IoT) sensors will also continue to provide amounts of information greater than ever, at lower cost and with greater reliability than previously possible.

In addition to this we witness an increase in so-called opportunistic sensing, lately facilitated by crowdsourcing, social media and citizen science that enables the general public to observe local environmental conditions. Couple these with Earth Observation (EO) developments which gather information about planets physical, chemical and biological systems and you get the perfect ingredients to assess the status of, and changes in, the natural and man-made environment.

In recent years, EO has become more and more sophisticated with the advancement of remote-sensing satellites and increasingly high-tech "in-situ" instruments.

Radars

Observing and monitoring rainfall in the tropics is extremely difficult. Tropical precipitation is characterized by highly localized events, so called convective storms. Where will the cloud burst and where precisely will the downpour happen? That is really very hard to forecast with any reasonable lead-time.

Singapore's National Water Agency PUB supported by the Hydroinformatics Institute (H2i) developed and installed a system based on a constellation of 6 X-band radars, which provides city-scale coverage about where the rainfall is and where it moves at a resolution of 100x100 meters. To nowcast and forecast the rainfall, H2i and PUB are relying on a deep learning model. This model in question is state-of-the-art deep learning architecture that gives up to 90 minutes rainfall forecast, unprecedented in the tropics. With increasing data availability deep learning is gaining popularity. Can we move from city-scale to hyper-local, street scale sensing of convective storms?

Can we refine this further to hyper-local, street scale sensing of convective storms?



Tweets?

Well tweets, of course tweets. Why tweets? People tend to post high volumes of content on social media, particularly when facing a natural disaster like a flood. Using natural language processing and computer vision to analyse tweeted images, one is able to draw information about what is happening on the ground. Aided by computer vision, one can extract the extent of the flooding and bring this into the computer model. In this way, video feeds processed by computer vision can identify not only rainfall intensity, but also extent of flooding. FloodTags or the RainScape project of Royal HaskoningDHV are working to achieve just this.

Computer vision for opportunistic rainfall monitoring

Using rain gauges is the classic approach to measuring rainfall. However, as we enter the age of the Internet of Things in which "anything may become data" so-called opportunistic sensing using unconventional data sources offers the promise to enhance the spatiotemporal representation of existing observation networks. One particular area attracting attention is the estimation of quantitative and analytical rainfall intensity from video feeds acquired by smart phones or CCTV surveillance cameras. Technological advances in image processing and computer vision enable extraction of diverse features, including identification of rain streaks enabling the estimation of the instantaneous rainfall intensity. Recent AI and machine learning approaches rely on the use of autoencoders, deep learning and convolutional neural networks to address the problems. Companies such as WaterView (Italy), the Hydro-informatics Institute (Singapore), as well as universities (Southern University of Science and Technology China, Shenzhen) have proposed and implemented practical approaches to weather hazards in energy, automotive and smart cities application domains.

Opportunistic sensing

CCTV cameras are already there. So capital expenditure for these "opportunistic monitoring devices" has been taken care of. People are tweeting all the time. In the opportunistic sensing context,

we are processing the data that are already collected. Moving into this direction brings unprecedented opportunities. Perhaps for the first time we have overwhelming volumes of data, and we have a lot of computing power to make sense out of it.

Where do we go from here?

Are these worrying developments?

What was once done by humans, now is increasingly processed by artificial intelligence. As Nobel Prize winner Wassily Leontief worried⁴, are we going the way of the horses? The population of horses that provided the backbone of our economy in late 19th in the United States alone consisted of around 21 million horses. By mid-20th Century, the number dropped to mere three million.

Are we, humans, hydraulic engineers, surrounded by powerful computing machines. Are we going to vanish like the horses? Is our work going to disappear?

I do not think so for several reasons.

We are entering the age of intelligent design. Applications of AI are merely in the first years of a shift in helping humans advance discoveries, leveraging scientific progress made over the past century via improved computing power and enhanced datasets. As a result, we are witnesses of the early successes in practical applications and barely are starting to gain a glimpse into the potential of the technology to match human intelligence¹. This is the time to fully embrace these opportunities. The opportunity is not just about enhancing capabilities but opening completely new chapters and avenues.

It seems plausible to state that a Human and AI combination performs better than any of these two working alone. No human may be better than a machine at some tasks, but no machine is better than a human with a machine. So, if we bring the best of AI to water managers and other professionals, we will be able to do a much better job.

The most important reminder, however.
Let us not be Luddites.



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