CHAPTER 56

TECHNOLOGY
INSTRUMENTATION AND CONTROL
ENGINEERING

Doctoral Theses

01. ABHISHEK KUMAR
Reinforcement Learning based Adaptive Control of Non Linear System.
Supervisor : Dr. Rajesh Sharma
Th 24185

Abstract
(Verified)

Reinforcement learning finds application in several real world problems, e.g., e-commerce, medicine, control engineering etc. owing to its ability to handle complex systems. In the context of control engineering, RL has been used to find optimal policy by modeling the environment as Markov Decision Process. To leverage RL MDP formulation is required, which is not always practically feasible. In our view, more autonomy is required in designing controllers for situations where human interference is fatal, e.g., rescue & search and space exploration. In such cases, an autonomous agent/controller must be designed to choose a safe and reliable action. Lack of stability guarantee is also a hurdle in applying RL to practical systems apart from "curse of dimensionality" issue. In the present work, we focus on the above issues. We have used bootstrapping to overcome some of the MDP shortcomings; introduce stability aspect in RL using Lyapunov's direct method and "curse of dimensionality" is taken care of by utilizing function approximators. Main contribution of this dissertation is infusing lyapunov stability criteria into the RL framework by: i) hybridizing lyapunov theory with RL and ii) constraining the controller action set using lyapunov theory linguistically, in RL, to give safe and reliable control action. Domain knowledge has been used to integrate lyapunov's direct method for constraining the action sets. Moreover, we also propose stable Markov game controller to generalize MDP to a multi agent RL setting by designing a stable "two player zero sum" game. We simulate our proposed RL based controllers on several nonlinear systems and compare the results with baseline controllers and some other recently proposed controllers to show its efficacy in terms of stability and reliability.

Contents

02. GOPAL
Analysis of Biometric Applications using Soft Computing Methods.
Supervisor : Prof. Smriti Srivastava
Th 24186

Abstract
(Verified)

Biometrics is a widely researched topic from last many decades which is used in personal security, public banking, forensic investigation and many more. This thesis focuses on data acquisition, pre-processing, feature extraction and different fusion schemes of biometric recognition system which are desired in a typical biometric system. The main focus is on multimodal biometric approaches to overcome the drawbacks of unimodal biometrics. In this thesis, a novel multilevel fusion of palm print and dorsal hand vein is proposed. Novel feature level fusion rules are suggested to spatially combine the information of the data samples. After feature level fusion, score level fusion is applied with dorsal hand vein and feature fused vectors from palm print. To validate its robustness, noise at different level of intensity is artificially added to the test samples. A novel adaptive histogram equalization (AHE) variant is proposed referred as effective area-AHE with weights and it is improved using a local AHE technique by varying the effective area with different effective weights. Next, a noise robust palm print recognition system is discussed with a novel feature extraction technique: two dimensional cochlear transform (2D-CT) based on the textural analysis of image sample. Orthogonality of 2D-CT is proved which shows the robustness of proposed 2D-CT to noise. Then, a multimodal personal authentication system using palm print, dorsal hand vein pattern and a novel biometric modality ``palm-phalanges print'' is presented. We propose fusion of three different biometric modalities which includes palm print (PP), palm-phalanges print (PPP) and dorsal hand vein (DHV) and perform score level fusion of PP-PPP, PP-DHV, PPP-DHV and PP-PPP-DHV strategies. Next, it has been shown that each finger phalanges can be used as biometric modality and give moderate/sufficient performance for low accuracy system. To further enhance the performance, score level and feature level fusion strategies are applied and compared.

Contents

03. GOYAL (Divya)
Design and Analysis of Current Conveyor Based Fractional Order Systems.
Supervisor : Dr. Pragya Varshney
Th 24184

Abstract
(Verified)

The real world physical processes are dynamic in nature. Mathematically, their dynamics are represented as integer order systems. Ease in designing and on chip availability are the key motivation behind vast utilization of integer order systems. However, this representation is an approximation of their performance. To obtain an accurate implementation of these procedures, it is beneficial to realize them as fractional order systems. Fractional order calculus provides advantageous solution for the processes in the fields of biomedical, fluid mechanics, advanced signal processing and real time controllers. In this thesis, focus is to design the analog model for fractional order systems. Integrators and differentiators of fractional orders are designed with current mode active elements as basic building block. CMOS realizations of these active elements are used to implement the fractional circuits. A fractional order element (FOE) is introduced in the circuit to provide fractional impedance and henceforth, the circuit operates like a fractional system. Analog realization of the FOE comprises of passive elements arranged in a

RC network. Value of these passive elements can be calculated using different methods. Similarly, their arrangement in different topologies is also feasible. In-depth analysis of numerous methods for implementing and designing the FOE has been done. The emphasis is on design of active elements based realizations of fractional circuits, which use grounded passive elements and grounded FOEs. As a result, the designs become simpler and are less sensitive to parasitic effects. Monte Carlo analysis has been performed to validate the robustness of the designed models. Also, influence of non-idealities of active elements on the performance of fractional order systems has been investigated. Comparisons with other related work have been presented to substantiate the proposed work.

Contents

1. Introduction 2. Current Conveyor based fractional order current integrator 3. Current conveyor based fractional proportional-integrator(FPI). 4. Differential voltage current conveyor transconductance amplifier based fractional order differ-integrators 5. Differential voltage current conveyor transconductance amplifier based integer order applications 6. Conclusions and suggestions for further work. References. List of publications. Biographical sketch.

04. NANDAN KUMAR NAVIN

Intelligent Adaptive Control of Nonlinear Systems Using Soft Computing Techniques

Supervisor : Dr. Rajneesh Sharma

Th 24285

Abstract
(Verified)

Unit commitment problem (UCP) is a nonlinear mixed integer optimization problem for minimizing overall generation cost and to schedule the operation of the generating units while satisfying power demand under several equality and inequality constraints. UCP is an optimization task for determining the on/off schedule of the generating units at each hour of planning horizon. Economic power dispatch (EPD) is a constrained power optimization and energy management problem in power system operation and control. Main aim of solving EPD is to find optimal power generation among the units for a given hour of scheduling to minimize the fuel costs of each unit and to satisfy equality constraints of power balance and inequality constraints of power output. In this thesis, two methods have been proposed for solving problems of various thermal unit commitment and economic power dispatch; one is through Meta-heuristic techniques i.e. Modified Differential Evolution (hybridizing differential evolution with shuffled frog leaping algorithm) and the other one is through Multiagent Fuzzy Reinforcement Learning Approach. Keywords: Multiagent fuzzy reinforcement learning, Gaussian shuffled differential evolution, unit commitment problem, economic power dispatch

Contents

1. Introduction 2. Potential optimization techniques 3. Potential optimization techniques for solution of unit commitment 4. Potential optimization techniques for solution of economic dispatch 5. Contributions and conclusions. Bibliography. Appendix.

05. NAIR (Sreejith S)
Some Investigations on Design and Analysis of Digital Filters.
Supervisors: Prof. K. P. S. Rana and Dr. Vineet Kumar
Th 24188

Contents

06. RAJESH KUMAR
Design and Implementation of Intelligent Controllers For Dynamical Systems.
Supervisors: Prof. Smriti Srivastava and Prof. J. R. P Gupta
Th 24187

Abstract
(Verified)

The thesis deals with the design and implementation of intelligent controllers for the dynamical systems. The main aim is to develop control strategies for the nonlinear dynamical systems using the Artificial Neural Networks (ANNs). For this, we have proposed several modifications in the existing ANN structures. In particular, several recurrent types of ANNs are proposed in this thesis. These networks not only contain the dynamics in the form of feedback loops (which constitutes the memory) in their structures but also require fewer TDLs to work with the nonlinear systems. The proposed design approach considered in this thesis doesn't require the dynamics of the plant under consideration to be known. In fact, ANN based identification model will also run in concurrence with the controller. The effectiveness of the proposed scheme depends upon the performance of the learning algorithm chosen. In literature, many evolutionary algorithms are available like Particle Search Optimization (PSO), Gravitational Search Algorithm (GSA), water drop method, Genetic Algorithm (GA) etc. All these techniques have been successfully applied in training the ANN models. But these techniques are quite complex and they don't ensure the stability of the system. We know that Lyapunov stability method is very effective in determining the stability of the nonlinear systems and dynamic back-propagation (DBP) is one of the simplest algorithms to implement. So, we have used Lyapunov stability method, heuristic method and DBP method to develop these new learning algorithms. Detailed simulation study has been carried out in this thesis for evaluating the performance of the proposed ANN structures and the learning algorithms. In the study, various complex benchmark nonlinear systems such as inverted pendulum, robotic manipulators etc. have been used on which the proposed methods are tested. The robustness analysis of the proposed schemes is also carried out.

Contents

systems 9. Conclusion and the future scope. Bibliography. Work published based on this thesis. Technical biography of author.

07. SHRIVASTAVA (Nitisha)
Analysis and Design of Fractional Order Differ – integrators.
Supervisor: Prof. Pragya Varshney
Th 24183

Abstract
(Not Verified)

The study deals with finding novel modulators of radiation injury using zebrafish as organism model. Amelioration of radiation induced injuries were assessed as end points in zebrafish embryo to find novel leads from John Hopkins Clinical Compound Library (JHCCL). Two small molecule, viz. ethynodiol diacetate (ED) and scopolamine methyl bromide (SMB) were identified from the library as radiomodulators in pre and post radiation scenario. ED was further evaluated under 30 days survival assay in murine model. ED exhibited 66.6% and 33.3% survival advantage respectively in pre and post radiation scenario. *In vitro* tumor sensitization studies performed with ED exhibited DMF (dose modifying factor) of 0.86 in A549 cell line. *In vivo* sensitization assay revealed 3 fold reduction in tumour volume and growth delay of 11 days. A 0.53 log cell kill was observed with ED and 15 Gy. ED also exhibited 9 days delay with a 0.24 log cell kill as a chemotherapeutic agent. *In silico* studies were done to assess functional targets that were modulated, succumbing radiation injury. A ChIN model was adopted and developed in the embryos to study immune markers of inflammation viz. neutrophils and macrophage. Semi-quantitative gene expression studies for inflammatory enzymes and cytokines were performed after radiation injury at two time points (6hoursand 24 hours). Both the molecules were majorly found to modulate inflammation acting as a glucocorticoid receptor agonist (ED, Binding Energy (B.E) -9.0 Kcal/mol) and Cox-2 antagonist (SMB, B.E -8.0 Kcal/mol). ED also has antioxidant potential (0.26 and 0.93 fold reductions in DCFDA fluorescence and MDA absorbance respectively) and SMB has anti-apoptotic potential (6%reduction in sub G1 population, 1.19 folds reduction in caspase-3 levels). These results suggest that ED and SMB are potential candidates that can be further evaluated in higher mammals for amelioration of ionising radiation induced injuries.

Contents

08. VIJAY MOHAN
Stability Analysis and Control of Non-Linear Systems using Intelligent Techniques
Supervisors : Prof. Vijander Singh and Prof. Asha Rani
Th 24212

Abstract
(Verified)

The present work aspires to design expert control strategies for nonlinear dynamic systems. These systems are difficult to control owing to the uncertain behaviour, external disturbances

and noise. Hybrid intelligent controllers derived from precise mathematical formulae are proposed for the purpose. The controller parameters are obtained using multi objective nondominated sorting genetic algorithm-II. The designed controllers are tested on two-link robotic manipulator and Double Inverted Pendulum (DIP). A Non-Linear Fractional order PID controller (NLF-PID) is designed for two-link manipulator by cascading a non-linear hyperbolic function of instantaneous error and current state with fractional order PID. The non-linear function provides adaptive control ability whereas fractional operator enhances the flexibility of controller. Results prove that NLF-PID provides robust and efficient control of robotic arm. Further fractional order fuzzy PID (FOFPI+D) is derived from FOPI and FOD schemes in discrete domain and formula-based fuzzy design is embedded in the derived control law. BIBO stability of control system is also proved graphically. FOFPI+D shows superior performance over existing control schemes. The efficient control of robotic manipulator requires simultaneous handling of multiple issues, therefore 2DOF fractional order fuzzy PI minus fractional order derivative filter is designed (2DOF FOFPI-D). The proposed controller provides robust and efficient control of robotic arm as compared to other designed controllers. Genetic algorithm tuned fuzzy controller and adaptive neuro-fuzzy controller are proposed for stabilizing and maintaining angular position of DIP. A suitable function is proposed to modify training data set of neuro-fuzzy inference system leading to Modified Neuro-Fuzzy Controller (MNFC). Comparative analysis reveals that MNFC exhibits superior control of DIP system as compared to LQR and fuzzy logic controllers in terms of IAE, settling time, overshoot and steady state error. It is thus revealed that expert control strategies provide an efficient solution for nonlinear dynamic systems.

Contents