

APPLICATIONS OF ARTIFICIAL INTELLIGENCE IN ORTHOPAEDICS: CURRENT AND FUTURE PERSPECTIVES

Abstract

Artificial intelligence (AI) is evolving as a promising technology in various fields including healthcare, revolutionizing various aspects of diagnosis, treatment planning, and patient care. By utilizing machine learning algorithms and deep neural networks, AI has the potential to enhance the accuracy and efficiency of orthopaedic procedures. One significant application of AI in orthopaedics is in the diagnosis of musculoskeletal conditions. AI algorithms can analyze medical images, such as X-rays, CT scans, and MRIs, to detect fractures, tumors, and other abnormalities with high precision. This can aid orthopaedic surgeons in making accurate diagnoses, predictions and determining the most appropriate treatment strategies. Furthermore, AI can assist in treatment planning by providing predictive models and personalized recommendations. AI algorithms can help identify the most effective treatment options for individual patients by researching and analyzing patient's data. This can result into reduced treatment costs and better patient care.

Keywords; Artificial intelligence (AI), Machine learning, Deep learning, Neural network

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I. ARTIFICIAL INTELLIGENCE: A CUTTING EDGE TECHNOLOGY

Artificial Intelligence (AI) is a branch of computer science that aims to create machines that can work like human brain and mimic, simulate, and execute tasks requiring human intelligence. These machines are designed to perceive their environment, reason about the information they receive, and make decisions like human being to achieve the desired goal. AI as a concept dates back to ancient times, with myths and legends featuring artificial beings capable of human-like actions. However, modern AI development began in the mid-20th century. Today, AI has emerged continuously, with rapid ongoing research pushing the boundaries of what machines can achieve, leading us closer to the realization of Artificial General Intelligence. In 1956, John McCarthy introduced the concept of AI, which proposed that computers could learn and accomplish tasks by recognizing patterns without significant human input. A contemporary and more accurate definition of AI refers to the utilization of algorithms that enable machines to solve problems that typically demanded human intelligence. This involves creating computer systems capable of learning, reasoning, and making decisions with minimal human intervention.

Artificial intelligence (AI) is a state-of-the-art technology that is revolutionizing various domains, notably healthcare. It entails crafting intelligent machines capable of performing tasks that usually demand human intelligence. These machines employ algorithms and learn from data to make predictions, identify patterns, comprehend natural language, and even make decisions. AI has witnessed remarkable progress in healthcare, finance, transportation, and education. In healthcare, for instance, AI algorithms can analyze medical data and aid in disease diagnosis, treatment planning, and outcome prediction. In finance, AI is utilized for fraud detection, algorithmic trading, and automated customer service. Self-driving cars exemplify AI's application in transportation. Additionally, AI-driven virtual assistants like Siri and Alexa have become pervasive in daily life.

AI's potential is vast, promising to transform industries, boost efficiency, and generate novel opportunities. Nonetheless, it also poses certain challenges, encompassing ethical concerns, job displacement, and privacy issues. As AI progresses, its impact is expected to soar, leading to breakthroughs such as advanced robotics, natural language processing, and deep learning. With continuous research and development, AI holds the potential to offer innovative solutions to intricate problems and become an integral part of our future society.

AI Technologies and Techniques include:

- 1. Machine Learning (ML):** Machine learning is a subset of AI that allows systems to enhance their performance without explicit programming. ML algorithms process vast datasets, detect patterns, and use those patterns to make predictions or decisions.
- 2. Deep Learning:** Deep learning is a subset of ML that uses artificial neural networks (ANNs) inspired by the biological structure of the human brain. Deep learning algorithms can process and analyze complex, unstructured data such as images, audio, and text, leading to advanced pattern recognition and decision-making capabilities. ANN and CNN are two important types of neural networks used in artificial intelligence. Artificial Neural Network (ANN) is a computational model inspired by the human brain's structure and functionality. It comprises interconnected nodes, known as neurons, which

process and transmit information. ANN learns from data through a process called training, where it adjusts the weights and biases of the connections between neurons to improve its performance on a specific task. ANN can be used for various purposes, such as pattern recognition, regression analysis, and decision-making. CNN, or Convolutional Neural Network, is a specialized type of ANN commonly used for image and video processing tasks. It is designed to automatically learn and extract features from visual data. CNN incorporates specialized layers, such as convolutional layers and pooling layers that perform operations like convolution and down sampling to identify patterns and spatial relationships in images. CNNs have proven to be highly effective in tasks like object detection, image classification, and image segmentation. While ANN and CNN are both neural networks, they differ in architecture and application. ANN is a more general-purpose network that can be used for a wide range of tasks, including non-visual data processing, while CNN is specifically tailored for processing visual data. The unique architecture of CNNs allows them to efficiently handle the complex and hierarchical nature of visual patterns, making them particularly suitable for tasks in computer vision.

- 3. Natural Language Processing (NLP):** NLP enables computers to understand, interpret, and generate human language, both written and spoken. It involves tasks such as speech recognition, language translation, sentiment analysis, and chatbot interactions.
- 4. Computer Vision:** Computer vision involves the use of AI algorithms to interpret and understand visual information from images or videos. It enables computers to recognize objects, scenes, and patterns in images, and is used in various applications like facial recognition, object detection, and autonomous driving.
- 5. Robotics and Automation:** AI is integrated into robots and automated systems to enable them to perform tasks autonomously or with minimal human guidance. This includes various applications such as industrial automation, surgical robots, and autonomous vehicles.

AI has transformative implications in various fields, including healthcare, finance, transportation, education, and more. It offers opportunities to enhance decision-making, automation, efficiency, and productivity. However, it also raises ethical concerns, such as privacy, bias, and job displacement, which need to be addressed.

II. AI AND HEALTHCARE: TECHNOLOGY LEARNING HUMAN MIND

There are several AI software applications currently being used in healthcare across various specialties and domains. Some of the common AI software applications used in healthcare include:

- 1. Electronic Health Records (EHR):** AI is used to analyze and interpret large amounts of patient data, including medical records, lab results, and clinical notes, to support decision-making, assist in diagnosis, and optimize treatment plans.
- 2. Clinical Decision Support Systems (CDSS):** CDSS integrates patient data with medical knowledge and guidelines to offer real-time recommendations and alerts to healthcare

providers. AI algorithms assist in analyzing patient data, identifying patterns, and providing personalized treatment suggestions.

- 3. Medical Imaging Analysis:** AI technologies are extensively used for analyzing medical images, such as X-rays, CT scans, MRIs, and ultrasounds. These applications can aid in the detection, segmentation, and classification of various medical conditions, including tumors, lesions, and abnormalities.
- 4. Drug Discovery and Development:** AI software is employed in pharmaceutical research to analyze vast datasets, genetic information, and molecular structures. It can assist in rapid drug discovery, target identification, and optimization of clinical trials, potentially accelerating the development of new medications.
- 5. Natural Language Processing (NLP):** NLP-based AI software helps in extracting and analyzing information from medical texts, such as research papers, clinical notes, and literature. It enables efficient literature reviews, information retrieval, and automated summarization for healthcare professionals.
- 6. Telehealth and Remote Monitoring:** AI-powered telehealth platforms and remote monitoring systems use algorithms to capture and analyze patient data, such as vital signs, symptoms, and patient-reported outcomes, allowing for remote diagnosis, real-time monitoring, and personalized interventions.
- 7. Chatbots and Virtual Assistants:** AI chatbots and virtual assistants are utilized to interact with patients, addressing their queries, offering basic medical advice, scheduling appointments, and providing healthcare-related information.

These are just a few examples of AI software applications currently used in healthcare. The field of AI in healthcare is rapidly evolving, and new applications and technologies continue to emerge, promising to improve patient care, clinical outcomes, and healthcare delivery.

III. AI IN ORTHOPAEDICS: TECHNOLOGY MEETS SKILLS

There are several AI technologies currently used in the field of Orthopaedics, including

- 1. Computer-assisted surgery:** AI is used to assist surgeons during surgeries, providing real-time feedback and guidance based on computer models and pre-operative imaging. It helps in accurate implant positioning, alignment, and surgical planning.
- 2. Predictive Analytics:** AI algorithms are utilized to analyze large volumes of patient data, including medical records, imaging scans, and genetic information, to predict outcomes and help in decision-making for treatment planning. This can aid in identifying potential risks, complications, and personalized treatment options.
- 3. Image Analysis:** AI algorithms are employed to analyze radiographic images, such as X-rays, CT scans, and MRIs, for detecting and diagnosing orthopaedic conditions, such as

fractures, degenerative changes, and tumors. It can assist in automated image interpretation and improve accuracy in diagnosis.

- 4. Rehabilitation and Motion Analysis:** AI-based motion analysis systems can track and assess patients' movement during rehabilitation exercises. By using computer vision, machine learning, and sensors, these systems can provide objective measurements, feedback, and personalized rehabilitation plans.
- 5. Wearable Devices:** AI is integrated into wearable devices, such as smart braces, orthotics, and prosthetics, to provide real-time feedback on patient movement and gait analysis. These devices can assist in monitoring progress, improving functional outcomes, and customizing treatment plans.
- 6. Virtual reality (VR) and Augmented Reality (AR):** AI technologies are employed in VR and AR-based training simulators for orthopaedic surgery residents and surgeons. These simulators can provide realistic surgical scenarios, haptic feedback, and objective performance metrics to enhance training and improve surgical skills.
- 7. Chatbots and Virtual Assistants:** AI-powered chatbots and virtual assistants are used to interact with patients and provide information about orthopaedic conditions, treatment options, and post-operative care. They can answer common questions, provide guidance, and help in scheduling appointments.

These AI technologies aim to enhance accuracy, efficiency, and overall patient care in Orthopaedics by assisting surgeons, improving diagnosis, personalizing treatments, and supporting rehabilitation processes.

IV. CURRENT AI TECHNOLOGIES USED IN VARIOUS DISCIPLINES OF ORTHOPEDICS

Table 1: Joint Reconstruction

AI Technologies	Purpose	Image analysis
VGG-16 Layer CNN	Diagnosis and severity of Osteoarthritis of hip and knee	Radiographs of hip and knee
CUDA/cuCNN	Severity of Knee Osteoarthritis	Radiographs of Knee
WND-CHRM	Prediction of Early Knee OA	T2 weighted MR images of knee
DenseNet CNN	Prediction of Early Knee OA	T2 weighted MR images of knee
Deep CNN	Detection of Implant Loosening	Radiographs of knee and hip
Deep CNN	Knee Implant Detection and Identification	Postoperative Radiographs

Deep CNN	Shoulder Implant Detection and Identification	Postoperative Radiographs
Naive Bayesian Model	Prediction of Length of Stay and Inpatient Costs for total hip & knee Arthroplasty	Patients hospital records
Lasso and SVM	Presurgical planning to improve workflow	Patients Hospital records
ANN and SVM	Implant Optimization	Postoperative Radiographs

Table 2: Spine

AI technology	Purpose	Analysis
Deep learning- AlexNet, GoogLeNet, ResNet-50, SqueezeNet	Automatic spine level identification	Ultrasound images of L1-S1 vertebral bodies
Deep learning- random forest	Automatic localization and identification of vertebrae	CT images
Deep learning- random forest and CNN	Automatic localization and identification of vertebrae	Spine CT with post-op and pathologic cases
Multilayer perceptron network	Categorizing back pain can be done in four distinct groups: simple back pain, radicular pain (associated with nerve root compression), pathologic pain (related to underlying medical conditions), and back pain with a significant psychological component	The clinical manifestations and previous medical records of 200 individuals experiencing back pain.
Deep learning- SVM	Image based diagnosis of lumbar herniation	MRI Lumbar spine

The role of artificial intelligence has significantly impacted the field of orthopedic oncology, particularly in the application of deep learning techniques. Various deep learning models have been employed for specific purposes in this domain. For instance, neural networks have been utilized to predict the survival rates of patients diagnosed with synovial sarcoma. EfficientNet-B0 convolutional neural networks (CNNs) have been leveraged to effectively differentiate between benign, intermediate, and malignant primary bone tumors, as well as to distinguish benign from malignant primary bone tumors. Inception v3, in conjunction with logistic regression, has been applied to predict the likelihood of local recurrence following intralesional curettage in giant cell tumors of bone. Multiple supervised residual networks have been employed for precise segmentation of osteosarcoma in CT images. Moreover, CNNs have been used for automatic segmentation, facilitating tumor burden calculation in prostate cancer bony metastasis.

In the field of sports medicine, the contribution of AI has been equally evident, with various applications of AI technologies. The MRNet CNN is employed for the detection of ACL and meniscal tears in Knee MRIs. Additionally, Support Vector Machine (SVM) and Random Forests models are utilized for the detection of Anterior Cruciate Ligament (ACL) injuries. Moreover, Fast-Region CNN (RCNN) and Faster-RCNN are employed for the detection of Meniscus tears.

V. AI IN ORTHOPAEDICS: CONFLICTS AND CONSTRAINTS

While AI indeed holds the potential to revolutionize orthopedics, there are several limitations and challenges that need to be addressed for its widespread adoption and successful integration in the field:

- 1. Limited Data Quality:** AI algorithms rely on large amounts of high-quality data to train and generate accurate predictions. However, collecting and curating high-quality orthopedic data can be a challenge, particularly when it comes to rare conditions or specific patient populations
- 2. Lack of Interpretability:** AI algorithms often provide predictions or recommendations without clear explanations of how they arrived at those decisions. This lack of interpretability can make it difficult for orthopedic surgeons to trust and fully understand the reasoning behind AI-generated suggestions.
- 3. Ethical Concerns:** The use of AI in orthopedics raises ethical considerations related to patient confidentiality, consent, and bias. Ensuring that patient data is properly anonymized and protected, obtaining informed consent for AI-based interventions, and addressing any biases in the algorithms are critical to maintaining patient trust.
- 4. Integration into Clinical Workflow:** Implementing AI systems into daily clinical practice can be challenging. Integration and compatibility with existing electronic health record systems, time constraints, and the need for additional training for healthcare professionals are factors that need to be carefully considered.
- 5. Generalizability:** AI algorithms trained on specific datasets may not always generalize well to different populations or clinical settings. Validation and testing of AI systems across diverse patient groups, geographical regions, and healthcare environments are crucial to ensure accuracy and reliability.
- 6. Legal and Regulatory Considerations:** The use of AI in orthopedics raises legal and regulatory concerns. Ensuring compliance with data protection, privacy, and medical device regulations is crucial to safeguard patient rights and ensure safe and responsible use of AI technologies.

Overall, while AI holds great promise in orthopedics, these challenges and limitations need to be carefully addressed to ensure its successful integration into clinical practice and to maximize its benefits for patients and healthcare providers.

VI. AI IN ORTHOPAEDICS: EXPECTATIONS HEREAFTER

The future of AI in Orthopaedics holds great potential for advancements in diagnosis, treatment planning, surgical guidance, and rehabilitation. Here are some areas where AI is expected to make significant contributions

- 1. Precision Medicine:** AI can analyze patients' medical records, genetic data, and imaging scans to identify patterns and develop personalized treatment plans. It can help predict patient outcomes, selecting the most suitable treatment options, and optimizing rehabilitation protocols.
- 2. Image Analysis:** AI algorithms will continue to advance in analyzing medical images, such as X-rays, CT scans, and MRIs, for improved accuracy in detecting orthopaedic conditions. AI can assist in early detection of fractures, identify subtle changes in joint degeneration, and aid in the diagnosis of musculoskeletal tumors.
- 3. Surgical Guidance:** AI can provide real-time feedback and guidance during orthopaedic surgeries, aiding in implant placement, alignment, and surgical precision. It can help surgeons achieve optimal positioning and improve surgical outcomes.
- 4. Predictive Analytics:** AI can leverage large datasets to predict patient outcomes, potential complications, and treatment responses based on various factors such as medical history, demographics, and preoperative imaging. This information can assist surgeons in making informed decisions and optimize treatment plans.
- 5. Rehabilitation and Monitoring:** AI-powered wearable's and motion analysis systems can aid in monitoring and guiding patients' rehabilitation progress. These technologies can assess patients' movements, provide real-time feedback, and personalize rehabilitation plans to optimize recovery.
- 6. Virtual Reality (VR) and Augmented Reality (AR):** AI can be integrated into VR and AR-based training simulators for orthopaedic surgeons and residents. These simulators can offer realistic surgical scenarios, haptic feedback, and objective performance evaluation, enhancing surgical skills and training efficiency.
- 7. Patient Education and Engagement:** AI-powered chatbots and virtual assistants can provide patients with personalized information, education, and support throughout their orthopaedic journey. They can answer common questions, offer guidance, assist in appointment scheduling, and improve overall patient experience.

While AI holds immense potential in Orthopaedics, it is essential to address challenges such as data privacy, ethical considerations, and integrating AI into clinical workflows. Collaboration between AI experts, orthopaedic surgeons, and healthcare providers will be crucial to ensure the successful implementation and translation of AI technologies into routine clinical practice.

VII. CONCLUSION

In conclusion, AI has the potential to transform orthopaedic practice by improving diagnosis accuracy, treatment planning, surgical guidance, prediction of outcome and rehabilitation programs. AI can also streamline surgical procedures by offering real-time guidance and decision support to orthopaedic surgeons. By integrating AI systems into the operating room, surgeons can receive immediate feedback on their actions, ensuring accurate implant placement and minimizing the risk of complications. Additionally, AI can facilitate robotic-assisted surgeries, allowing for increased precision and dexterity during complex orthopaedic procedures. While further research and development are needed, AI in orthopaedics holds the promise of enhancing patient care and outcomes in the field of musculoskeletal medicine.

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