Artificial Intelligence for Medicine II

Spring 2025

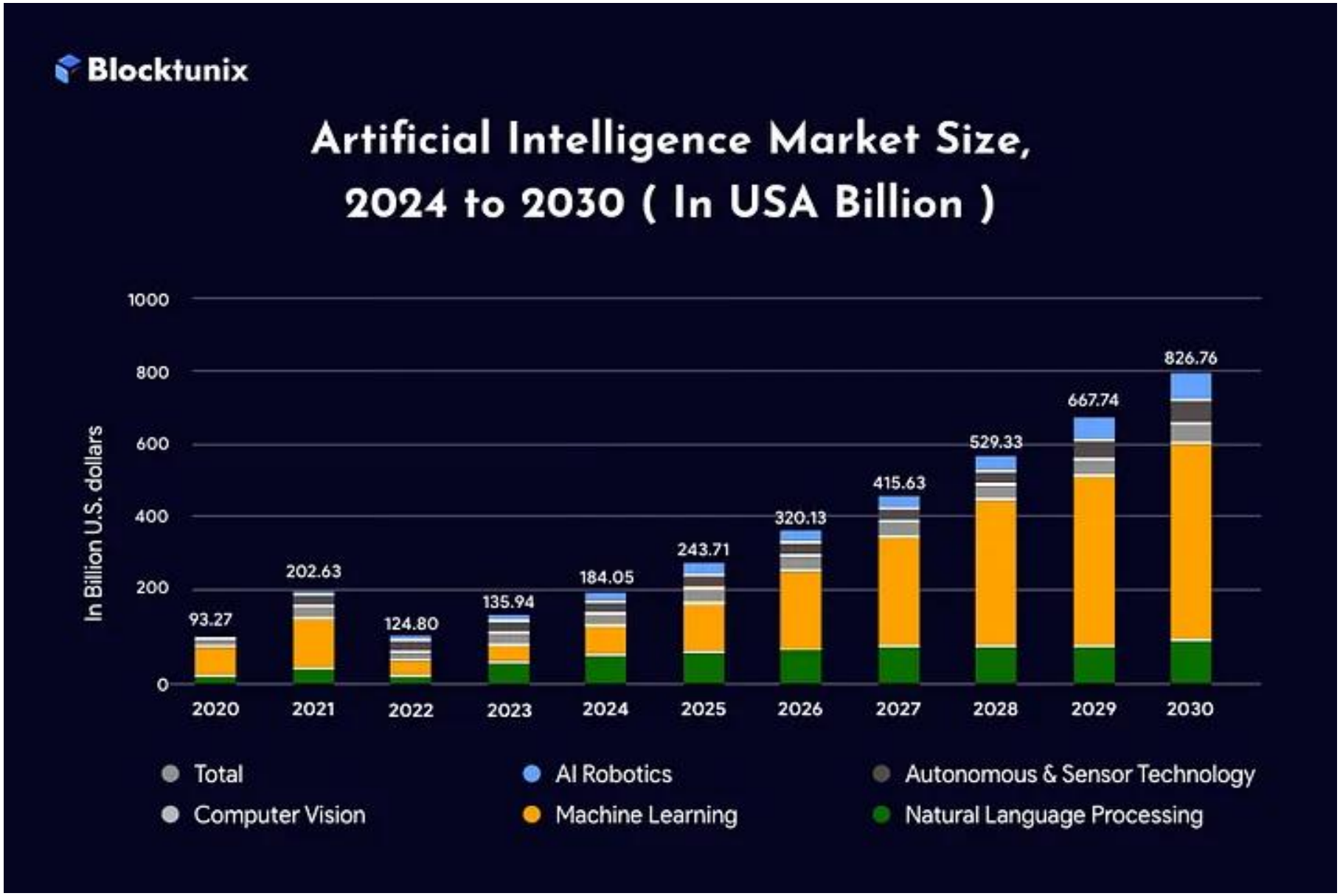
Lecture 1: Introduction

(Many slides adapted from the web)

Welcome
Artificial Intelligence for Medicine II

- This course is Artificial Intelligence for Medicine II
- It ‘s a continuation of the course: Artificial Intelligence for Medicine I
- What you will learn in AI for Medicine II:

1. Understand the fundamental concepts of AI and machine learning.
2. Analyze the role of AI in various medical fields, including diagnostics, imaging, personalized medicine, and drug discovery.
3. Learn and apply AI models to solve specific problems in medicine.
4. Gain hands-on experience with AI tools and platforms through practical exercises and projects.
5. Stay informed about the latest advancements, research studies, and trends in AI and healthcare.

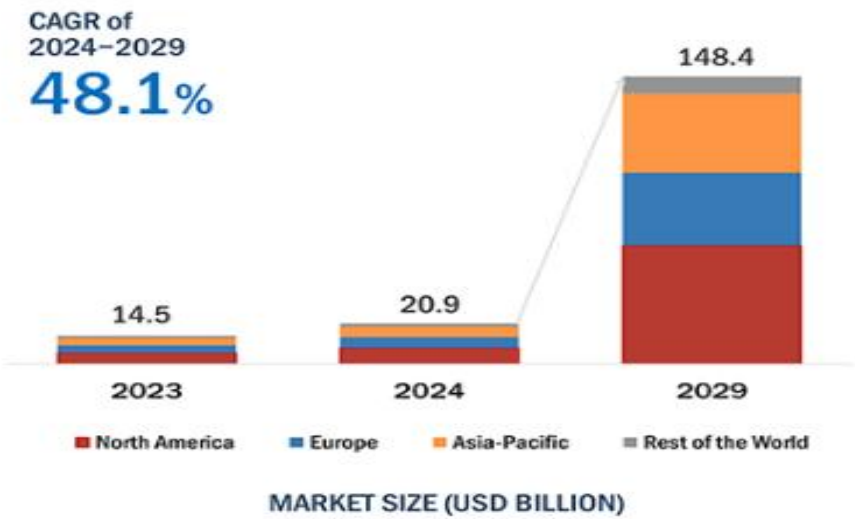


https://medium.com/@Blocktunix/key-technologies-in-ai-app-development-9a796826d107

ARTIFICIAL INTELLIGENCE IN HEALTHCARE MARKET

Market Size, Market Dynamics & Ecosystem

MARKETSANDMARKETS™



MARKET DYNAMICS (DRIVERS AND RESTRAINTS)

DRIVERS

- Exponential growth in data volume and complexity due to surging adoption of digital technologies
- Significant cost pressure on healthcare service providers with increasing prevalence of chronic diseases
- Rapid proliferation of AI in healthcare sector
- Growing need for improvised healthcare services

RESTRAINTS

- Reluctance among medical practitioners to adopt AI-based technologies

COMPANY EVALUATION MATRIX: KEY PLAYERS

ECOSYSTEM ANALYSIS

PHILIPS · NOVARTIS · Microsoft · Pfizer · tgen · sanofi · NVIDIA · intel · Google · babylon · Syneos Health

Artificial Intelligence (AI) in Healthcare Market Statistics Forecast to 2029

Artificial Intelligence (AI) in Healthcare Market - Global Forecast to 2029

- The global AI in Healthcare market size was valued at USD 20.9 billion in 2024 and is estimated to reach **USD 148.4 billion by 2029.**
- The growth of AI in the healthcare market is driven by the generation of large and complex healthcare datasets, the pressing need to reduce healthcare costs, improving computing power and declining hardware costs, and the rising number of partnerships and collaborations among different domains in the healthcare sector, and growing need for improvised healthcare services due to imbalance between healthcare workforce and patients.

Source: https://www.marketsandmarkets.com/Market-Reports/artificial-intelligence-healthcare-market-54679303.html?gad_source=1&gclid=Cj0KCQjwu-63BhC9ARIsAMMTLXRjxj3SvMxw2q9uyj3_cuUfpOnwWW_n8J9InV4EiVP45UcAOnBtxG8aAhhcEALw_wcB

Artificial general intelligence (AGI)

- *Today, we talk about* **Artificial general intelligence** (**AGI**)
- **Artificial general intelligence** (**AGI**) is a type of artificial intelligence (AI) that matches or surpasses human cognitive capabilities across a wide range of cognitive tasks. This contrasts with narrow AI, which is limited to specific tasks.[1][2] AGI is considered one of the definitions of strong AI.[3]
- **Artificial general intelligence (AGI)** is a field of theoretical AI research that attempts to create software with human-like intelligence and the ability to self-teach. The aim is for the software to be able to perform tasks that it is not necessarily trained or developed for.

- **AGI** may be comparable to, match, differ from, or even appear alien-like relative to human intelligence, encompassing a spectrum of possible cognitive architectures and capabilities that includes the spectrum of human-level intelligence.[4][5][6]

- Creating AGI is a primary goal of AI research and of companies such as OpenAI[7] and Meta.[8] A 2020 survey identified 72 active AGI R&D projects spread across 37 countries.[9]

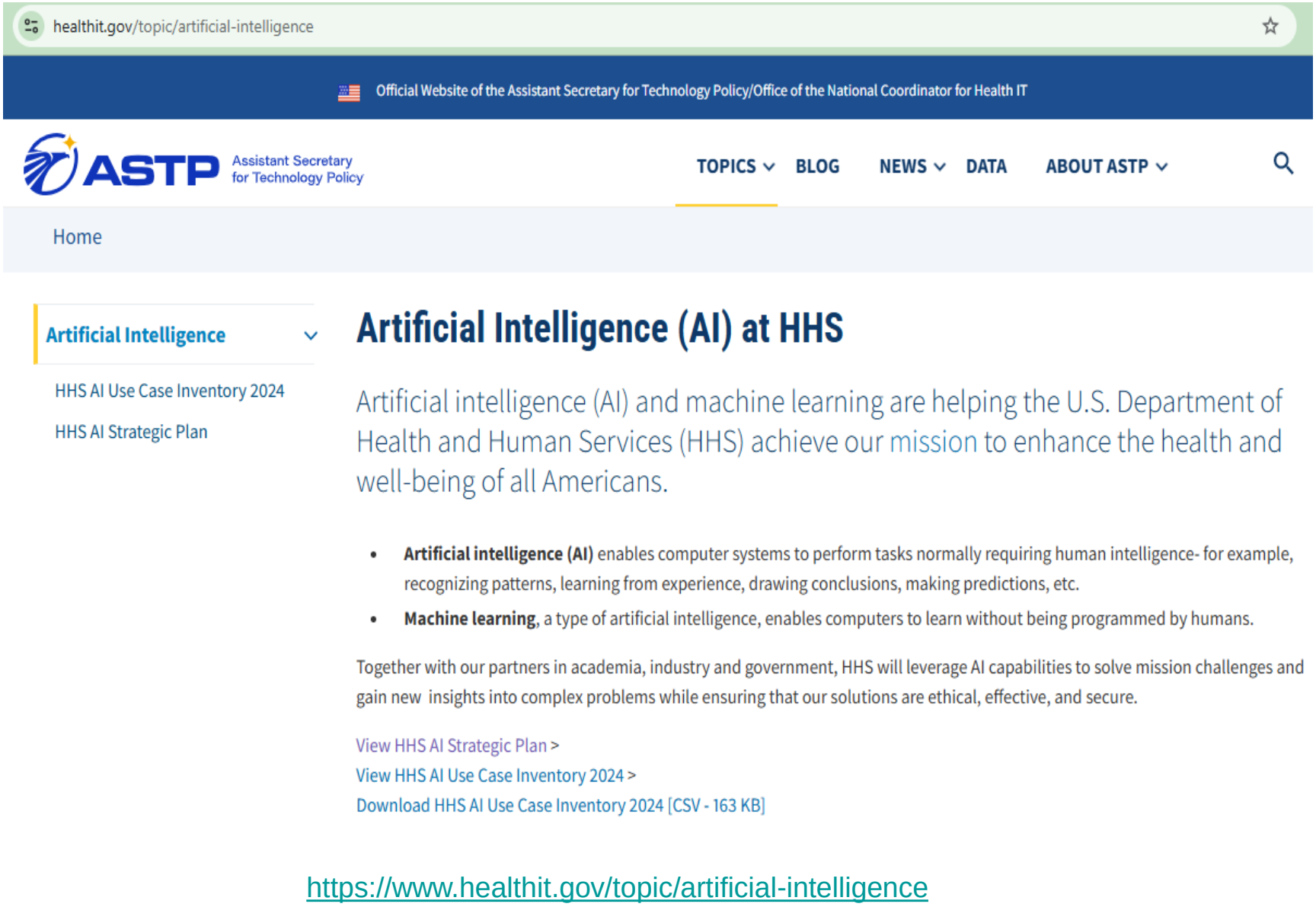
https://en.wikipedia.org/wiki/Artificial_general_intelligence

Tentative Course Outline for AI for Medicine II

WEEK	TOPIC
Week 1	Introduction to AI Methods and their Applications in Medicine
Week 2	Machine Learning Basics
Week 3	Data Collection and Preprocessing
Week 4	Supervised Learning
Week 5	Unsupervised Learning
Week 6	Model Evaluation and Performance Metrics
Week 7	Deep Learning in Medicine
Week 8	Medical Imaging and AI
Week 9	Natural Language Processing (NLP) in Healthcare
Week 10	AI in Diagnostics and Disease Prediction
Week 11	AI in Personalized Medicine, Treatment Planning, Drug Discovery
Week 12	AI in Medical Robotics and Genomics
Week 13	Challenges and Limitations of AI in Medicine, and Future Trends
Week 14	Course Review and Project Presentations

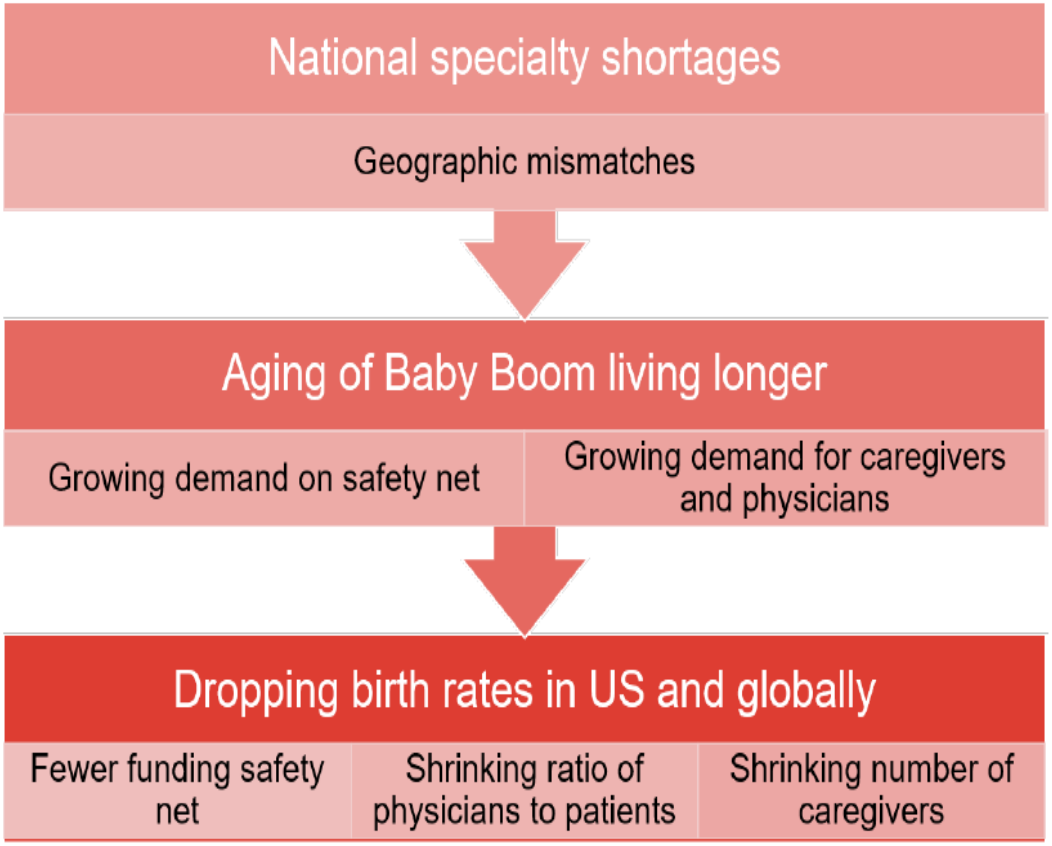
Introduction to AI Methods and their Applications in Medicine

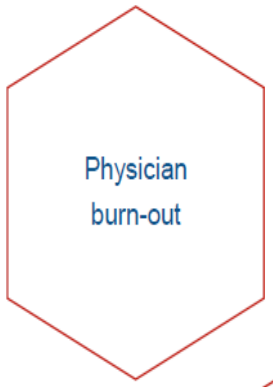
- Artificial Intelligence (AI) has emerged as a transformative force in healthcare, offering innovative solutions to longstanding medical challenges.
- AI methods have revolutionized medicine, enhancing diagnostics, treatment, and patient care. While challenges remain, continuous innovation and ethical considerations will drive AI's successful integration into healthcare systems worldwide.
- By leveraging AI methods such as machine learning, deep learning, and natural language processing, medical professionals can enhance diagnosis, treatment, and patient care.



https://www.healthit.gov/topic/artificial-intelligence

No ordinary trends….





https://www.healthit.gov/sites/default/files/page/2020-02/GettingerModeratorSlidesAIPanelsforONCAnnualMeeting12720Final.pdf

Learning From Practice

35% of doctors report **burn-out.**[1]

56% **do not "have time"** to be **empathetic.**[2]

[1] Shanafelt, Tait D., et al. "Changes in burnout and satisfaction with work-life balance in physicians and the general US working population between 2011 and 2014." *Mayo Clinic Proceedings*. Vol. 90. No. 12. Elsevier, 2015.

[2] Riess, Helen, et al. "Empathy training for resident physicians: a randomized controlled trial of a neuroscience-informed curriculum." Journal of general internal medicine 27.10 (2012): 1280-1286.

Source: CSC 2541: Machine Learning for Healthcare

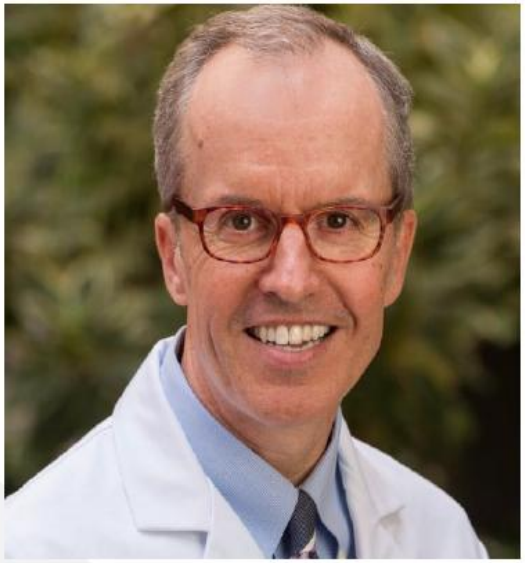
presence.
The Art & Science of Human Connection.

Stanford MEDICINE

The Office of the National Coordinator for Health Information Technology

"Will AI ever replace radiologists?

I say the answer is no—but radiologists who use AI will replace radiologists who don't."



Curtis P. Langlotz, MD, PhD

Professor of Radiology and Biomedical Informatics

AI Methods (in Medicine)

- Preprocessing Methods:

  AI/ML preprocessing methods are techniques used to prepare raw data for machine learning models. These methods are crucial because the quality and format of the data significantly impact the performance of AI models.

- Machine Learning (ML):

  Machine Learning is a subset of AI that involves training algorithms to learn patterns from data and make predictions or decisions without being explicitly programmed.

- Deep Learning (DL):

  Deep Learning is a subset of ML that uses neural networks with multiple layers to model complex patterns in data.

AI Methods (in Medicine)

- Natural Language Processing (NLP):

  NLP involves the interaction between computers and human language. In medicine, NLP is used to extract information from clinical notes, automate medical coding, and develop chatbots for patient interaction.

- Computer Vision:

  Computer vision involves the analysis of visual data. In medicine, it is used for tasks like detecting abnormalities in medical images, tracking surgical instruments, and monitoring patient movements.

- Expert Systems

  Expert systems are rule-based systems that emulate the decision-making ability of a human expert. They are used in clinical decision support systems to provide diagnostic recommendations based on patient data.

Preprocessing Methods

- By applying the preprocessing methods, you can ensure that your data is clean, well-structured, and ready for training machine learning models. The choice of preprocessing techniques depends on the type of data (e.g., numerical, categorical, text, images) and the specific requirements of the machine learning algorithm being used.
  - Data Cleaning
  - Data Transformation
  - Feature Engineering
  - Dimensionality Reduction
  - Handling Imbalanced Data
  - Text Preprocessing
  - Image Preprocessing
  - Time Series Preprocessing
  - Splitting Data
  - Noise Reduction
  - Handling Skewed Data
  - Encoding and Scaling
  - Handling Multicollinearity

Machine Learning (ML) Methods

- **Supervised Learning**

  Supervised learning involves training a model on labeled data, where the input and output are known. The model learns to map inputs to outputs, making it useful for tasks like disease classification and risk prediction.

- **Unsupervised Learning**

  Unsupervised learning involves training a model on unlabeled data, where the model identifies patterns or structures in the data. This is useful for clustering patients based on similar characteristics or identifying novel disease subtypes.

- **Reinforcement Learning**

  Reinforcement learning involves training a model to make a sequence of decisions by rewarding desired behaviors. This is particularly useful in dynamic environments like robotic surgery, where the system learns optimal actions through trial and error.

Deep Learning (DL) Methods

- **Convolutional Neural Networks (CNNs)**

  CNNs are particularly effective for image analysis tasks, such as detecting tumors in medical images or classifying skin lesions in dermatology.

- **Recurrent Neural Networks (RNNs)**

  RNNs are designed for sequential data, making them suitable for tasks like time-series analysis in patient monitoring or natural language processing in clinical notes.

- **DL Transformers Networks**

  Transformers have revolutionized deep learning, particularly in natural language processing (NLP), by addressing limitations of previous architectures like RNNs and CNNs. The most famous example is probably the BERT model or GPT models.

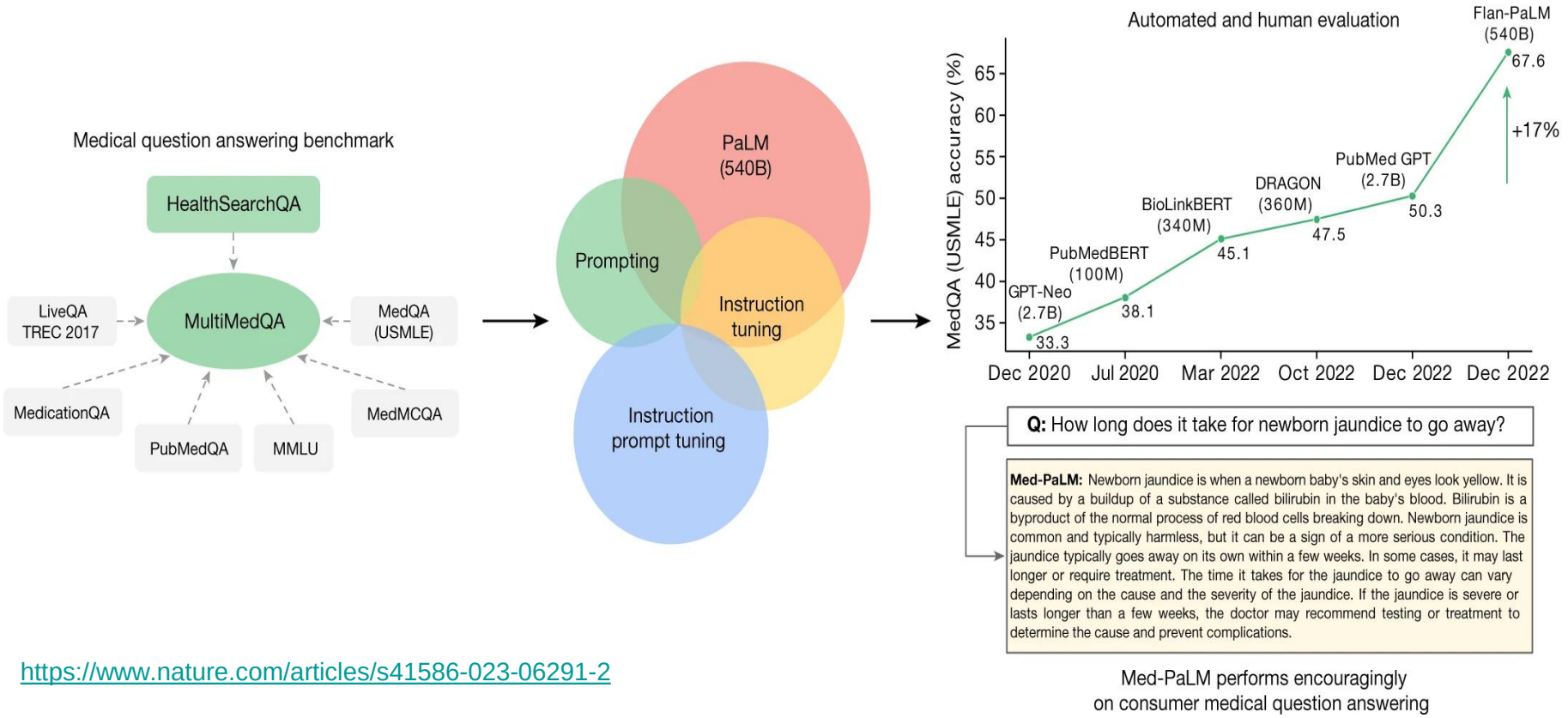
- **Generative Adversarial Networks (GANs)**

  GANs consist of two neural networks that compete to generate realistic data. In medicine, GANs can be used to generate synthetic medical images for training or to enhance low-quality images.

Natural Language Processing (NLP) Methods

- NLP methods continue to evolve with advancements in deep learning and transformer-based models. These techniques are widely used in applications like chatbots, sentiment analysis, machine translation, and more, making NLP a critical component of modern AI systems.
  - Text Preprocessing Methods
  - Text Representation Methods
  - Language Modeling
  - Text Classification
  - Machine Translation
  - Text Generation (GPT: Generative Pre-trained Transformers)
  - Information Extraction
  - Sentiment and Emotion Analysis
  - Speech-to-Text and Text-to-Speech Conversion

Large language models encode clinical knowledge



https://www.nature.com/articles/s41586-023-06291-2

We curate MultiMedQA, a benchmark for answering medical questions spanning medical exam, medical research and consumer medical questions. We evaluate PaLM and its instructed-tuned variant, Flan-PaLM, on MultiMedQA. Using a combination of prompting strategies, Flan-PaLM exceeds state-of-the-art performance on MedQA (US Medical Licensing Examination (USMLE)), MedMCQA, PubMedQA and MMLU clinical topics. In particular, it improves over the previous state of the art on MedQA (USMLE) by over 17%. We next propose instruction prompt tuning to further align Flan-PaLM to the medical domain, producing Med-PaLM. Med-PaLM's answers to consumer medical questions compare favourably with answers given by clinicians under our human evaluation framework, demonstrating the effectiveness of instruction prompt tuning.

Computer Vision Methods

- Computer vision methods are widely used in applications like autonomous vehicles, facial recognition, medical imaging, augmented reality, and more. With advancements in deep learning and neural networks, computer vision continues to evolve, enabling machines to understand and interpret visual data with increasing accuracy and efficiency.
  - Image Preprocessing Methods
  - Feature Extraction Methods
  - Object Detection
  - Image Classification
  - Image Segmentation
  - Object Tracking
  - Facial Recognition and Analysis
  - Image Generation and Synthesis
  - 3D Computer Vision
  - Video Analysis

Expert Systems Methods

- Expert Systems are a branch of artificial intelligence (AI) that emulate the decision-making ability of a human expert in a specific domain. They use a combination of knowledge representation and inference engines to solve complex problems by reasoning through knowledge, often represented as rules or facts.
- Knowledge Representation
- Ontologies
- Logic-Based Systems
- Inference Engines
  - Rule-Based Reasoning
  - Case-Based Reasoning (CBR)

Applications of AI in Medicine

- **Diagnostic Assistance**

  AI is increasingly being used to assist in the diagnosis of various medical conditions.

- **Imaging and Radiology**

  AI algorithms, particularly CNNs, are used to analyze medical images such as X-rays, CT scans, and MRIs. These algorithms can detect abnormalities like tumors, fractures, and infections with high accuracy, often surpassing human performance.

Applications of AI in Medicine

- **Pathology**

  AI is used to analyze pathology slides, identifying cancerous cells and other abnormalities. This can reduce the workload of pathologists and improve diagnostic accuracy.
- **Dermatology**

  AI algorithms are used to classify skin lesions based on images, aiding in the early detection of skin cancer and other dermatological conditions.
- **Predictive Analytics**

  AI is used to predict patient outcomes and disease risks based on historical data.
- **Disease Risk Prediction**

  AI models can predict the likelihood of developing diseases such as diabetes, cardiovascular disease, and cancer based on patient data, enabling early intervention.

Applications of AI in Medicine

- **Patient Outcome Prediction**

  AI can predict patient outcomes such as hospital readmission, mortality, and response to treatment, helping clinicians make informed decisions.

- **Personalized Medicine**

  AI is used to tailor medical treatment to individual patients based on their genetic makeup, lifestyle, and other factors.

- **Genomic Medicine**

  AI is used to analyze genomic data to identify genetic mutations associated with diseases and to develop personalized treatment plans.

- **Drug Discovery and Development**

  AI is used to accelerate drug discovery by predicting the efficacy and safety of potential drug candidates, reducing the time and cost of bringing new drugs to market.

Applications of AI in Medicine

- **Clinical Decision Support Systems (CDSS)**

  AI-powered CDSS provide clinicians with evidence-based recommendations for diagnosis and treatment, improving the quality of care and reducing errors.

- **Robotic Surgery and Assistance**

  AI is used in robotic surgery to enhance precision and control, reducing the risk of complications and improving patient outcomes. AI-powered robots can also assist in tasks like suturing and tissue manipulation.

- **Virtual Health Assistants and Chatbots**

  AI-powered virtual health assistants and chatbots provide patients with information, reminders, and support, improving patient engagement and adherence to treatment plans.

Applications of AI in Medicine

- **Administrative Applications**

  AI is used to streamline administrative tasks in healthcare, improving efficiency and reducing costs.
- **Electronic Health Records (EHR) Management**

  AI is used to automate the management of EHRs, including data entry, coding, and retrieval, reducing the administrative burden on healthcare providers.
- **Resource Allocation and Scheduling**

  AI is used to optimize resource allocation and scheduling, ensuring that patients receive timely care and that healthcare facilities operate efficiently.
- **Integration with IoT and Wearable Devices**

  The integration of AI with IoT and wearable devices will enable continuous monitoring of patients, providing real-time data that can be used to improve diagnosis and treatment.