

## Review

# The Application of Reinforcement Learning to Pumps—A Systematic Literature Review

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**Abstract:** Reinforcement learning, a subset of machine learning in the field of engineering informatics, has revolutionized the decision-making and control of industrial pumping systems. A set of 100 peer-reviewed papers on the application of reinforcement learning to pumps, sourced from the Scopus database, were selected. The selected papers were subjected to bibliometric and content analyses. The existing approaches in use, the challenges that have been experienced, and the future trends in the field are all explored in depth. The majority of the studies focused on developing a control system for pumps, with heat pumps being the most prevalent type, while also considering their economic impact on energy consumption in the industry. Future trends include the use of Internet-of-Things sensors on pumps, a hybrid of model-free and model-based reinforcement learning algorithms, and the development of “weighted” models. Finally, ideas for developing a practical reinforcement learning-bundled software for the industry are presented to create an effective system that includes a comprehensive reinforcement learning framework application.

**Keywords:** bibliometric analysis; reinforcement learning; pump unit; control system; heating ventilation and air-conditioning systems



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## 1. Introduction

A pump is a mechanical device that converts electrical energy into hydraulic energy and uses it to move fluids or slurries. Pumps are used in a variety of industries, including water treatment plants; automobile factories; industrial plants; energy industries; oil and gas industries; heating, ventilation, and air conditioning (HVAC) systems; and medical facilities, among others. Pump performance research is primarily focused on two goals: improving pump reliability and lowering energy usage in the industry [1,2]. In the literature, there are several strategies based on artificial intelligence (AI) methods for solving the challenges mentioned above in a manufacturing firm [3]. Some of these AI methods include areas such as engineering informatics [4–7]. In our work, however, we limit our review to reinforcement learning techniques applied to pump systems. Pump reliability is frequently improved by forecasting the remaining useful life of the pump; examples can be found in some works (see [8,9]). Pump maintenance procedures that are optimized tend to lower maintenance costs, which in turn reduces industrial energy consumption [10,11]. However, the application of reinforcement learning to the pump system or rotating machinery comprising pumps shows an interesting trend toward better and improved control pumping systems that integrate the two-fold performance indices [12–14].

Reinforcement learning (RL), which is derived from a neutral stimulus and a response, is a type of machine learning algorithm that has grown in popularity due to its ability to

# 13 5 Review And Reinforcement

**Farhad Shahnian, Josep M. Guerrero**



### 13 5 Review And Reinforcement:

**Prentice Hall Chemistry** ,2000      El-Hi Textbooks & Serials in Print, 2005 ,2005      *Deep Learning and Its Applications for Vehicle Networks* Fei Hu,Iftikhar Rasheed,2023-05-12 Deep Learning DL is an effective approach for AI based vehicular networks and can deliver a powerful set of tools for such vehicular network dynamics In various domains of vehicular networks DL can be used for learning based channel estimation traffic flow prediction vehicle trajectory prediction location prediction based scheduling and routing intelligent network congestion control mechanism smart load balancing and vertical handoff control intelligent network security strategies virtual smart and efficient resource allocation and intelligent distributed resource allocation methods This book is based on the work from world famous experts on the application of DL for vehicle networks It consists of the following five parts I DL for vehicle safety and security This part covers the use of DL algorithms for vehicle safety or security II DL for effective vehicle communications Vehicle networks consist of vehicle to vehicle and vehicle to roadside communications This part covers how Intelligent vehicle networks require a flexible selection of the best path across all vehicles adaptive sending rate control based on bandwidth availability and timely data downloads from a roadside base station III DL for vehicle control The myriad operations that require intelligent control for each individual vehicle are discussed in this part This also includes emission control which is based on the road traffic situation the charging pile load is predicted through DL and vehicle speed adjustments based on the camera captured image analysis IV DL for information management This part covers some intelligent information collection and understanding We can use DL for energy saving vehicle trajectory control based on the road traffic situation and given destination information we can also natural language processing based on DL algorithm for automatic internet of things IoT search during driving V Other applications This part introduces the use of DL models for other vehicle controls Autonomous vehicles are becoming more and more popular in society The DL and its variants will play greater roles in cognitive vehicle communications and control Other machine learning models such as deep reinforcement learning will also facilitate intelligent vehicle behavior understanding and adjustment This book will become a valuable reference to your understanding of this critical field

El-Hi Textbooks and Serials in Print ,2006      **Handbook of Robotic Surgery** Stênio de Cássio Zequi,Hongliang Ren,2024-10-02 Handbook of Robotic Surgery serves as a primer covering the main areas of knowledge in robotic surgery This comprehensive book provides essential information on all aspects related to robotic surgery from the present up to the future The discussion presented in sections ranges from the historical background of robotic surgery up to more recent and future technological innovations such as remote controls surgically distant collaboration simulators modern surgical robotics fluorescence guided surgery and virtual reality The book also contains sections dedicated to the safety conditions in surgery and patient protection which will be suitable for surgeons health professionals biomedical engineering professionals healthcare administrators and students There are specific chapters for all areas in which robotic surgery has been used in

daily clinical practice or is under development Written by doctors engineers and nurses thus eliminating communication barriers and making it accessible for health and engineering professionals Provides initial literature offering a broad overview of all aspects of robotic surgery that will serve as a solid theoretical base for future developments in robotic subfields Analyzes cost effectiveness of robotic surgery discussing its use in developing countries ethics medical legal aspects education training mentorship leadership certification of professionals and credentialing of robotic centers Contributed to by key opinion leaders from several nations and continents taking into account different socioeconomic and cultural regional realities which can influence the widespread use of robotic surgery in the world SPI/CI 52nd Annual Conference and Exposition 1997 Technomic,Spi,2022-01-26 This book is a collection of the marketing technical regulatory sessions of the Composites Institute s International Composites EXPO 97 held at Nashville Tennessee on January 27 29 1997 Advanced Concrete Technology Set John Newman,B S Choo,2003-11-06 Based on the Institute of Concrete Technology s advanced course this new four volume series is a comprehensive educational and reference resource for the concrete materials technologist An expert international team of authors from research academia and industry has been brought together to produce this unique reference source Each volume deals with different aspects of the properties composition uses and testing of concrete With worked examples case studies and illustrations throughout this series will be a key reference for the concrete specialist for years to come Expert international authorship ensures the series is authoritative Case studies and worked examples help the reader apply their knowledge to practice Comprehensive coverage of the subject gives the reader all the necessary reference material Technical Abstract Bulletin Defense Documentation Center (U.S.),1964 **Clinical and Organizational Applications of Applied Behavior Analysis** Henry S. Roane,Joel E. Ringdahl,Terry S. Falcomata,Wiliam Sullivan,2025-10-01 Clinical and Organizational Applications of Applied Behavior Analysis Second Edition offers a comprehensive revision that delves into data based decision making to guide treatment selections for behavior changes across various populations and contexts This edition s chapters thoroughly address vital aspects such as data collection single case research design methodology objective decision making and visual data inspection The book s updated content ensures that practitioners are well equipped to implement effective and evidence based procedures in diverse settings from schools and homes to community environments In addition to these foundational topics the revised edition introduces new chapters that explore integrated healthcare adjudication of children s academic interventions and applied animal behavior The book highlights the applied behavior analysts role in utilizing research to develop and execute effective procedures especially for addressing behaviors linked with autism and other developmental disorders The principles of this therapeutic approach have shown increasing effectiveness when applied to a broader range of populations settings and behaviors Reviews current evidence based practices to provide a comprehensive guide to the application of ABA principles across a range of clinical contexts and applications Divides clinical applications into three sections for ease of use Child adult

and broad based health Explores the breadth of ABA based treatment beyond autism and developmental disorders Includes new chapters on applications of behavior therapy to disadvantaged youth culture and diversity and sexual development in IDD

**Childhood Depression** Kevin Douglas Stark,1990-08-03 It is now generally acknowledged that depression is as much a disorder of childhood as of adulthood Yet it is also clear that the manifestation of depression in children is more varied complex and difficult to detect It may for instance show up in the form of anger somatic symptoms or lowered school performance While school professionals are often the first to recognize that a child has a problem they may be unable to accurately diagnose it as depression or provide any treatment within the school setting Childhood Depression is designed specifically for school practitioners who wish to increase their understanding of depression in children so that they may identify it assess its severity and plan appropriate interventions In this book Kevin Stark provides a thorough review of the empirical basis for the diagnosis of depression in children and detailed information on how to make this assessment He also describes a multi component treatment program cognitive behavioral family therapy and school consultation which has been validated with a large number of children The main feature of this volume is the step by step description of how to implement such a program A session by session outline case examples and clinical insights are given and the author provides an array of treatment related methods i e the pleasant events schedule exercises to facilitate cognitive restructuring and sample behavioral contracts which further enhance the book s usefulness Childhood Depression is a concise practical and up to date guide for any professional working with school age children It is particularly relevant for school psychologists counselors social workers administrators and students in these areas

**Fire Management Notes** ,1982 *From Animals to Animats* 13 Angel P. del Pobil,Eris Chinellato,Ester Martínez-Martín,John Hallam,Enric Cervera,Antonio Morales,2014-07-08 This book constitutes the proceedings of the 13th International Conference on Simulation of Adaptive Behavior SAB 2014 held in Castell n Spain in July 2014 The 32 papers presented in this volume were carefully reviewed and selected for inclusion in the proceedings They cover the main areas in animat research including the animat approach and methodology perception and motor control navigation and internal world models learning and adaptation evolution and collective and social behavior

**From Animals to Animats 3** Dave Cliff,1994 August 8 12 1994 Brighton England From Animals to Animats 3 brings together research intended to advance the front tier of an exciting new approach to understanding intelligence The contributors represent a broad range of interests from artificial intelligence and robotics to ethology and the neurosciences Unifying these approaches is the notion of animat an artificial animal either simulated by a computer or embodied in a robot which must survive and adapt in progressively more challenging environments The 58 contributions focus particularly on well defined models computer simulations and built robots in order to help characterize and compare various principles and architectures capable of inducing adaptive behavior in real or artificial animals Topics include Individual and collective behavior Neural correlates of behavior Perception and motor control Motivation and emotion Action selection and behavioral

sequences Ontogeny learning and evolution Internal world models and cognitive processes Applied adaptive behavior Autonomous robots Hierarchical and parallel organizations Emergent structures and behaviors Problem solving and planning Goal directed behavior Neural networks and evolutionary computation Characterization of environments A Bradford Book

**Bibliography of Medical Reviews**, 1966      EBOOK: Psychology 5e HOLT, 2023-02-09 The fifth edition of Psychology The Science of Mind and Behaviour continues to build on its strong biopsychosocial approach and balancing of classical and contemporary theory The celebrated pedagogical design has been reinforced with additional pedagogical features and real world issues to offer an exciting and engaging introduction to the study of psychology The fifth edition has been fully updated to reflect new developments in the field and the scientific approach brings together international research and practical application to encourage critical thinking about psychology and its impact on our societies and daily lives Key features Brand New The Bigger Picture takes a step back and reflects on how a subject can be interpreted from different angles Replacing the Levels of Analysis feature the Bigger Picture explores not only the biological psychological and environmental levels but also cultural and developmental aspects as well Brand New Learning Goals and Review Questions encourage students to consider the core learnings of each chapter and critically assess their real world implications New and Updated Psychology at Work interviews from Psychologists in the field are now included in every chapter They provide a glimpse into their day to day work and the career path they have taken since completing a psychology degree Research Close Ups reflect new research and literature as well as updated critical thinking questions to encourage analysis and evaluation of the findings Current issues and hot topics such as Covid 19 fake news workplace psychology social media prosociality and critical perspectives of positive psychology prompt debates on the questions facing psychologists today Nigel Holt is Head of Department of Psychology at Aberystwyth University Wales Andy Bremner is Professor of Developmental Psychology and Head of Education at the University of Birmingham UK Michael Vliek is an affiliate of the University of Amsterdam The Netherlands and lectures at the University of Leiden The Netherlands Ed Sutherland is an Associate Professor in Psychology and Director of Learning and Teaching at the University of Leeds UK Michael W Passer is an Associate Teaching Professor at the University of Washington USA Ronald E Smith is Professor Emeritus of Psychology at the University of Washington USA

*ICFIMEMM - 2016* S. Aravindan, R. Shanmuga Prakash, 2016-10-10 International Conference on Futuristic Innovations in Mechanical Engineering and Manufacturing Management Selected peer reviewed papers from the International Conference on Futuristic Innovations in Mechanical Engineering and Manufacturing Engineering and Manufacturing Management ICFIMEMM 2016 March 30 31 2016 Karur India      Psychopharmacology Bulletin, 1978      **Microgrids and Virtual Power Plants** Farhad Shahnia, Josep M. Guerrero, 2024-11-01 This book highlights recent research advancements in the area of microgrids and virtual power plants Microgrids and virtual power plants are the future of power generation and delivery systems and there has been significant research interest in this area over the past decade The key emphasis of this book is on

the various modelling analysis and management aspects of microgrids and virtual power networks Interesting topics such as their planning operation and technology accommodation are presented in detail The chapters in the book discuss existing and new modelling approaches control and management methods as well as their structures planning monitoring protection and coordination This book introduces and covers these topics in a comprehensive and coherent way for professionals and researchers

**Cumulated Index Medicus** ,2000      **An Introduction to Behavior Analysis** Gregory J. Madden,Derek D. Reed,Florence D. DiGennaro Reed,2021-05-10

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