Related Works on Personalized Healthcare using Artificial Intelligence

Djelloul Daouadji Fadela

April 22, 2025

Abstract

This report summarizes recent research and developments in the field of AI-based personalized healthcare. It highlights the key contributions, methodologies, and challenges faced by existing systems.

1 Introduction

The use of Artificial Intelligence (AI) in healthcare has opened new avenues for personalized treatment. This report reviews existing studies and methods used in AI-driven healthcare solutions.

2 Related Works

2.1 A Primer on Reinforcement Learning in Medicine for Clinicians

Article Reference: [1]

Overview

Reinforcement Learning (RL) is a machine learning approach that enhances clinical decision-making by addressing uncertainties and optimizing sequential treatment strategies. This review introduces RL to clinicians, emphasizing how it leverages patient data to generate personalized treatment plans that improve outcomes and resource efficiency. It also explores foundational RL concepts, applications, challenges, and future directions.

Categories of RL

- **Model-based RL:** Learns a model of the environment to simulate outcomes and make decisions. Example: AlphaZero.
- **Model-free RL:** Learns policies directly from experience without modeling the environment. Includes:

- *Value-based methods:* e.g., Q-learning, SARSA
- *Policy-based methods:* e.g., REINFORCE
- *Hybrid methods:* e.g., Actor-Critic

RL shifts AI in healthcare from prediction to actionable, real-time decision-making.
Applications in Healthcare RL has demonstrated potential in:

- Creating personalized treatment plans (e.g., chemotherapy, sedation, insulin dosing)
- Optimizing resource allocation in critical care (e.g., ventilator weaning, sepsis treatment)
- Enhancing adaptive interventions using offline RL and simulation environments

Evaluation Challenges Evaluation is constrained by safety, ethical, and logistical concerns. RL often relies on:

- Simulated environments
- Off-Policy Evaluation (OPE) methods like FQE and Doubly Robust methods

Implementation Issues Practical deployment of RL in healthcare is hindered by:

- Challenges in reward function design
- High-dimensional state and action spaces
- Necessity for domain expertise in clinical evaluation

Future Directions Future developments may include:

- Integration with Large Language Models (LLMs)
- Privacy-preserving learning (e.g., Federated Learning)
- Real-time adaptive interventions and decision support

Real-World Examples Examples include:

- DeepMind's AlphaZero and AI Clinician for sepsis treatment
- RL-based models for sedation weaning, cancer therapy, and insulin control
- Clinical trials like REINFORCE and glycemic control interventions

2.2 Reinforcement Learning Algorithms and Applications in Healthcare and Robotics: A Comprehensive and Systematic Review

Article Reference: [2]

Overview

Reinforcement learning (RL) is a powerful branch of artificial intelligence (AI) that enables agents to make intelligent decisions in dynamic and uncertain environments. This review explores the fundamentals of various RL algorithms, compares them, and emphasizes their applications in robotics and healthcare.
In robotics, RL enhances capabilities in tasks such as object manipulation and grasping. In healthcare, it is applied to optimize cell growth and aid in treatment development, demonstrating the broad utility of RL across different domains.

Methodology

The study follows a systematic literature review (SLR) approach to answer well-defined research questions. The methodology involves:

- Establishing specific research questions,
- Defining inclusion and exclusion criteria,
- Conducting structured searches across multiple databases.

This rigorous approach ensures the quality and relevance of the evidence used to evaluate current practices in RL applications.

Applications of Reinforcement Learning

The paper highlights two primary domains of RL application: **robotics** and **healthcare**. Here's an overview of each:

1. Robotics

- **Object Grasping and Manipulation:** RL algorithms are increasingly used to enhance robotic capabilities in grasping and manipulating objects. This area is rapidly evolving and has significant implications for automation in dynamic environments.
- **Precision and Adaptability:** Through trial-and-error learning, RL improves the precision and adaptability of robots, enabling them to perform complex tasks more effectively in real-world, unstructured settings.

2. **Healthcare**

- **Cell Growth Optimization:** RL is applied to optimize conditions for cell culture growth, contributing to advancements in biotechnology, particularly in drug discovery and cellular research.
- **Data-Driven Therapeutics:** By leveraging RL's data-driven nature, healthcare practitioners can enhance therapeutic strategies and improve biotechnological processes, leading to more efficient and targeted treatment development.

Challenges, Conclusions, and Future Directions

The review identifies several challenges in applying RL to robotics and healthcare:

- **Dexterity in Robotic Tasks:** Achieving fine motor control in robotic manipulation remains difficult.
- **Sample Efficiency:** RL algorithms often require large amounts of data, which can be costly or impractical.
- **Sim-to-Real Transfer:** Training in simulated environments does not always translate effectively to real-world performance.

Future Directions include:

- Improving sample efficiency through better exploration strategies,
- Developing transfer learning techniques to bridge the sim-to-real gap,
- Enhancing data collection frameworks to support RL in real-time applications.

2.3 Reinforcement Learning in Healthcare: Optimizing Treatment Strategies, Dynamic Resource Allocation, and Adaptive Clinical Decision-Making

Article Reference: [3]

Overview

Reinforcement Learning (RL) is an advanced paradigm within artificial intelligence (AI) that is particularly effective in optimizing complex, real-time decision-making processes in healthcare. By learning from continuous feedback, RL enables dynamic adjustments in treatment protocols, efficient resource allocation, and personalized clinical interventions. Its capabilities are well-suited for adaptive therapies, precision medicine, robotic-assisted surgery, and intelligent diagnostic systems. Despite its transformative potential, successful real-world deployment of RL in healthcare is contingent upon overcoming challenges related to data quality, model interpretability, and ethical compliance.

2.4 Applications of RL in Healthcare

- **Treatment Strategy Optimization:** Personalized drug dosing (e.g., chemotherapy, insulin, antihypertensives), sepsis management, and adaptive clinical trials.
- **Dynamic Resource Allocation:** ICU bed management, ventilator distribution during pandemics, and adaptive staff scheduling.
- **Clinical Decision Support:** Real-time diagnostic support, surgical planning using robotic systems, and emergency triage optimization.
- **Rehabilitation and Assistive Systems:** Adaptive physiotherapy, prosthetic limb control, and deep brain stimulation adjustment.

2.5 Challenges and Limitations

- **Data Limitations and Privacy:** Medical data is often sparse, fragmented, and governed by strict privacy regulations (e.g., HIPAA, GDPR), limiting the availability of high-quality training data.
- **Model Interpretability:** Many RL models function as "black boxes," making it difficult for clinicians to understand and trust their recommendations.
- **Ethical and Regulatory Issues:** Concerns around algorithmic bias, accountability, and the legal framework for AI-driven clinical decisions must be carefully addressed.

2.6 Future Prospects

- **Multi-Agent Reinforcement Learning:** Enabling coordinated care across multiple AI agents, particularly in complex hospital ecosystems.
- **Federated Learning and Blockchain Integration:** Supporting decentralized training across institutions while preserving data privacy and security.
- **Predictive Healthcare Analytics:** Using Deep RL and Transfer Learning for early disease detection, personalized risk assessment, and proactive intervention planning.

3 Conclusion

Personalized healthcare using AI continues to evolve, offering significant potential to improve patient care. However, integration into real-world clinical settings remains an ongoing challenge.

References

[1] Pushkala Jayaraman, Jacob Desman, Moein Sabounchi, Girish N. Nadkarni, and Ankit Sakhuj. A primer on reinforcement learning in medicine for clinicians. November 2025.

[2] Mokhaled NA Al-Hamadani, Mohammed A Fadhel, Laith Alzubaidi, and Balazs Harangi. Reinforcement learning algorithms and applications in healthcare and robotics: a comprehensive and systematic review. April 2024.

[3] Hassan Ali. Reinforcement learning in healthcare: optimizing treatment strategies, dynamic resource allocation, and adaptive clinical decision-making. January 2022.