
In the Name of God

Artificial Intelligence & Pain Medicine

Dr Mehran Rezvani Fellowship of pain medicine
7/14/2023

Artificial intelligence (AI), defined as intelligence operated by a machine, has been introduced to share/replace the work requiring human intelligence

- Concerning the medical field, human intelligence is necessary for:
  - ✓Selection of the most possible diagnosis
  - ✓Most appropriate assessment
  - ✓Most relevant therapeutic strategy

- Enthusiastic proponents of AI claim that machines can outperform humans in many areas of medical diagnosis

- A principal subcategory of AI is Machine Learning (ML), where algorithms learn from data to make decisions or predictions

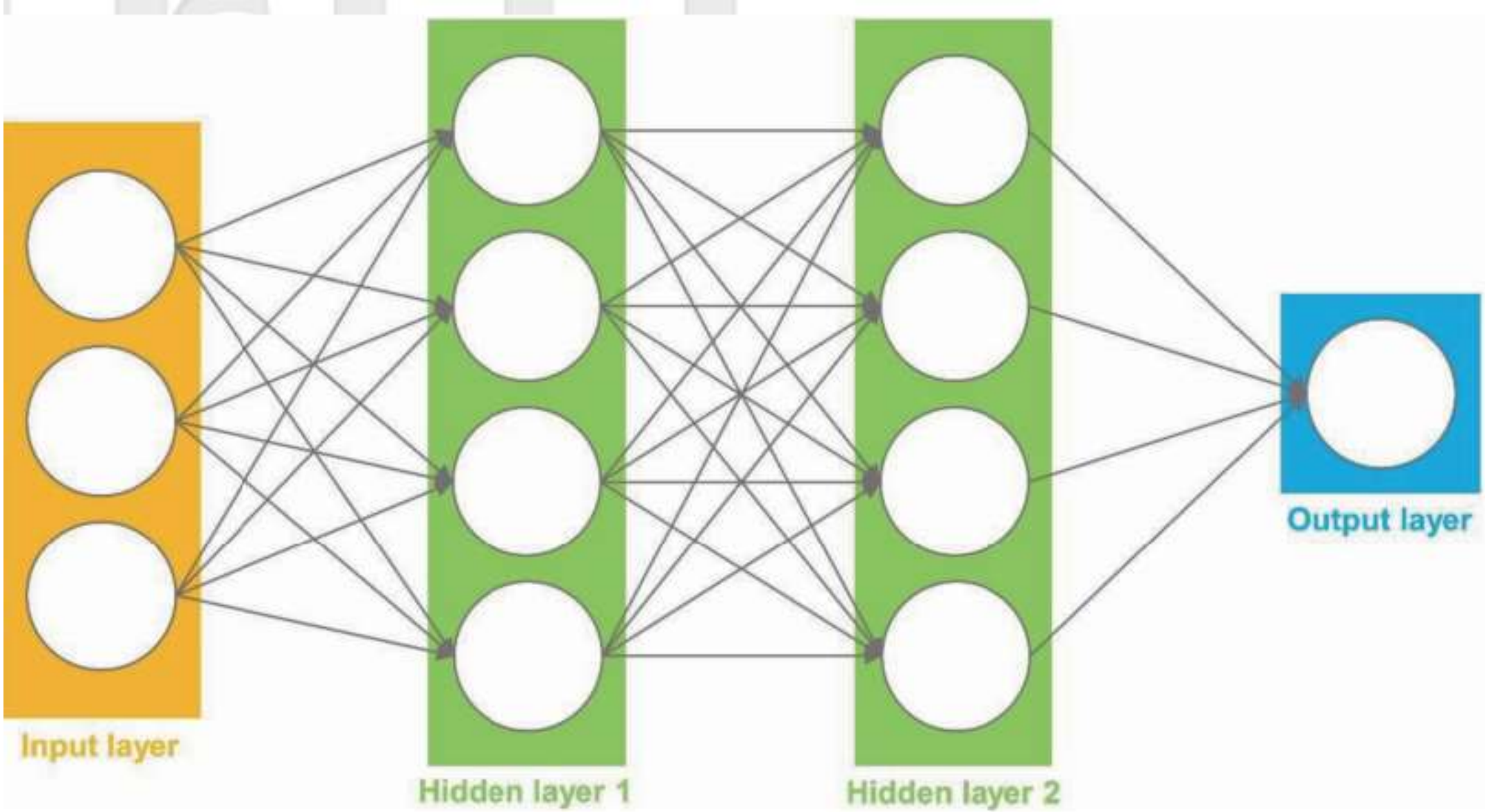
- In Deep Learning, a computational structure has used that attempts to mimic, in a crude way, the architecture of the human brain

- This structure is the Artificial Neural Network (ANN), comprised of "layers" of simple elements (mimicking neurons in the cerebral cortex) connected in a network structure

- A main subset of AI is machine learning, denoting a model that can automatically learn and improve from given data

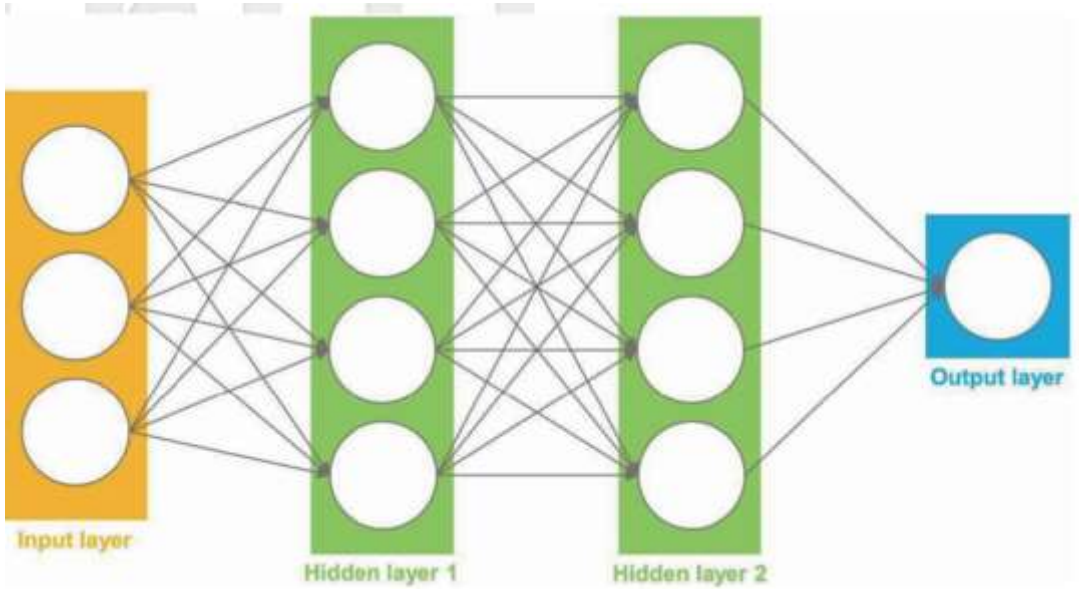
- Deep learning, a subdivision of machine learning, incorporates deep neural networks for model training

- Deep neural networks simulate relays of human neurons which have inputs from multiple sources and yield a fewer number of outputs

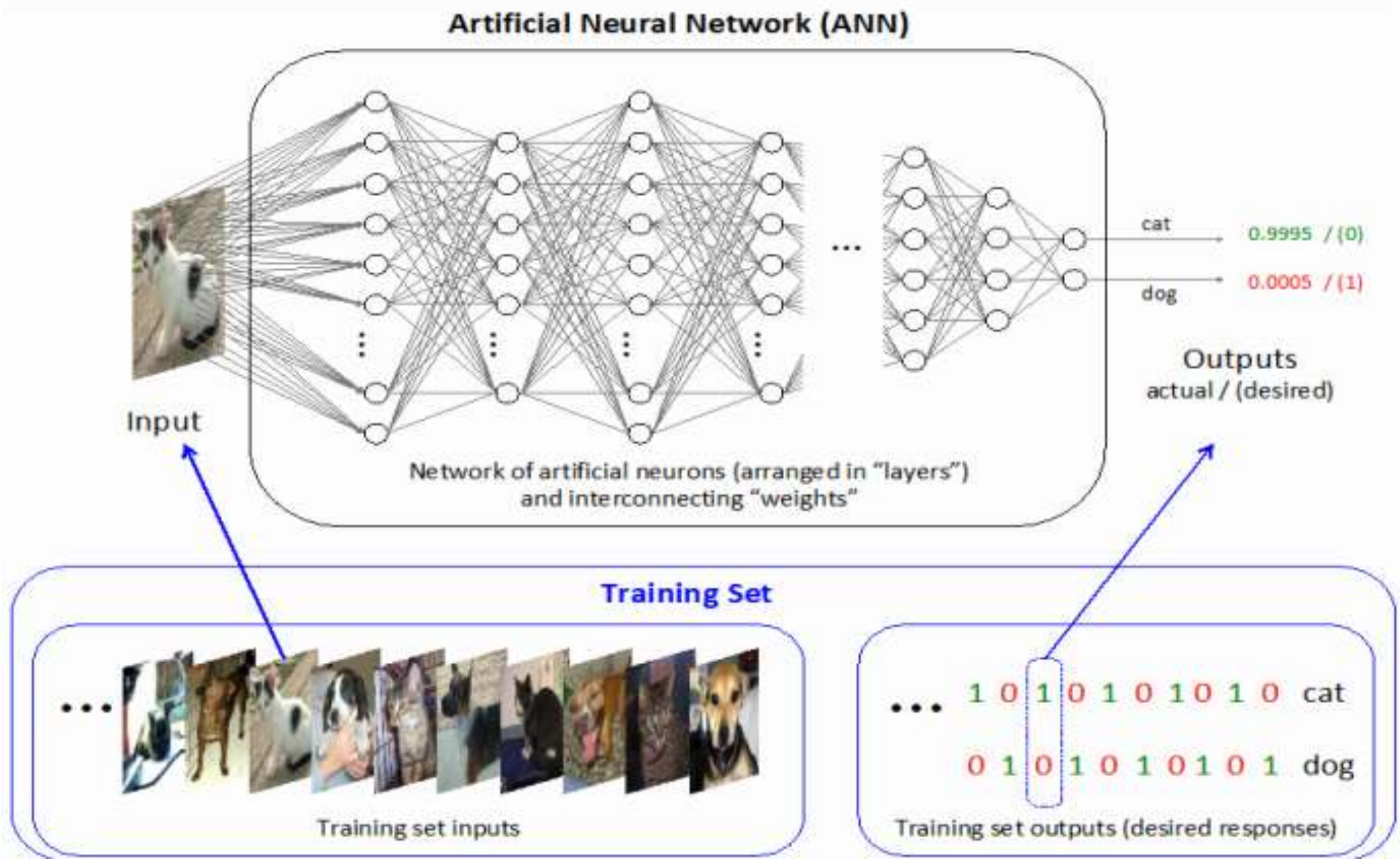

Input layer
Hidden layer 1
Hidden layer 2
Output layer

What distinguishes different neural networks?

- Principally, it is the number of layers of neurons in the network. Here, for example, we see a network with 4 layers, one input, 2 internal ("hidden") and one output



- It is commonly recognized that the more hidden layers there are in a neural network, the more powerful it is
- The original ("shallow") neural networks of the 80's and 90's had one or two hidden layers, restricted by computer hardware limitations
- The deep networks of the current century have rapidly advanced to have dozens of layers (hundreds are not uncommon)
- Generally, a network is regarded as deep if it has six or more layers


Artificial Neural Network (ANN)
Input
Network of artificial neurons (arranged in "layers")
and interconnecting "weights"
cat
0.9995 / (0)
dog
0.0005 / (1)
Outputs
actual / (desired)
Training Set
Training set inputs
1 0 1 0 1 0 1 0 1 0 cat
0 1 0 1 0 1 0 1 0 1 dog
Training set outputs (desired responses)

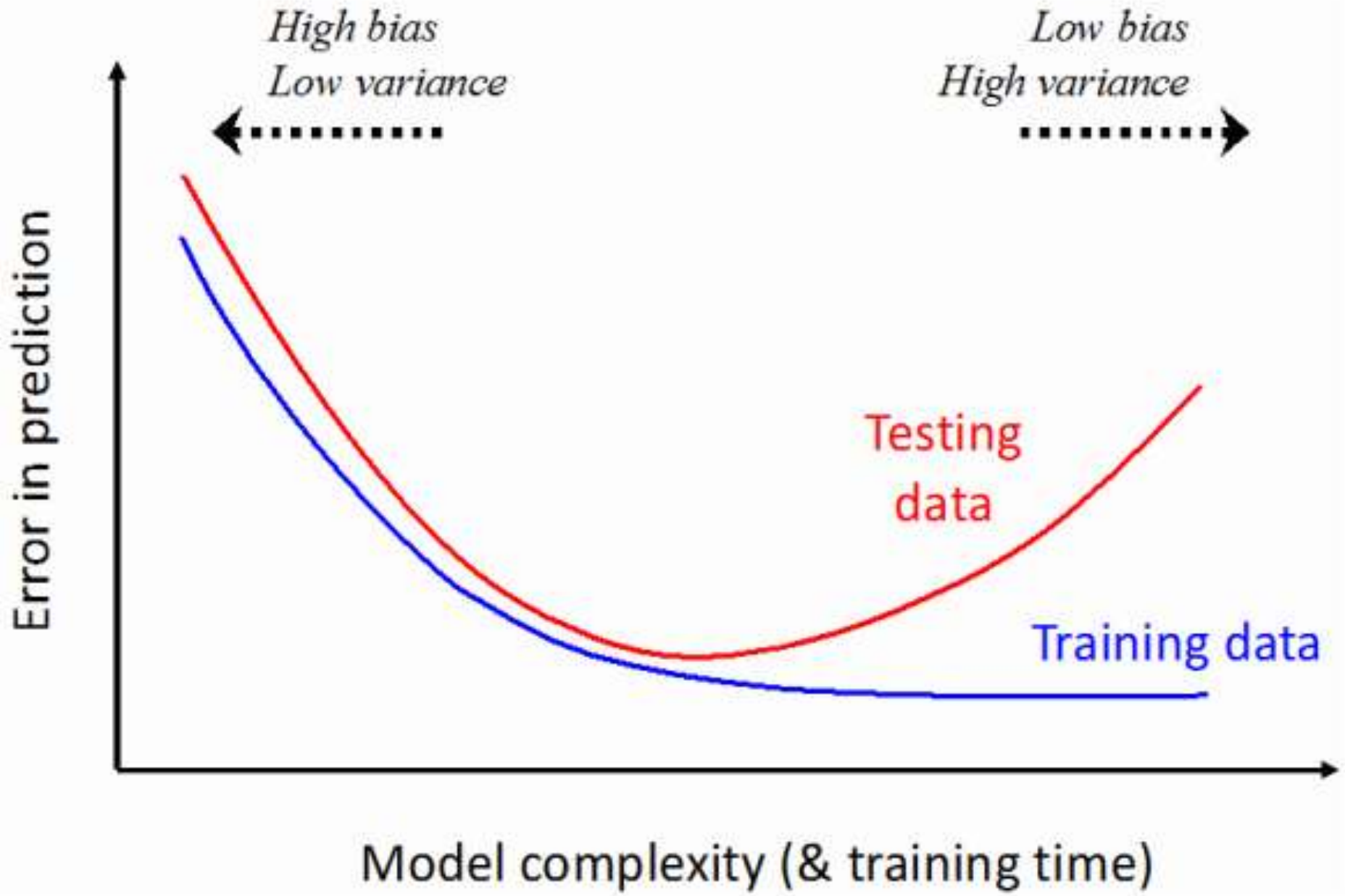
- What makes ANNs different from typical computer programs is that they are trained, rather than programmed

- The difficulty of AI and machine learning models is the classifier and training dataset used

- The performance is essential to minimize the prediction error, this directly relates to having a large dataset

- **Difference between the actual output and predicted output is the error**

- The Error is a summation of reducible and irreducible error
- The reducible Error is bias and Variance
- Bias is how far are the predicted values from the actual values
- If the average predicted values are far off from the actual values then the bias is high
- Variance occurs when the model performs well on the trained dataset but does not do well on a dataset that it is not trained on
- Variance tells us how scattered is the predicted value from the actual value


High bias
Low variance
Low bias
High variance
Error in prediction
Testing
data
Training data
Model complexity (& training time)

Anaesthetics Benefits of AI

- The main Areas that AI will influence Anesthestics will be:

1) Classification of ASA Score
2) Monitoring and Control of Drug Dosage
3) General Data Collection of Post and Pre-Operative Data

Classification of ASA Score

- American Society of Anaesthesiologists' (ASA) classification is the assessment system used for preoperative surgical patients, variations of this grading system are a common clinical problem

- The difficulty of ASA score is due to anesthesiologists interpretation, based on other factors to indicate operative risk such as the type of surgery, age, anaemia, obesity, and with patients who have recovered from a myocardial infarction

❖The specific correlation of ASA scores with operating times, hospital length of stay, postoperative infection rates, overall morbidity and mortality rates following gastrointestinal, cardiac, and genitourinary surgery has also been extensively studied

➢The human error factor and Variance of the ASA score allows for AI and Deep learning Algorithms to support and guide clinicians in more accurate and consistent allocation to this grading system

Monitoring and Control of Drug Dosage

- Anesthesiology involves the delivery and monitoring of targeted control drugs
- Target-controlled infusion (TCI) is part of anesthesia delivery in many countries, resulting in the precision, reliability, efficacy, and safety of IV anesthesia delivery

- Depth of anaesthesia monitors is **subjective** and depends on patients classification and surgery type to allow accurate drug administration against the measured state of arousal of the patient

- The variation of patients sensitivity, the intensity of surgical stimulation varies throughout surgery, and the haemodynamic effects of the anaesthetic drugs may limit the amount that can be given safely
- It is not uncommon for there to be critical imbalances between anaesthetic requirement and anaesthetic drug administration

- Under dosing may be because of equipment failure or error may occur
- Inappropriate titration of the hypnotic components, leading to an excessive depth of anaesthesia ,might compromise patient outcome

General Data Collection of Post and Pre-Operative Data

- In anaesthetics the collection of pre-and post-operative information concerning patients and surgical procedures will provide an excellent controlled environment where efficiencies errors can be reduced can be achieved

- Storage, security and use of this information are something that is of concern in only health care system

- Physician needs to be sure that the machine will not generate “wild” responses in unforeseen operating conditions
- Currently, acceptable methods solve this by increasing the training sets and more complex levels of processing, without a precise analysis of cognitive bias that may occur
- Decision making for use in anaesthetics cannot be a nondeterministic closed process, and clinicians need to have full control and understanding of the decisions developed by these rule-based algorithms

- AI Systems using Machine based Learning tools and software can be very useful in some aspects of clinical decisions within anaesthetics

- How can AI be applied in pain medicine?

- A simple literature search of PubMed by using the combination of "artificial intelligence" and "pain" yields

SEVERAL ARTICLE ABOUT AI & PAIN MEDICINE

- Pedoia et al. collected T2 MRIs of knees from 4,384 participants

- They proved the feasibility of voxel-based relaxometry in a combination of densely connected neural network to differentiate patients with and without osteoarthritis

Osteoarthritis Cartilage. 2019;27(7):1002-1010.

doi:10.1016/j.joca.2019.02.800

- Fraiwan et al. collected whole spine radiographs from 338 participants with scoliosis (n = 188), spondylolisthesis (n= 79), and normal spine (n = 71)

- By using the deep transfer learning model, the maximum accuracy of three-class classification could reach 98.02

Using deep transfer learning to detect scoliosis and spondylolisthesis from X-ray images. PLoS One. 2022;17(5):e0267851.

doi:10.1371/journal.pone.026785

- Kim et al. included 180,271 lumbar radiographs from 34,661 patients with recent lumbar MRIs

- By using a deep learning-based algorithm, the area under the curve of the receiver operating characteristic for predicting lumbar herniated nucleus pulposus was up to 0.73

Development and validation of deep learning-based algorithms for predicting lumbar herniated nucleus pulposus using lumbar X-rays. J Pers Med. 2022;12(5):767

doi:10.3390/jpm12050767

- Maraş et al. collected lateral cervical radiographs from 416 patients and applied the transfer learning method to discriminate participants with normal spine from those with pathologies (e.g., loss of cervical lordosis, narrowing of the disc space, or degenerative vertebral changes)

- They found that a pre-trained VGG-16 network had better performance than other models concerning accuracy (93.9%), sensitivity (95.8%), specificity (92.0%), and precision (92.0%) of classification

Diagnosis of osteoarthritic changes, loss of cervical lordosis, and disc space narrowing on cervical radiographs with deep learning methods. Jt Dis Relat Surg.

2022;33(1):93-101. doi:10.52312/jdrs.2022.445

- Wu et al enrolled 746 video clips from 64 critically ill patients

- The use of VGG-16 network could dichotomize facial expression of pain with an accuracy ranging from 0.81 to 0.88

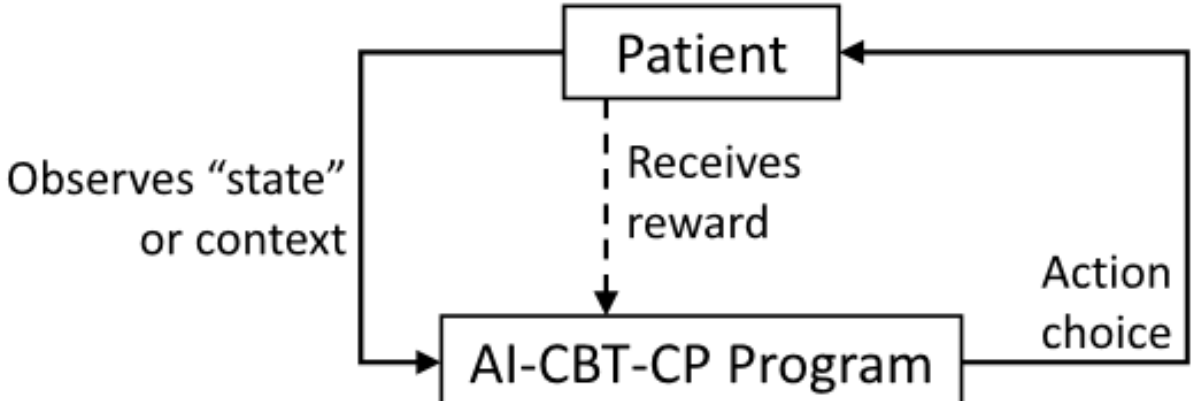
Deep learning-based pain classifier based on the facial expression in critically ill patients. Front Med (Lausanne). 2022;9:851690.

doi:10.3389/fmed.2022.851690

Piette‘s study
In Cognitive Behavioral Therapy for chronic pain (CBT-CP)

Intelligence-Based Medicine6 (2022) 100064

https://doi.org/10.1016/j.ibmed.2022.100064



- In Piette's study Cognitive Behavioral Therapy for chronic back pain (CBT-CP) driven by artificial intelligence (AI-CBT-CP) increased its effectiveness through patient interactions

- A program of CBT-CP driven by AI can learn from experience what treatment modalities work best to improve outcomes while conserving clinician time
- As systems interact with more patients over longer periods of time, AI-driven disease management programs can become even more effective

- The program focused on common behaviors (e.g., sleep, relaxation, and physical activity) and maladaptive thoughts (e.g., fear of movement)
- AI-CBT-CP group reported daily step counts during IVR assessments, and standard CBT-CP patients recorded steps using a log
- Weekly step count goals represented a 10% increase in steps compared to the prior week
- AI-CBT-CP was able to use RL(reinforcement learning) to adapt its mode of patient interaction and more effectively target therapist interactions

- This learning process led to significant improvements in patient reported outcomes

- AI-CBT-CP illustrates how chronic illness care supported by AI and mobile health monitoring can improve patient outcomes while more effectively targeting scarce clinical resources

Using artificial intelligence to improve pain assessment and pain management: a scoping review

Meina Zhang, Linzee Zhu, Shih-Yin Lin…

Journal of the American Medical Informatics Association, 30(3), 2023, 570–587

https://doi.org/10.1093/jamia/ocac231

- ❑ The electronic databases searched include Web of Science, CINAHL, PsycINFO, Cochrane CENTRAL, Scopus, IEEE Xplore, and ACM Digital Library
- ❖ The search initially identified 6946 studies
- ➢ After screening, 30 studies met the inclusion criteria

- Inclusion criteria were:

(1) study design: feasibility studies, pilot studies, evaluation studies, experimental studies, and quasi experimental studies

(2) study focus: a study testing an AI including ML, data mining, and natural language processing to improve pain assessment and management for adult patients

Country	
• United States	13 (43.3%)
• China	3 (10%)
• Denmark	2 (7%)
• India	2 (7%)
• Australia	1 (3%)
• Germany	1 (3%)
• Finland	1 (3%)
• Czech Republic	1 (3%)
• India	1 (3%)
• Kingdom of Saudi Arabia	1 (3%)
• Iran	1 (3%)
• Korea	1 (3%)
• Japan	1 (3%)
• United Kingdom	1 (3%)
• Taiwan	1 (3%)

Kharghanian R, Peiravi A, Moradi F. Pain detection from facial images using unsupervised feature learning approach. Annu Int Conf IEEE Eng Med Biol Soc 2016; 2016: 419–22.

Types of AI approaches	
• Pain management	10 (33%)
• Pain assessment	8 (27%)
• Others	12 (40%)
Types of pain	
• Back pain	7 (23%)
• Shoulder pain	5 (17%)
• General chronic pain	5 (17%)
• General pain	7 (23%)
• Not specify	6 (20%)
Sample size (# of participants)	
• >500	8 (27%)
• 100–499	10 (33%)
• 50–99	7 (27%)
• 11–49	4 (13%)
• ≤10	1 (3%)

Type I - AI-based approaches related to the pain assessment

- Seven studies developed novel models for pain recognition with ML

- These studies often detect pain automatically through facial action units

- Taken together, these studies support the notion that AI-based interventions potentially improve pain assessment

Type 2: AI-based approaches related to pain prediction and clinical decision support

❖Five studies developed **an app** to facilitate patients' pain management with an ML algorithm

✓Sandal et al developed and tested the effectiveness of the selfBACK app to provide weekly tailored self- management plans targeting physical activity, strength and flexibility exercises, and education for patients with low back pain

Type 2: AI-based approaches related to pain prediction and clinical decision support

- Outcomes of all above studies were measured at baseline and postintervention
- Most of the studies used a questionnaire or interview to evaluate if the intervention is effective before and after the intervention, and all of the mobile apps have some positive effects on patient's health outcomes

Machine Learning in Pain Medicine: An Up-To-Date Systematic Review

Maria Matsangidou . Andreas Liampas . Melpo Pittara

Pain Ther (2021) 10:1067–1084

https://doi.org/10.1007/s40122-021-00324-2

Inclusion Criteria

(1)Human subjects were involved

(2) The full article was written in English

(3) Papers studied ML in pain medicine

In total, 26 papers met the inclusion criteria and were used for this review

These studies were published between 2015 and 2021

- ML techniques for classifying the intensity of pain were found to be effective in patients with:

low back pain (LBP) osteoarthritis, ankylosing spondylitis, spinal cord injury , thoracic pain, sickle cell disease(SCD) , evoked heat pain, and other types of pain

Study	Type of pain	Study population	Use of ML	Main findings
Abdollahi 2020	Low back	94 patients, age 20–50 years	Classification	ML can effectively classify pain intensity based on quantitative kinematic data
Lee 2019	Low back	53 patients, age 18–60 years	Classification	ML can effectively classify intensity of evoked pain
Liew 2020	Low back	33 patients and 16 controls, age 18–55 years	Classification	ML can effectively classify pain intensity using electromyographic and kinematic data
Rahman 2018	Various causes	782 patients	Manifestation	ML can effectively measure and predict pain volatility
Santana 2019	Low back fibromyalgia	60 patients and 98 controls, age 18–55 years	Classification	ML can effectively classify pain intensity using fMRI data

Snyder 2021	Low back	10 subjects	Manifestation	ML can classify the relative risk of low back pain due to lifting activities, using gyroscope and accelerometer data
Kimura 2021	Osteoarthritis	23 patients, age 44–80 years	Classification	ML can effectively classify pain using EEG data
Levitt 2020	Spinal cord injury	37 patients and 20 controls, age ≥ 25 years	Classification	ML can effectively classify pain using EEG data
Rojas-Mendizabal 2021	Thoracic	256 patients	Classification	ML can effectively classify pain using demographic and clinical data
Gruss 2015	Evoked heat pain	85 subjects, age 18–65 years	Classification	ML can effectively classify evoked pain using biopotential data
Santra 2020	Low back	30 patients	Diagnosis	ML can effectively diagnose the cause of low back pain

Rogachov 2018	Ankylosing spondylitis	71 patients and 62 controls, age 18–61 years	Classification	ML can effectively classify pain using fMRI data
Grauhan 2021	Shoulder	2442 patients	Diagnosis	ML can effectively diagnose the cause of shoulder pain analysig plain X-rays
Darvishi 2017	Low back	92 patients and 68 controls, age 29–50 years	Manifestation	ML can predict development of work-related low back pain
Miettinen 2021	Various causes	277 patients, age 18–77 years	Classification	ML can effectively predict pain based on sleep patterns

- More than half of the studies included in this review were published **since 2020**, which indicated that the use of ML for pain has increased over time

- The large number of papers in this literature review shows that the use of ML in research on pain has been of great importance and is considered to be highly beneficial for classifying, predicting, diagnosing, and managing pain health devices such as mobile applications and wearables

- This review revealed that a wide variety of ML techniques have been employed in pain medicine

Thank you