FROM INTELLIGENCE TO WISDOM

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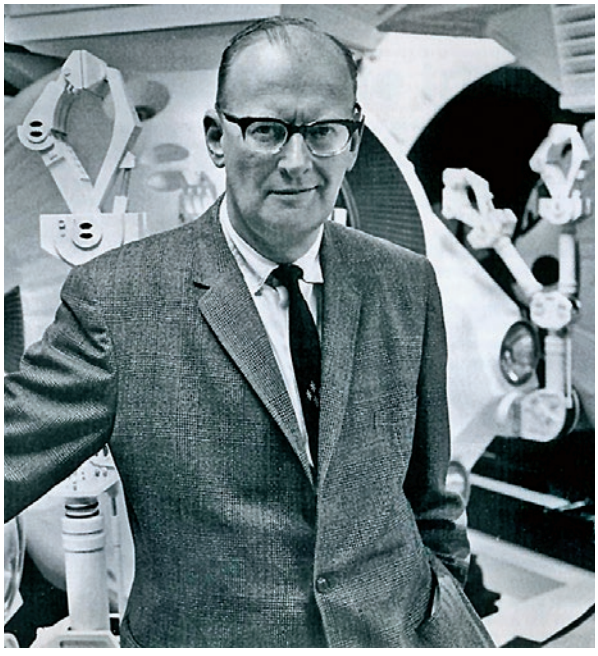
> *When a distinguished but elderly scientist states that something is possible, he is almost certainly right. When he states that something is impossible, he is very probably wrong.*
> Arthur C. Clarke



Introduction

Importance of radiology as a profession is massive. Rarely will any hospitalised patient finish his journey without visiting the radiology department. So, if we develop a system that will help radiology to increase productivity and accuracy while keeping the patient safe, the effects of this technology will also be massive. Artificial Intelligence (AI) has shown a potential to be one possible technology to revolutionise the radiology service.

Over the last ten years, publications on AI in radiology have increased from 100–150 per year to 700–800 per year (Pesapane *et al.*, 2018) highlighting the importance of the topic. In 2016 was predicted that „machine learning will displace much of the work of radiologists and anatomical pathologists“ (Obermeyer and Emanuel, 2016), and that machines will replace doctors because „when professional work is broken down into component parts, many of the tasks involved turn out to be routine and process-based. They do not, in fact, call for judgment, creativity, or empathy“ (Susskind and Susskind, 2016). There is more evidence of scientists overestimated the potential of AI, and probably the most famous one was from one of the AI pioneers, winner of the Association for Computing Machinery Turing Award, who stated in 2016: „People should stop training radiologists now“ (*Geoff Hinton: On Radiology – YouTube*, 2016).

Today, the predictions are alleviated, and some of the scientists mentioned already revised their forecasts (Hinton,

2018). Nevertheless, it has been shown that radiology professionals still lack exposure to current scientific medical articles on artificial intelligence.

Technology or magic?

> *Any sufficiently advanced technology is indistinguishable from magic.*
>
> Arthur C. Clarke

In 1770, Wolfgang von Kempelen (known to some by his real name, Kempelen Farkas) wanted to impress Maria Theresa, so, he has built a giant chess-playing machine. Stop for a second and try to consume this thought (and you may, or may not be impressed with the way he decided to impress someone); 250 years ago he constructed a machine that could beat even the best chess-players in the world. The legend has it that machine was even better than Napoleon Bonaparte and Benjamin Franklin. Just imagine, the automatic chess-playing machine that has the pieces mysteriously moving on their own, 2 50 years ago. It was a miracle; it was magic!

Today, we would not be impressed by such a machine. Technology is so incorporated in our lives that it is entirely usual to see something like this, but, in 1770, it was magic. Now, to calm down the sceptic ones among you: The Machine was called „The Turk", and it was operated by the chess master hidden in the beneath the table, who was moving the chess pieces above with magnets.

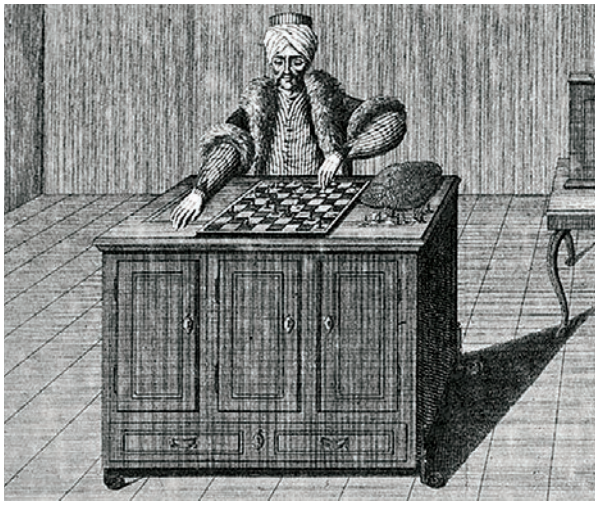


Image of a copper engraving from Karl Gottlieb von Windisch, 1783
From Wikimedia Commons, the free media repository:
https://commons.wikimedia.org/wiki/File: Tuerkischer_schachspieler_windisch4.jpg

Artificial intelligence

From the list of Artificial Intelligence definitions, I have selected a few personal favourites. For a start, we can define the Artificial Intelligence as „the capability of a machine to imitate intelligent human behaviour" or „a branch of computer science dealing with the simulation of intelligent behavior in computers „(*Artificial Intelligence* | *Definition of Artificial Intelligence by Merriam-Webster*, no date). I also would recommend the following one:

> *The field devoted to building artificial animals, or at least artificial creatures that – in suitable contexts – appear to be animals or appear to be persons*
>
> *Artificial Intelligence, Stanford Encyclopedia of Philosophy*, no date

Still, one of my personal favourites is this one:

> *Artificial intelligence is what we can do that computers can't...yet*
>
> *Self Aware Patterns*, 2014

Here, we also need to mention „Strong AI", where we have systems that think „like humans do" and they carry out tasks on their own. In „Weak AI" systems are working without figuring out how human reasoning works, and systems rely heavily on human interference. Strong AI algorithms will make decisions on their own, while all weak AI systems actions are pre-programmed by a human.

Like usually in life, we also have a category between those two, where systems can use human reasoning as a model, but this is not necessarily the end goal.

Artificial intelligence in clinical practice

The journey of Artificial Intelligence in clinical practice is usually following the development of computer science.

In the 1950s, we have started with computers that could assist with clinical decision making (Lipkin and Hardy, 1958). By 1970s, there was ARAMIS system at Stanford University (Fries, 1972), HELP System at the University of Utah (Warner, Olmsted and Rutherford, 1972), Cancer

chemotherapy system in Alabama (Mesel *et al.*, 1976) and Interactive system at Boston's Beth Israel Hospital (Bleich, 1972). The first attempts of Computer-aided diagnosis (CAD) in Radiology are beginning to be developed around the same time. **Around 50 years ago, for the first time, computers became more successful than clinicians alone.**

Later, in the 1980s, the first concepts of Machine Learning (ML) were developed and finally implemented in 2000s as Supervised Learning. In the 2010s, we have started the journey in Deep Learning and Hybrid un/supervised learning. This all has resulted in over 70 FDA Cleared AI Algorithms in 2020. Today, we have tools that can perform the following tasks (author's short selection):

- Prioritizing the clinical assessment of adult non-contrast head CT and chest XR cases
- Triaging and notifying in the analysis of cervical Spine on CT images, non-enhanced CT and CTPA images, non-enhanced Head CT images, Head CTA images, Abdominal CT images, Mammography
- Quantitative and qualitative analysis and presentation (including visualisations) of results for reporting: MRI brain, MRI breast, CT Brain, CT Pulmonary, CT Musculoskeletal, CT Cardiovascular, Hepatic CT, CT Brain Perfusion, CT KUB, US, Mammography, Breast Tomosynthesis, XR Chest, Skeletal XR
- Automatic labelling, visualization, and volumetric quantification – MRI Brain, CT Brain
- Classifying and characterizing ROI from Breast US
- Identifying and communicating images of specific patients to a specialist, independent of a standard of care workflow
- Viewing, manipulation, 3D- visualization and comparison of medical images from multiple imaging modalities
- Combining current and prior chest exams showing areas of change
- Mammography density classification
- MRI image enhancement (head, spine, neck and knee MRI)
- Noise reduction of FDG and amyloid PET images (including PET/CT and PET/MRI)
- Measurement of R2 and iron concentration in the liver from MRI scans
- Confirmation of line/tubes from radiographic images
- Estimation of left ventricular ejection fraction from US images

Of course, I do not need to mention that the list of promising applications and tools in developing stage is much longer. However, where will all this lead us to? For a start, I am hoping that by 2030s, we will be ready to start implementing Unsupervised learning and Cognitive computing.

We can easily conclude this section with a statement that there is no doubt that AI will impact healthcare positively (Hinton, 2018). Radiology wise, AI has the potential to improve most steps in radiology workflow, from patient triage and scheduling, clinical decision support, detection and interpretation of pathological findings, post-processing, dose estimation, quality control or reporting (Waymel *et al.*, 2019).

Still, we as humans, to understand something, we must understand what we are dealing with. What is „*intelligence*"? Where is that line, or milestone, that AI needs to cross to be considered intelligent? Is it essential, or humans feel vulnerable?

The „thinking machines"

> *"The question of whether machines can think is about as relevant as the question of whether submarines can swim.*
>
> Edsger Dijkstra, 1984

We have already shown that Computer-aided diagnosis (CAD) is the predecessor of Artificial Intelligence in radiology, with good and promising results (Bates *et al.*, 2003; Kahn, 2005; Berlin, Sorani and Sim, 2006), but it did not possess the „intelligence" level currently possible with deep learning and neural networking. Later, machine learning (Erickson *et al.*, 2017; Kohli *et al.*, 2017; Giger, 2018; Thompson *et al.*, 2018; Nichols, Herbert Chan and Baker, 2019) and deep learning (Erickson *et al.*, 2018; Hinton, 2018; Yasaka and Abe, 2018; Parekh and Jacobs, 2019) have all show a potential to maximise the benefits of radiology service. Now we need to ask ourselves the question: Is this our ultimate goal?

To answer this question, I would like to bring in the quote from the start of this section again. We keep asking ourselves how closely Artificial Intelligence can mimic our intelligence like this is our real point or goal. Machines

are better at some things than human, and that is obvious – humans excel at common sense, morals, compassion, imagination, dreaming, abstraction, and generalisation. Machines excel in pattern identification, natural language, machine learning, eliminating bias and are benefiting from almost endless capacity. Machine intelligence can go practically in countless directions, and we are still focusing on human-like decisions. I am assuming that it will not be practical for Artificial Intelligence to have an inner dialogue or emotions. What will be the practical nature if the machine will „desire" something? They will still be machines, and we can design them to be (almost) anything. I do understand that some people like human alike machines, but, besides the publicity, what is the real practical value of these machines? I firmly believe this is a significant failure of human imagination.

Now, no matter what direction we will choose, the technology will be cheaper and will become available to the hobbyists, hackers (white-hat and red-hat) and profit-pursuing enthusiasts. Then the interest may come, to design the machines that do not share the interest with humans, or machines entirely uncorrelated with our intentions. That is the reason why we also need to focus and minimise the possibilities to create Artificial Intelligence that will turn on its creators. If we paraphrase the famous quote by Robert Frost: „Don't ever take a fence down until you know why it was put up" – when discussing Artificial Intelligence – we have just started to build a fence.

Consciousness

Some authors believe that AI could develop consciousness, and they usually defend this with the fact that our consciousness is based on the matter only. Since a good part of the AI decision-making process is coming from the black-box environment, humans cannot really understand or find out how Artificial Intelligence is making decisions. One might say, that is the last step before creating its sub-conscious. As Artificial Intelligence is progressing, the code might become so complex and complicated that will contain the emotional, conscious world inside. And if it is in the black-box environment – humans will not know.

And how can we even tackle consciousness? What is it? How can we define it? One should not be confused with *subjective awareness* or *subjective experience* – consciousness is more than that. Some authors assumed that something amorphous and slippery as consciousness could never be explained scientifically, while I am reasonably sure that it is understandable and buildable as any item that makes up its content (decision-making, visual processing, memory, etc.), while, at the same time, the experience of being conscious seems unsolvable. The memory alone is not the same as the act of being conscious of the same memory.

In 1950, Alan Turing proposed a famous way to test if machines can think. However, is this enough to make conclusions of inner experience or consciousness? For

example, if our machine can pass the Turing test, we still do not know if the machine has inner experience. On the other hand, if we could build a genuinely conscious machine, there is no guarantee that it will pass the Turing test. In the end, a 3-year old child would not pass the Turing test. Some of you might not either. Speaking of you – I do not know if you are conscious or not – you could be only pretending that you are! I know that I am because I can experience my mind (let us ignore the idea that my consciousness is an illusion for now), but I will never know if other people or animals are conscious. Similar to that, we will not be able to prove the existence of inner experience or consciousness in a machine. Turing test is „just" the next best thing.

For all these reasons, Artificial intelligence researchers do not spend so much time on this question – it is not so important as we might think. Still, it should be self-explanatory now why we already need tools and policies to understand the hidden AI code, and of course, why we need to keep reassessing the role of AI in our society continually. We do not even have a cultural model for how conscious machines might change and operate with us. Science Fiction is not helpful since the conscious machines there, are usually the second (or third) class citizens serving the humans. And while most people assume that developing consciousness in a machine is similar to „waking up" the machine, let me just say that machines do not need the consciousness to think that humans are obstacles before they possibly decide to turn on us.

Conclusion(s)

> *Intelligence is knowing the right answer. Wisdom is knowing when to say it.*
>
> Tim Fargo

I believe that I have covered a reasonable amount of ideas and theories to keep you interested in the following pages in this Special Edition of our Journal. The main idea is to encourage your critical thinking about this technology – as we should have been critical to any technology in healthcare.

Artificial Intelligence is about tasks and not about intelligence (at least for now). Think about the chess, for example – although the number of moves is almost infinite, still, there are finite, and the rules of the games are known – they specify what is possible and what is not. Computers are better than humans in those environments. On the other hand, computers are usually not the best in unexpected situations, until the (successful) first time. If you give a computer a finite set of inputs, and a known variety of decisions (outputs), sooner or later that computer will become better, faster and cheaper at dealing with them than a person. Indeed like in a famous quote by Ong Ye Kung „*If you work like a robot, you will be replaced by a robot*". Thus, humans need to move from tasks to projects, to projects where they will decide which tasks to solve next in order to strive for the better. That is also the reason why **we need to educate people to lead where there are no user manuals**.

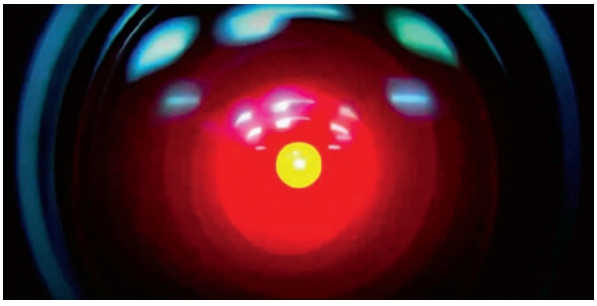
When people are building machines, whether they are elevators or competent computed tomography readers, they need to take responsibility for the outcomes of the produced machines. If Artificial Intelligence is not working as it should, somebody failed to do a good job. If Artificial Intelligence is in a black-box environment, we cannot just say that we do not understand how the system is working and that patient harm is a system fault. Something like in a well-known movie, when famous Artificial Intelligence system was asked about the discrepancy between that and one other system, the following conversation happened:

HAL: *Well, I don't think there is any question about it. It can only be attributable to human error. This sort of thing has cropped up before, and it has always been due to human error.*

Frank: *Listen HAL. There has never been any instance at all of a computer error occurring in the 9000 series, has there?*

HAL: *None whatsoever, Frank. The 9000 series has a perfect operational record.*

Frank: *Well of course I know all the wonderful achievements of the 9000 series, but, uh, are you certain there*



has never been any case of even the most insignificant computer error?

HAL: *None whatsoever, Frank. Quite honestly, I wouldn't worry myself about that.*

Artificial Intelligence systems will (at least for some time more) behave like they were programmed. For the outcomes (positive or negative), we need to focus our search to the responsible human. First, we need to ask ourselves: „Where is a responsible human who designed, checked and proofed this machine?" When designing those systems, we always need to wonder where the responsible human is going to be. Then, we need to ask ourselves: „Where is the human that is going to use this machine?". Those people are responsible for the outcomes of the Artificial Intelligence systems, and not the systems alone.

In the end, Artificial Intelligence systems are producing tasks without „knowing" what they are producing. It is not our job to make computers „know"; **our task is to own the outputs of what we are teaching these machines to do.** ■

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