Imagine/project how A.I. will improve people's lives by 2035. Propose the role of natural Scientists in making this happen.

The Dawn of Artificial Intelligence in Medical Imaging

Medical diagnosis is the process of determining the condition or disease which is causing a patient's ill symptoms. The impact of medical imaging on diagnosing such diseases has been apparent in the accelerated research and development in the field over the last 120 years or so. The X-ray was first discovered in 1895 by Wilhelm Conrad Röntgen [1] accidentally whilst he was experimenting with electrical currents through cathode ray tubes. He used them to produce an image of his wife's hand two weeks later and this was the first time it was made possible to look inside the human body without opening it up.[2] Since then, medical physics research has allowed for an agglomeration of new imaging techniques such as ultrasound, computed tomography (CT) and nuclear magnetic resonance imaging (MRI).

Artificial Intelligence is the field of study where we teach computers how to learn, just like we teach our children in their early years. Machine Learning is one way of doing this by designing codes of programmes that teach computers stuff over time by interacting with the environment or simply observing it.

The 7 steps of machine learning are as follows:

Gathering data – The quality of the dataset which will be used by the machine is the first and arguably most important step of machine learning. It is what will be used by the predictive model in the training step. In the example of the walking robot, this dataset used is not that simple. The robot takes data from previous robots when they were in similar positions to themselves.[3]

In medical imaging, this dataset is huge. Everyone living in developed countries (excluding third world countries) has an electronic record of their medical background and will have taken an X-ray or MRI scan at some stage in their lives. Although it is not so simple in current times for companies to gain access to this data, there is a huge potential for cooperation between hospitals and AI technology companies to be able to make the most of this data.

Data preparation – The collected dataset needs to be prepared in a format where it can be entered into the model. This preparation includes randomising the data so that the order of the data doesn't affect the outcome of the model. In the case of teaching a robot to walk, the data from other robots must not be fed into the model in its original order. This is because as previous robots learn, they will improve over time.

In medical imaging, the randomisation of the data is also important. The reason for this being, if you want a machine to make a correct judgement on the diagnosis of a patient using just an image, it must have been fed data of previous images. These images must train the machine and for this to be most effective, the images should not be categorised with respect to attributes of the patients such as gender, age or ethnicity.

Creating a model – The model is very specific to the role of the machine. Some are well suited to guide a robot walk, some create music sequences whilst others are suited to image data. For walking robots, the model is not exactly simple as there is a lot of maths involved. The model will score every move the robot makes according to a scoring formula. If the move aids in the process of walking, that particular move gets a high score and vice versa. In maths, what was previously explained is given in the Bellman equation shown below:

$$Q(s_t, a_t) \leftarrow (1-\alpha) \cdot \underbrace{Q(s_t, a_t)}_{\text{old value}} + \underbrace{\alpha}_{\text{learning rate}} \cdot \overbrace{\left(\underbrace{r_t}_{\text{reward}} + \underbrace{\gamma}_{\text{discount factor}} \cdot \underbrace{\max_a Q(s_{t+1}, a)}_{\text{estimate of optimal future value}} \right)}^{\text{learned value}}$$

Figure 1: Bellman equation [4]

To create a model that will be fit for diagnosing patients from images a similar process is followed. Below is an image showing how images are put through a neural network to allow diagnoses to be made. The action with maximum reward is either a benign diagnosis or a malignant one.

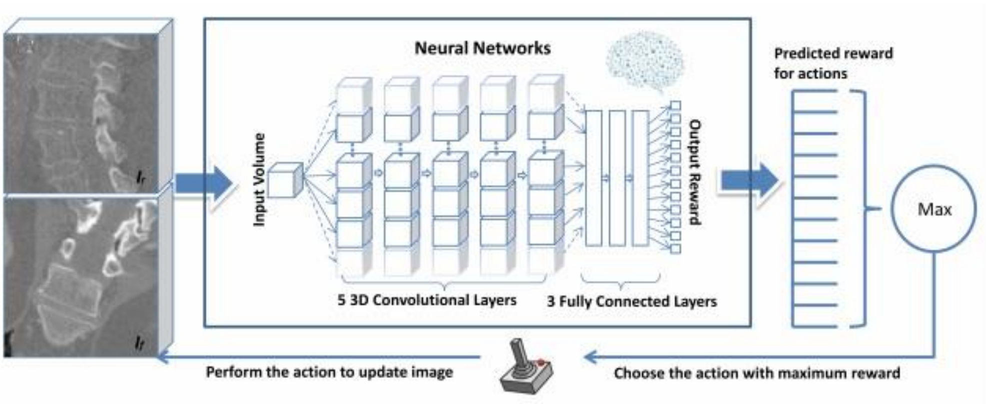

Figure 2: Deep learning in medical imaging [5]

Training – This is the stage where the model's ability to give a correct diagnosis is incrementally improved. Essentially, it is a realisation of the phrase 'practice makes perfect.' In the case of the walking robot, the analogy to a human learning to drive a car can be made. By correcting their mistakes, the robots learn how to walk and will not forget how to do so ever again.

In medical imaging, the algorithms in the neural network read the medical images similar to radiologists (by identifying patterns that is). Computer-aided software has been helping doctors find areas where they would want to have a closer look at for years. However, unlike computer-aided software, AI software has much more cognitive ability as it has been trained by large clinical data sets.[6]

Evaluation – This is a more simple stage. Here, the AI software compares the model created with datasets which have never been used for training. This provides a representation of how the model will perform in the real world. A fraction of the dataset which would have been used in the training steps should always be left for this stage.

Parameter tuning – After a full evaluation, it is possible to now look for improvements in the AI software. Furthermore, this enables the AI software to experience different initial conditions to those assumed when the training was performed. This will lead to higher accuracies in future runs.

Prediction – This is the final step. This is where we receive our answer for all the previous work put into creating the software. We can finally say whether the image from a patient shows they have the disease X or not.

Example of Osteoarthritis

Osteoarthritis is a disease that cannot be detected until after the damage is done. It is a very common disease that occurs especially in old age; 1 in 10 people develop osteoarthritis in their knee at some stage in their life. Osteoarthritis is where the thin cushion of cartilage between two bones wears out and so bone grinds against bone painfully. These signs of pain are usually what cause patients to seek medical help. However, at this point the damage has been done.

Below are images of the MRI scans of the knee cartilage of a sample group of patients that were monitored over a period of three years. The MRI scans are split into two groups, one where osteoarthritis developed after three years and one where it did not. It is clear that the human eye cannot tell the difference between the two samples.

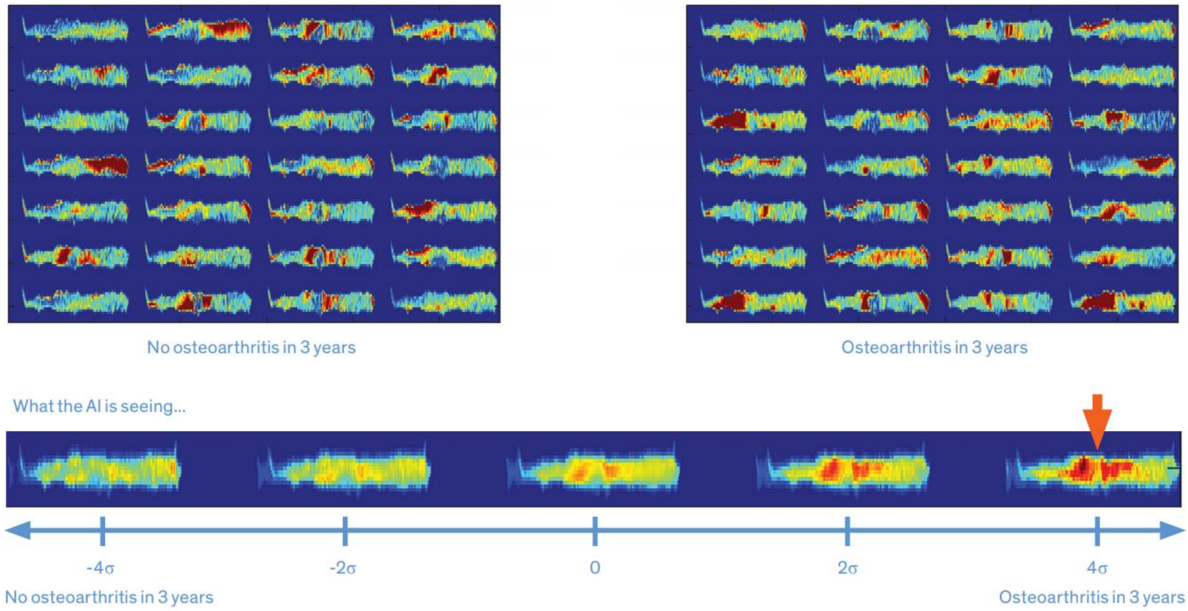

Figure 3: AI helps detect osteoarthritis 3 years in advance [8]

However, the AI software applied to these images used a technique called 'generative modelling' where the AI created a new version of the MRI scan that showed a knee that was guaranteed to develop the condition osteoarthritis. "We enabled a black box classifier to generate an image that demonstrates the patterns it's seeing as it makes its diagnosis," Kundu (the researcher of this project) explains. She goes on to say that this research "helped humans understand what the early developmental process of arthritis might be. "[8]

In conclusion, it is clear that artificial intelligence has changed medical imaging forever and will continue to do so undoubtedly. Researchers of the growth in this field have projected the market for machine learning in medical imaging to top $2 billion by 2023. [9] The ways in which AI will transform imaging and medical diagnostics is by collectively enhancing productivity, increasing accuracy, personalising treatment planning and ultimately improving clinical outcomes.

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