

# Applications of Reinforcement learning for Medical Decision Making

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## Abstract

Reinforcement Learning(RL) is used for decision-making by interacting with uncertain/complex environments with the aim of maximizing long-term reward following a certain policy along with evaluative feedback for improvement. RL is advantageous in medical decision making compared to other forms of learning as it focuses on long-term rewards, it is also able to handle long and complex sequential decision-making tasks with sampled, delayed, and exhaustive feedback. It has emerged as a suitable method for developing satisfactory solutions in the healthcare domain. Improvement in the healthcare system can be achieved by integrating traditional health care practices with RL methods by considering health status of a patient. In this paper, we have discussed various applications of RL that would be helpful in providing effective decisions for improving patient health treatment, prognosis, diagnosis, and condition. RL could be effective in the area of healthcare right from medical diagnosis to handling various critical decision-making tasks. The paper provides a broad view of the various applications of RL in the sector of healthcare. The paper illustrates various RL applications that would be effective in improving the existing healthcare sector at same time being efficient in handling complex medical decision-making tasks.

## Keywords

Reinforcement Learning, Medical Decision Making, Healthcare, Medical Diagnosis

## 1. Introduction

In recent years, Reinforcement Learning has emerged as one of crucial area in field of artificial intelligence impacting the field of health care including diagnosis, prognosis, and other medical treatments. Reinforcement learning methods have been very useful for a long time in sequential decision-making tasks in robotics, gaming, and simulation like healthcare that are able to solve long and complicated decision-making tasks with the use of policies, aiming at maximizing reward as their final goal. Ini-

tially, RL has been used for treatment of patients in a closed-loop manner having varied advantages compared to supervised learning. Traditionally, supervised learning algorithms work on labeled data whereas RL has unique feature of finding the pattern in given problem statement and bound to learn from its experience. Also, Evolution in RL from the past to present has made it capable of handling various issues like exploration and exploitation, credit assignment, and at the same time maximizing the reward using the optimal policy for a specific medical decision-making task. RL has gained popularity among practitioners dealing with dynamic treatment regimes, medical diagnosis, and other decision-making tasks. Reinforcement learning has been applied for simulations in healthcare domains like drug dosage, examination time, assessment of patient's health status among others. Application of RL in medical decision mak-

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ing has to deal with patient health concern issues due to the risks involved in the medical treatment for a particular decision made by RL method. However, it is imperative to choose an optimal method for treatment of specified medical disease or medical condition.

## 2. Applications of Reinforcement Learning in medical decision making

Reinforcement learning in healthcare follows certain steps like agent (medical device/computer/equipment/system) that takes a particular action in medical environment using defined policy to get a specific reward and then uses evaluative feedback to improve its performance[1].RL provides various methods to solve sequential decision-making problems with the goal of maximizing reward by interaction with environment using trial and error method. Also, exploring and exploiting the environment for taking decisions by evaluative feedback from environment and learning effective strategies during the process. Reinforcement Learning has emerged as a prominent solution in decision-making tasks in medical sector and has application right from Dynamic Treatment Regimes, medical diagnosis to various other complicated and cognitive decision-making tasks.

1. **Dynamic Treatment Regimes(DTR)**  
-DTR designed for sequential decision-making problems by using reinforcement learning methods for developing policy with respect to automation for process of developing treatment regimes for patients by consideration of long term health benefits[2].

- a) **Chronic Diseases**-Chronic diseases persist for a long period of time.Hence, practitioners follow chronic care model(CCM) sequence of medical interventions to access patient health status[3].RL would be helpful to practitioners for continuous decision-making by helping in treatment of chronic diseases including anemia, cancer, diabetes, human immunodeficiency viruses(HIV), mental illnesses among many other long-lasting diseases.
  - i. **Cancer**- Q-learning with support vector regression and extremely randomized trees is used for treatment of cancers[4] like cell cancer, chemotherapy effect, and other cancer conditions.
  - ii. **Diabetes**-Proper sequential dosage of insulin in cases of Type 2 diabetes[5] with specified time and amount by application of reinforcement learning methods for getting long-term health benefit.
  - iii. **Anemia**-Lack of RBC that can be controlled using by RL method[6]by applying control input as the amount of endogenous erythropoietin and target under control is hemoglobin level that also has an impact on iron storage in the patient's body with the state component of hemoglobin and avoids any damage to patient body's by administering erythropoiesis-stimulating agent.
  - iv. **HIV**-HIV/human immunodeficiency virus[7] are treated with the combination of anti-HIV drugs that are referred to as highly active antiretro-

viral therapy(HAART) requires long term treatment using decision-making approach could be effectively dealt by using reinforcement learning algorithm like Batch RL.

- v. **Mental illness-** Mental illness usually persists for a long period of time requiring significant adaptations/changes in terms of dosage as well as treatment type involving very complex decision-making process. Thus, it can be handled using our RL approaches to solve the problems of Depression[8], Schizophrenia[9] among many other mental issues.
  - b) **Intensive/Critical Care-**RL method would prove to be helpful in cases of critical care treatment like mechanical ventilation[10] as well as treatment of diseases like sepsis[11] and other critical care treatment
    - i. **Sepsis** - Using model-based reinforcement learning techniques[11] with improvised policies has led to better treatment for the condition of sepsis in patients.
    - ii. **Anesthesia** - Anesthesia is the process of using specific drugs to reduce the effect of sensation in body with the use of RL-based control methods [12] like temporal difference to detect distribution of drug in patient's body.
    - iii. **Others Critical Situation** As RL method are used for handling decision making system in uncertain environment ,it would be effective in dealing with critical situation such as Mechanical Ventilation[10], Heparin Dosing[13] among other critical care conditions
2. **Medical Diagnosis-** Medical Diagnosis[14] is helpful in decision-making using RL with medical condition data in form of image and text data.
    - a) **Computer Vision**  
**Medical Image-** Medical Image data obtained from various computer vision techniques are used for feature extraction, image segmentation, localization, tracing, and object detection along with RL algorithm[15].
    - b) **Natural Language Processing**  
**Clinical text data-** Clinical text data has also been used for treatment of patients using RL method[14] that are able to diagnose inferences in RL methods like DQ method.
    - c) **Human-Computer Interface Dialogue Systems, Chat-bots, and Advanced Interfaces-** Multi-agent systems were found effective in monitoring clinical data using RL method for developing user interface that is able to adapt itself for specific user[16].
  3. **Other Medical Decision-making Tasks for healthcare systems**
    - a) **Resource scheduling and task allocation** - Resource allocation problem in RL are usually modeled using Markov Decision Process with reinforcement learning using appropriate policies to provide better service to the patient[17].
    - b) **Optimal Process Control** - Healthcare tasks like simulation of surgical operation, adaptive control for medical video streaming, and functional electric simulations policies control are used with RL methods like Q-learning, IRL, DRL among

others in the best possible way to achieve desired results[18].

- c) **Drug Discovery** -De novo design [19] has lead to development of RL methods for structural evolution and development of drugs using generative and predictive neural networks.
- d) **Patient Health Management** - Personalized Health Recommendation System[20] has developed by using functionality of RL methods to deal with consultation, dosage, nutrition and health activities.

### 3. Conclusion

The paper aims at providing a detailed overview for applications of reinforcement learning to solve a variety of decision-making problems in healthcare domain. Reinforcement learning applied in various healthcare ailments was found effective in providing optimal solutions for decision making in various healthcare tasks right from chronic diseases, medical diagnosis to various other healthcare decision-making problems. In this paper, reinforcement learning was found effective in dealing with medical data by using optimal policy resulting in maximizing long-term rewards. Application of reinforcement learning in healthcare will improve the performance of existing healthcare system by increasing the efficiency, safety, and robustness of handling real-time data for decision making in healthcare sector.

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