

Artificial intelligence and radiation protection. A game changer or an update?

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<https://doi.org/10.1051/radiopro/2022004>

1. Introduction

The first contact of the Y generation (*i.e.* 30–40 years old) to artificial intelligence (AI) was usually through movies and comics where AI was depicted as a breakthrough invention that can perform tasks far better than human (like the cubicle robot in *Interstellar*), take in tedious works (*Wall-E* cleans garbage), compete in poetry contest (Zéphir *et al.*, 2019) or empathize with us using impressive conversational skills (Samantha, the OS in *Her*). But more frequently AI transcend mankind and wipe us off from Earth (Skynet in the *Terminator* series) or at least put us in slavery (*The Matrix*). The older generations certainly recall *2001: A Space Odyssey* where computer HAL is taking control of the ship or the murderous human-replicas in *Blade Runner*.

Although movies and comics tend to exaggerate for dramatic purposes, there might be some truth behind. After impressive achievements, AI, machine learning, neural network and big data have become popular terms in media and are promised to be everywhere in the future, the nuclear sector being no exception (Gomez-Fernandez *et al.*, 2020; NEA, 2021). Therefore, knowing what AI is actually and its capacities seems crucial.

In the framework of a global reflexion about innovation and the future of radiation protection (RP) ignited by Bourguignon *et al.* (2017) and continued in Ménard *et al.* (2019), the Young Club of the French Society for Radiation Protection has decided to assemble a working group “AI & RP” (in March 2020) to further investigate this topic.

To obtain a picture of the landscape, the working group has performed a bibliometric analysis of publications on “artificial intelligence” and synthesized publications about the usage of AI in Radiation Protection (RP) and its allied fields. Informal interviews with RP professionals engaged in AI projects and data scientists were also conducted. The purpose of this article is to present the result of this working group.

2 What is artificial intelligence?

2.1 And what is machine learning?

The first issue was the meaning of “artificial intelligence”. The term was introduced in 1956 (Minsky, 1961), so it is almost as old as the computer itself, but its definition has always been loose, debatable and evolving with the techniques. Two branches of AI have co-existed: symbolic (or logic) IA which import factual and heuristic knowledge of human experts to achieve the solution was popular in the 1950s and the 1980s while numerical AI has followed a different path: rather than explaining to the computer how to solve a problem, machine learning (ML) “gives computers the ability to learn from and improve with experience, without being explicitly programmed” (Parliament, 2018).

One feature of ML is the “artificial neuron”, an original informatics architecture mimicking the functioning of the brain. The simplest artificial neuron receives inputs from several “synapses”, weight them, calculate a score and passes an output if above a threshold/activation function. The trick is that some parameters of this algorithm are adjusted during a learning phase by the back propagation of the distance between the output and the “true” result. A neural network (NN) is constituted with more than 3 layers of neurons, inclusive of the inputs and outputs. Training multiple layers of neurons constituted the basic of deep learning (DL).

The artificial neuron was theorized precociously in 1943 and built in 1957 (Rosenblatt, 1958) but this branch of IA suffered from technical limitations and faced a lack of innovation and investment for almost 30 years (Le Cun *et al.*, 2015). Particularly in France, this technique faced reluctance for not producing enough predictable outputs and not being “cartesian” enough (ENS, 2018).

The U-turn came around 2012: the availability of massive banks of data (big data) for training the NN and the innovations in graphical process units (GPU), initially designed to make numerous simple calculations in parallel, have unlocked the chains of DL. Further advancements include the number of layers (up to hundreds now) or convolutional NN (NN including pooling and convolution functions). In the media, DL probably pinnacle when AlphaGo¹ defeated a human Go player in 2016. The mediatic buzz has weakened, but soon, policy makers have

¹ AlphaGo is an artificial intelligence program developed by DeepMind, a subsidiary of Google. It gained significant attention for its success in playing the ancient Chinese board game called Go. Using a combination of deep neural networks and reinforcement learning, AlphaGo became the first AI program to defeat a world champion Go player, Lee Sedol, in a five-game match in 2016. This achievement marked a significant milestone in the advancement of AI and its capabilities in complex strategy games.

46 turned their attention to the topic and laid down strategies for ML and DL (often generally referred as AI)
47 ([Parliament, 2018](#)), France being no exception ([Villiani, 2018](#)).
48 We decided to focus on ML techniques; one of the most popular achievement of this technique today is image
49 recognition.

50

51 **2.2 Fundamentals of machine learning**

52 Simply put, ML is an ensemble of algorithms producing a model from data, the key feature being the algorithm
53 learns the model from the data and do not use pre-programmed rules. Implicitly, the model should be difficult
54 to describe: complex, non-linear phenomena, multiple inter-related parameters (or dimensions). The inferred
55 model is typically used for predictive analysis, ML can be also used to approximate function or explore (large)
56 data set. All types of data can fit: time series, image, text, measured or computed, etc.:

- 57 • supervised learning is one form of ML, using data labelled by humans, for classification purposes (assign
58 a category) or regression (to predict a numerical value). Popular algorithms include linear classifiers,
59 support vector machines (SVM) or decision tree. On the downside, the models can be time-consuming
60 to train, and the labelling require human time and expertise;
- 61 • unsupervised learning lets the algorithm alone in charge to find structures: aggregate of resembling
62 data (clustering) making use of K-Means or DBSCAN algorithms or trends/rules in data (association) ex.
63 with naïve Bayes. Unsupervised learning models are often computationally complex as they need a
64 large training set to produce intended outcomes;
- 65 • in reinforced learning, the algorithm adjusts its weight based on its observation of the impact of its
66 output on the environment to make a different decision next time. AlphaGo was trained by playing Go
67 against other programs.

68 Not limited to, the preparation of the data includes: collection, harmonization, outlier's exclusion, normalisation.
69 The data must be separated between the training, validation and testing sets, in a manner to avoid bias,
70 underfitting (the algorithm does not converge) and overfitting (the algorithm cannot generalize to data outside
71 the learning set).

72 Different data preparation, algorithms and metrics (cost function, performance, etc.) will be tested to design
73 the most suitable ML algorithm for the problem under consideration. The expression "*no free lunch*" used by
74 data scientists expresses the fact that no algorithm can solve all the issues: if one algorithm works well against
75 one problem, it will need adjustments to work against another, even comparable. Finally, the prototype will be
76 tested (eventually fixed) and deployed. Altogether, a ML project is like any engineering task ([Prevision.io, 2020](#)).
77 The data scientist cannot work alone: most steps require discussion and collaboration with the experts in the
78 field.

79

80 **4 Machine learning and radiation protection: examples of application**

81 This part presents examples of applications of ML in radiation protection and its allied fields (without pretending
82 to be exhaustive). The initial aim was to focus on French publications (published by French teams or institutions),
83 however, we extended this scope for some fields due to the scarcity of the initial results.

84

85 **4.1 The medical sector**

86 **4.1.1 Medial image recognition**

87 ML has become famous for pattern recognition, an apropos capacity for medical image interpretation. Examples
88 of concrete applications reported in France are listed by Malchair and Maccia (2020): detection of
89 abnormal/hard-to-detect findings, classification of nodule or tumours. AI (in this case: ML) for cancer detection
90 was one topic of the last INCA congress (JSD, 2020) and the focal topic of the annual seminar of the Radiologists
91 Society (FNMR, 2018). The press regularly echoes usages of AI in the field (AP-HP, 2019).

92 The French Association of Medical Physics has embedded AI in its last annual congress (SFPM, 2021). At
93 European level, the Federation of Medical Physics has even published a focus issue (EFOMP, 2021) where several
94 meta-analyses corroborated that image recognition is the prevalent usage of ML in RP (70% of the publications
95 in the Italian context) and that all imaging practices using radiation are concerned, with a particular attention
96 on lung cancer diagnosis (not to mention the use of AI to screen the lung in CT of Covid patients [Glangetas
97 et al., 2021]). In a second row, AI-based techniques have been used for image quality improvements (denoising),
98 segmentation and the reconstruction of 2D/3D images and it has been considered to use AI to elaborate
99 personalized low-dose imaging protocols rather than using generic sets (Lewis et al., 2019).

100 By (pre)processing the huge number of images generated in the workflow of clinical practice, ML has optimized
101 time for the staff to concentrate on the problematic cases. By improving image quality and/or interpreting image
102 from low-doses ones, ML could have assisted staff in reducing the exposure of patients (EFOMP, 2021).

NOME COMPLETO: _____ DATA: _____

1. Mark True or False. According to the author, as stated in the Introduction (lines 1 – 20):

- () 30-40 years ago artificial intelligence (AI) was already imagined as an important future invention.
- () Amongst others, AI was depicted as an invention that could be applied to situations where repetitive work had to be done.
- () AI was imagined as capable of being better than mankind and a threat to our existence.
- () The memory of 2001: A Space Odyssey, where the ship's computer HAL seizes control, and Blade Runner's depiction of homicidal human replicas, is undoubtedly ingrained in the minds of the older generations.
- () In order to gain an understanding of the landscape, the task force conducted a bibliometric analysis of literature concerning "artificial intelligence." They subsequently synthesized works discussing the application of AI in the realm of RP and related disciplines.

VVVVV

2. What is artificial intelligence? According to the author (lines 23-49), we will find stated in the text, Section 2.1, that:

- I. Machine learning is a subset of artificial intelligence (AI) that involves the development of algorithms and models that enable computers to learn from and make predictions or decisions based on data.
 - II. There types of machine learning techniques are three: Supervised Learning, Unsupervised Learning, Semi-Supervised Learning.
 - III. Around 2012, a pivotal shift occurred. The emergence of extensive repositories of data (commonly referred to as big data) to train neural networks, along with advancements in graphical processing units (GPUs) originally intended for parallel processing of simple computations, led to a significant transformation in the landscape of deep learning. This breakthrough liberated deep learning from its constraints.
- a) Only I is True.
 - b) Only I and II are True.
 - c) Only III is True.
 - d) All affirmatives are True.

3. In line 31, the author introduces the term "artificial neuron" which is, according to the author:

- a) a novel computational structure designed to emulate the operations of the human brain. The basic artificial neuron takes input from multiple "synapses," assigns them weights, computes a score, and transmits an output only when surpassing a predefined threshold or activation function.
- b) a sort of a traditional algorithm, mathematical functions, or other processing units that don't involve the concept of receiving inputs.
- c) a structure that receives inputs from other neurons through synapses, process these inputs through various chemical and electrical signals, and then produces an output signal that can be transmitted to other neurons.
- d) a structure composed of 3 layers, encompassing both input and output layers.

4. The "mediatic buzz" that the author refers to in line 45 was caused by:

- a) the availability of massive banks of data (big data).
- b) advancements include the number of layers of neurons.
- c) an AI program could defeat a world champion Go player.
- d) novel achievements in the technique of image recognition.

5. According to the author, “the U-turn came around 2012” (line 41). Why?

- a) The presence of extensive repositories of data (big data) to train neural networks, along with advancements in graphical processing units (GPUs) originally created to perform numerous simple computations concurrently, has unshackled the potential of deep learning (DL).
- b) AlphaGo defeated a human Go player. This achievement marked a significant milestone in the advancement of AI and its capabilities in complex strategy games.
- c) Due to the widespread availability of personal computers around the year 2012, there was a significant transformation in various fields, particularly in technology and computing. This era marked a crucial turning point in terms of accessibility and computational power.
- d) As a result of significant progress made in the realm of novel algorithms theory in 2012, there were substantial breakthroughs in various fields that heavily depend on computational methods.

6. Compare lines 51-56 in Section 2.2 *Fundamentals of machine learning (ML)* to the following statements:

- (I) Machine Learning (ML) constitutes a collection of algorithms that generate a model based on data. The crucial aspect is that these algorithms acquire knowledge from the data to build the model, rather than relying on predetermined rules. Inherent to this approach is the notion that the resulting model is intricate and challenging to articulate—characterized by its complexity, capacity to capture non-linear phenomena, and the presence of numerous interconnected parameters or dimensions. The model that is deduced from this process is primarily employed for predictive analysis, although ML also offers the capability to approximate functions or navigate through extensive datasets.
- (II) Machine Learning (ML) is a compilation of algorithms that craft a model using data, with the pivotal element being that the algorithm learns from the data itself, rather than relying on pre-programmed instructions. Implicit in this is the idea that the resulting model is intricate to expound upon: it embodies complexity, addresses non-linear phenomena, and grapples with multiple interconnected parameters or dimensions. The ascertained model typically finds utility in predictive analysis, although ML's potential also extends to function approximation and the exploration of expansive datasets.

- a) Both statements are phrases equivalent to the original text.
- b) Only I is equivalent to the original text.
- c) Only II is equivalent to the original text.
- d) None of the statements is equivalent to the original text.

7. Marque V ou F. De acordo com as linhas 56-71, que:

() A aprendizagem supervisionada é uma forma de Aprendizado de Máquina (AM), que utiliza dados rotulados por seres humanos, para fins de classificação (atribuir a uma categoria) ou regressão (prever um valor numérico). Algoritmos populares incluem classificadores lineares, máquinas de vetor de suporte (SVM) ou árvores de decisão. A grande vantagem é que os modelos podem ser treinados rapidamente e a rotulagem pela expertise humana os torna mais precisos.

() A aprendizagem não supervisionada permite que o algoritmo atue por conta própria para encontrar estruturas: conjuntos de dados semelhantes (agrupamento) utilizando algoritmos como K-Means ou DBSCAN, ou tendências/regras nos dados (associação), como por exemplo com o Naïve Bayes. Modelos de aprendizagem não supervisionada frequentemente são computacionalmente complexos, uma vez que necessitam de um grande conjunto de treinamento para produzir os resultados desejados.

() No aprendizado por reforço, o algoritmo ajusta seus pesos com base na observação do impacto de sua saída no ambiente, visando tomar uma decisão diferente da próxima vez. O AlphaGo foi treinado jogando Go contra outros programas.

() A preparação dos dados inclui: coleta, harmonização, exclusão de outliers e normalização. Os dados devem ser separados em conjuntos de treinamento, validação e teste, de maneira a permitir o viés na direção correta, o subajuste (o algoritmo não converge) e sobreajuste (o algoritmo não consegue generalizar para dados fora do conjunto de aprendizado).

FVVF

8. Marque V ou F. Na seção 4.1.1 *Medial image recognition* o autor afirma:

- () A Aprendizagem de Máquina tornou-se famosa pela capacidade de reconhecimento de padrões, uma habilidade apropriada para a interpretação de imagens médicas.
- () Exemplos de aplicações concretas relatadas na França mostraram que a AI pode realizar a detecção de achados anormais/difíceis de identificar, classificação de nódulos ou tumores.
- () A Associação Francesa de Física Médica incorporou a Inteligência Artificial em todos os seus congressos anuais.
- () O reconhecimento de imagens é a utilização predominante de Aprendizado de Máquina na proteção contra radiações (Radiation Protection = RP).
- () A IA foi usado para detectar lesões em pacientes com COVID.

VVFVV

9. *"In a second row, AI-based techniques have been used for image quality improvements (denoising), segmentation and the reconstruction of 2D/3D images and it has been considered to use AI to elaborate personalized low-dose imaging protocols rather than using generic sets (Lewis et al., 2019)."* Em relação à este texto, é correto afirmar que:

- a) Técnicas baseadas em IA têm sido utilizadas para melhorias na qualidade de imagem (remoção de ruído), segmentação e reconstrução de imagens 2D/3D, e tem sido considerado o uso de IA para elaborar protocolos genéricos para imagens baixa dose.
- b) Métodos impulsionados por IA têm sido aplicados para aprimorar a qualidade da imagem por meio da remoção de ruído, bem como para segmentação e reconstrução de imagens 2D/3D além de disponibilizar o desenvolvimento de protocolos de imagens de baixa dose personalizados, afastando-se de conjuntos genéricos.
- c) Técnicas impulsionadas por IA têm sido utilizadas para reduzir a dose através da redução de ruído, bem como para segmentação e reconstrução de imagens 2D/3D. Além disso, há uma tendência crescente de explorar o potencial da IA na elaboração de protocolos de imagem de baixo ruído baseados em conjuntos padronizados de imagens.
- d) Métodos impulsionados por IA têm sido aplicados para aprimorar a qualidade da imagem através da redução de ruído, além de serem usados para segmentar e reconstruir imagens 2D e 3D. Além disso, há uma crescente inclinação para explorar as capacidades da IA na elaboração de protocolos de melhoramento da imagem para situações de baixa dose.

10. *By (pre)processing the huge number of images generated in the workflow of clinical practice, ML has optimized time for the staff to concentrate on the problematic cases. By improving image quality and/or interpreting image from low-doses ones, ML could have assisted staff in reducing the exposure of patients (EFOMP, 2021)."* Em relação à este texto, é correto afirmar que:

- a) O pré-processamento de grandes volumes de dados foram usados como a base de dados para melhorar a qualidade da imagem dos casos desafiadores e com baixas doses.
- b) Ao (pré)processar um grande volume de imagens geradas no fluxo de trabalho clínico, a IA otimizou o tempo para a equipe se concentrar em casos problemáticos.
- c) A redução da dose foi possível por conta da otimização do tempo de processamento.
- d) A IA poderia ter auxiliado a equipe a minimizar a exposição dos pacientes pela indicação de novos fluxos de prática clínica.