Preface

Synthesizing and evolving intelligent behaviour, analyzing natural processes and biological systems, and imitating their behaviour in complex artificial systems are considered major challenges in artificial life and intelligent systems design. Addressing these challenges requires crossing boundaries between various disciplines and thinking across established fields of study. In this context, mathematical and computational methods, and analysis and modelling tools, which are used in innovative ways, are critical to get insights that go beyond conventional knowledge domains.

This book brings together researchers from various disciplines whose work aims to address issues related to the above mentioned challenges. It is a collection of original research and development work in artificial life, analysis, and modelling of living systems and real world applications. It can play the role of a reference for those working in the area as it captures the state-of-the-art and provides insight into the future of artificial life and intelligent systems research. It can also be used as an advanced upper-level course supplement and resource for instructors to help them design activities that would assess the benefits of the various approaches and technologies. High-level undergraduate and postgraduate students can find in this book examples of artificial life and intelligent systems design and implementation that cover key stages in their development, and analyses of how they are performing or perceived by users. It may benefit readers from different disciplines helping them to gain holistic view of the various aspects of analysis, design, and synthesis, and technologies’ deployment for complex artificial systems.

The book is organized in three parts. In Section 1, “Analysis and Modelling of Living Systems,” contributions address open problems in living systems through new models, frameworks and methods for describing biological and cognitive functions, natural processes and phenomena, and examine their potential to provide real-world solutions. Developing a comprehensive understanding of the operation of living systems, and of their components and ways they communicate with each other play a key role in deciphering life processes. Chapters of this part combine hypothesis-driven experimentation with computer-based modelling and simulation to analyse and model biological functions, natural phenomena, and real life behaviours.

Section 2, titled “Mathematical and Analytical Techniques with Applications,” presents mathematical and analytical techniques for modelling living systems and provides insights on how these can be exploited further in real-world applications. The importance of mathematics in the study of living systems and in the development of artificial life applications is well established. Advances in applied mathematics have facilitated the extension and development of analytical approaches and techniques, which are frequently supported by computer simulation, in order to tackle some challenging real problems in this area.

Section 3, titled “Intelligent Information Processing and Applications,” focuses on knowledge-based and data-driven computational methods for modelling and exploratory data analysis of biological and cognitive processes. It proposes intelligent information processing and representation models that in-
corporate Artificial Intelligence (AI) techniques, such as symbolic AI, fuzzy logic and neural systems. Heuristic search and real world test cases are also employed to evaluate the effectiveness of the computations in applications.

In what follows, an overview of the book chapters is presented.

SECTION 1: ANALYSIS AND MODELLING OF LIVING SYSTEMS

In *Resistance of Cell in Fractal Growth in Electrodeposition*, Shaikh, Khan, Patange, Pathan, and Behere present a study of dynamic electrical resistance of the electrodeposition cell. Electrodeposition is a technique commonly used for the growth of metallic dendritic patterns, which often exhibit fractal pattern formations. The authors aim to explore the patterns developed as a result of Diffusion Limited Aggregation (DLA), which is often encountered in various processes in physical and chemical sciences, and engineering. To this end, the electric resistance of the circular electrodeposition cell is measured in real time using a computer-based data acquisition system. Their acquisition system has been designed for this particular study and is implemented based on standard analogue to digital controller ADC interfaced to the computer through the printer port. It allows cell voltage and current through the cell to be sampled at pre-defined intervals and measures the dynamic electrical resistance of the electrodeposition cell during growth. The findings suggest that the study of growth pattern under constant electric field conditions could help improving our understanding of the DLA.

*Propagation of Front Waves in Myelinated Nerve Fibres: New Electrical Transmission Lines Constituted of Linear and Nonlinear Portions,* by Nkomidio and Woafo, is a study that aims to improve our understanding of the impulse propagation in myelinated nerve fibres. To this end, the authors consider Ranvier nodes as nonlinear portions and myelin sheath as linear portions. Moreover, they extend the results of their analysis to the propagation of front waves in electrical transmission lines with alternated linear and nonlinear portions. The work explores in particular the effects of the components of the linear portion on the profile and velocity of the wave. Through numerical simulations, the authors show that the front wave introduced in the nonlinear portion deforms itself in the linear portion but recovers its initial profile and velocity in the next nonlinear portion. This form of deformation and recovery can be used for the development of new and low cost electrical transmission lines for high amplitude nonlinear signals, and for the research of neuronal prosthesis.

In *What Does Artificial Life Tell us about Death?* Gershenson discusses how concepts developed within artificial life (ALife) can help demystify the notion of death in living systems. The aim is to provide insights on how living information can be maintained and/or reproduced in digital systems. Adopting the general notion of life as a process or organization and describing living systems from a functional perspective, the author examines notions of death from a systematic point of view. Within this perspective, different notions of death can be derived from different notions of life, resulting in loss of organization. In addition, the author explores the relations between notions of life and death and the mind, cognition, awareness, and consciousness. A criterion is proposed in which the value of a living system depends on its uniqueness and replaceability. In general, living systems are difficult to replace because of their epigenesis, i.e. the information acquired in their lifetime through experience. In ALife however, it is easy to maintain and reproduce the organization acquired through development of digital organisms, as epigenetic information can be stored and replicated.
A Constructive Approach to the Evolution of the Planning Ability by Minoya, Unemi, Suzuki, and Arita explores the dynamics inherent in the mechanism of evolutionary acquisition of planning abilities in social environments. They adopt a constructive approach which attempts to create not only a symbolic model of a living system but also a symbolic living object. Their model is elaborated without direct and precise reference to empirical biological reality. A blocks world problem is used as a task to be solved by the agents and encode an inherent planning parameter into the genome. Simulation experiments show there is a general tendency for planning ability to emerge when the problem is difficult to solve. When considering social relationships, especially in the collective situation, the planning ability is difficult to evolve when the problem is complex because there is a conflict between personal and collective interests. Also, the simulation results indicate that sharing information facilitates evolution of the planning ability, although the free rider problem tends to be more serious in this case than in the case where the agents do not share information. According to the authors, the results imply that there is a strong link between evolution of the planning ability and symbolic communication. These findings provide insight into the mechanism of the co-evolutionary dynamics of the planning and symbolic communications when two kinds of groups, sharing and no sharing information, coexist in the same population.

In Noise Power Spectrum for Firecrackers, Patange, Khan, Behere, and Shaikh investigate the sound of firecrackers which is a type of intensive impulsive noise that is hazardous. It is well known that noise is often a limiting factor for the performance of a device or system. In the context of living systems, the term “noise” is associated with variance amongst measurements obtained from identical experimental conditions. The authors experiment with noise produced by firecrackers during celebration festivals in Aurangabad, India. The noise is analyzed from the study of power spectra for different types of firecrackers. Noise measurements of firecrackers show that they produce high sound pressure peak levels at their characteristics frequencies. Plots of noise power versus frequency for different crackers are presented and the inferences are discussed. Typical firecracker peak noise levels are also described. As frequency of noise can affect human beings in different ways, the findings of this study may provide further insight into the extent environmental noise affects biological functions and the relation between external noise and noise that depends on intrinsic system properties.

In the same vein, Traffic Noise: 1/F Characteristics by Patange, Khan, Behere, and Shaikh explores the characteristics of the so-called pink noise. Samples of Traffic Noise are collected from selected locations from busy roads of Aurangabad city in Maharashtra state (India) and the data are analyzed. It is observed that in many cases the traffic noise possesses pink noise (1/f noise) prevailing over appreciable range of frequency. The log-log plot of noise power versus frequency results in a straight line with a slope approximately equal to unity confirming the presence of pink noise. After certain frequency, the noise power no longer behaves like pink noise (1/f noise) and becomes more or less constant with random fluctuations. Plots of noise power versus frequency on log-log basis for different locations studied are presented and the inferences are discussed. The results could contribute to our understanding of the environmental noise and the extent the natural environment influences the behaviour of living systems.

SECTION 2: MATHEMATICAL AND ANALYTICAL TECHNIQUES WITH APPLICATIONS

Existence of Positive Solutions for Generalized p-Laplacian BVPs, by Lian, Wong, Lo, and Yeh, concerns a mathematical problem which arises when modelling living systems. It is widely acknowledged that nonlinear equations and numerical analysis techniques are important to the description of complex multi-component systems, in general, and living systems in particular. In this work, the authors exam-
ine the existence of positive solutions for nonlinear boundary value problems (BVP). In particular, the authors look at multiple solutions for higher order BVPs with p-Laplacian operator. Their theoretical results have implications for a class of BVPs that has received attention because a number of physical, biological, and chemical phenomena are described in this way.

In Mathematical Model to Assess the Relative Effectiveness of Rift Valley Fever Countermeasures, Gaff, Burgess, Jackson, Niu, Papelis, and Hartley study mathematical modelling of infectious diseases. This is an area that has attracted attention because it concerns the mechanics of disease propagation, intervention strategies, and control, as well as sensitivity of countermeasures. The authors use a Rift Valley Fever (RVF) model to study the efficacy of countermeasures to disease transmission parameters. RVF is a viral infectious disease that propagates through infected mosquitoes and primarily affects animals but also humans. The RVF model consists of a deterministic ordinary differential equation system that predicts the spread of RVF in mosquitoes and a livestock population. Disease control and countermeasures for RVF include the application of insecticide to vector populations targeting either adult mosquitoes or mosquito larvae, livestock vaccination, or finally culling of exposed and/or infected animals. The authors first extend the mathematical model of RVF to include transmission of RVF between two vector populations and a single livestock population. The new model allows them to experiment with four types of disease intervention strategies: vector adulticide, vector larvicide, livestock vaccination, and livestock culling. They explore each of these approaches through simulation for various degrees of intensity and efficacy of intervention and evaluate the sensitivity of the models to the various disease transmission parameters. Results suggest that, under certain conditions, livestock vaccination, and culling offer the greatest benefit in terms of reducing livestock morbidity and mortality. As there is currently lack of comparative evaluation studies between countermeasures for RVF, this work can provide decision maker insights about disease intervention strategies and control.

Uribe-Sanchez and Savachkin, in Resource Distribution Strategies for Mitigation of Cross-Regional Influenza Pandemics, develop new pandemic mitigation models that offer dynamic decision support capabilities. Their aim is to assist public health policy makers in developing effective dynamic predictive distribution strategies of limited resources during influenza pandemics. The authors study the evolution of disease, the population dynamics and employ simulation optimization to generate dynamic resource distribution strategies. While the underlying simulation mimics the disease and the population dynamics of the affected regions, their optimization model generates progressive allocations of mitigation resources, including vaccines, antivirals, healthcare capacities, and social distancing enforcement measures. The proposed approach minimizes the impact of ongoing outbreaks and the expected impact of the potential outbreaks, considering measures of morbidity, mortality, and social distancing, translated into the cost of lost productivity and medical expenses. The model was implemented on a simulated outbreak involving four million inhabitants and compared to pro-rata and myopic strategies. The pro-rata policy allocates the total available resources to all network regions a-priori, in proportion to the regional population, while the myopic policy allocates the available resources from one actual outbreak region to the next, each time trying to cover the entire population at risk of the region. The simulation results provide evidence that on average, the new strategy outperforms both the pro-rata and the myopic policy at all levels, providing efficient resource utilization.

A Computational Model of Mitigating Disease Spread in Spatial Networks, by Kim, Li, Zhang, Sen, and Ramanathan, examines the problem of damage spreading and containment in spatial networks. The authors focus on disease spreading in two-dimensional fixed-radius random networks, and pay particular attention on the kinematics of disease spreading with respect to how damage is controlled by their
model. They propose control strategies that are potentially relevant in diverse contexts spanning a range of spatial and temporal scales, such as culling during epidemics in farm animals, fire fighting to wildfires and social bullying in community networks. In addition, they analyze both the sensitivity of disease progression and the effect of the containment process with respect to various parameter settings as well as the correlation of model parameters. The findings of this study suggest that the radius of containment process is the most critical parameter, e.g. the kinematics of the spatial-temporal patterns is particularly sensitive to the radius of the containment process region. Thus finding the best available values in the computational model would allow reducing damages from disease spread of a future pandemic. Insights from this study can be useful to control other virus spread problems in spatial networks, such as disease spread in a geographical network and virus spread in a brain cell network.

Easton, Carlyle, Hunt, Anderson, and James’ work, titled *Simulating the Spread of an Epidemic in a Small Rural Kansas Town*, is concerned with the spread of infectious diseases and the impact of mitigation strategies. Predicting whether or not a disease impacts an entire town and becomes a pandemic is extremely sensitive to changes in probabilities or mitigation strategy, and has an immense impact on the number of infected individuals. In this context, mathematical models have been used to derive interesting theoretical results, such as how fast a disease dies out and how a disease spreads from host to host. Also, substantial research has been dedicated to simulating the spread of infectious diseases with a focus on major urban centres. In contrast to existing models, which assume that time is divided into periods and each individual is classified in a particular state for an entire period, the authors generate a contact network to simulate how the disease spreads and consider multiple different states. Their work also exploits the concepts of disease tracks, which enable different groups of individuals to have distinct disease paths. Thus, each disease track could be associated with different parameter values. Furthermore, the contact network enables the diseases to spread according to the individual’s habits. Moreover, the authors focus on people living in rural areas, who have drastically different interaction and travel patterns than urban people. They demonstrate the use of their model and simulation package in modelling and predicting the spread of an epidemic on a small rural town and the effectiveness of various mitigation strategies.

*A Structural Model to Investigate Factors Affect Patient Satisfaction and Revisit Intention in Jordanian Hospitals*, by Al-Refaie, investigates the factors, including hospital performance, hospital stay, hospital facilities, interaction with patients, service quality, and patient security culture, that have an impact on patient satisfaction and revisit intention in Jordanian hospitals. The author combines qualitative and quantitative methods in order to model patient satisfaction and uses structural equation modelling as a means to empirically support the effectiveness of the derived models. The study employs data collected from five main hospitals and shows that hospital performance has no significant effect on patient satisfaction and revisit intention. The findings indicate that patients are facing difficulties with admission and registration services as well as waiting and response time for test results. Also, hospital stay, hospital facilities, service quality, and patient security culture are found to play an important role in achieving patient satisfaction and revisit intention. This form of analysis and modelling based on patient’s perceptions can contribute to our understanding of the extent hospitals meet patient’s expectations and can be useful to hospital managers to determine service design requirements and delivery improvements that contribute to patient satisfaction and revisit intention. Moreover, the findings of this work can provide assistance to policy makers and planning managers in determining the factors that improve hospital performance, maintain quality medical services, and plan future improvements in the design and development of medical health care services in Jordan.
In *Generating Fully Bounded Chaotic Attractors*, Elhadj investigates how dynamical systems make a transition from regular behaviour to chaos. The issue of generating chaotic attractors has several applications in artificial intelligence and artificial life application where nonlinear dynamics emerge. The author explores a particular class of 2-D nonlinear mappings, which has been widely studied because it is the simplest example of a dissipative map with chaotic solutions. In this case, fully bounded chaotic attractors emerge for all bifurcation parameters. The work describes in detail the dynamical behaviour of this map and discusses other dynamical phenomena. The work presents some phase portraits and discusses dynamical properties of the given simple family of fully bounded 2-D discrete mappings, revealing some new chaotic attractors.

The issue of constructing self similar patterns is investigated by Singh, Mishra, and Jain in the context of fractal geometry. Their work, titled *Orbit of an Image under Iterated System II*, concerns orbital pictures that are expressed in terms of transformations of an Iterated Function System-IFS. An orbital picture of this type is a mathematical structure that is developed by following the path of an object under IFS. This is typically implemented by using one-step feedback process namely, the function iterative procedure. Although, the one-step process works well for contractive transformations, sometimes problems arise when the transformations are non-contractive. The authors extend previous work introducing the role of superior iterative procedure to find the orbital picture under IFS. They use this procedure to generate orbital pictures of different variability for non-contractive and non-expansive transformations using two-step feedback process. Their algorithm mode is experimentally evaluated. The findings show that the superior iterative procedure generally works very well to construct orbital pictures in case of non-contractive transformations. Moreover, it converges smoothly wherein one-step process does not converge. This means that the sequence of objects obtained by superior iterations gives an attractive orbital picture, while the sequence of objects obtained by the function iterative procedure oscillates and does not converge towards a regular pattern. These promising results demonstrate the potential of this approach to compute 2-variable orbital pictures, which is useful in computational mathematics and fractal image processing applications, e.g. biological modelling, computer graphics, image compression, and in other application areas of fractal geometry.

Along the same line the work titled *Superior Koch Curve* by Prasad investigates the design of Superior Koch Curve with different scaling factor. The Koch curve is the limiting curve obtained by applying the self similar divisions to infinite number of times. In the Koch curve, self-similar patterns can be obtained by dividing a line into three equal parts and replacing the middle segment of this straight line by a triangle of the same length as the segment being removed and then applying this construction an infinite number of times on the resulting segments. This process of fractals construction yields an iterated function system. The particular curve proposed in this work has been designed using the technique of superior iteration, i.e. the scaling factor is based on superior iteration. The proposed design approach has implication in a range of real world applications, such as computer graphics and antenna miniaturization.

SECTION 3: INTELLIGENT INFORMATION PROCESSING AND APPLICATIONS

Chowdhury, Scoglio, and Hsu, in *Mitigation Strategies for Foot and Mouth Disease: A Learning-Based Approach*, study models that learn from data to predict the spread of the Foot and Mouth Disease (FMD) in time. Their work is in the field of predictive epidemiology studying disease dynamics in order to predict future outbreaks. This is an area where several analytical spatio-temporal models exist to spatially locate epidemic outbreaks in time mainly employing explicit mathematical models. In contrast, the authors’
approach is data-driven, assuming that spatial information regarding disease dynamics is imprecise, and exploits learning-based predictive models as a promising alternative. In their formulation, local information regarding the temporal evolution of infection is hard-coded in geographical regions, and a utility function is defined to assess the cost-effectiveness of mitigation strategies. Their study analyzes temporal predictions from neural network, autoregressive, Bayesian network, and Monte-Carlo simulation models which are validated using FMD incidences reported in Turkey. The findings support their claim that it is possible to generalize local learning-based models to recover the latent spatial parameters. In addition, the authors perform simulations of mitigation strategies based on the predictive models to study the cost-effectiveness of culling, vaccination and movement strategies in order to minimize the total number of infected livestock at the end of a period under study. They conclude that neural networks are better predictors than other models and that vaccination and movement ban strategies are more cost-effective than premise culls only before the onset of an epidemic outbreak.

In *Considerations on Strategies to Improve EOG Signal Analysis*, Wissel and Palaniappan explore on Human-Computer Interfaces that employ Electrooculogram (EOG) signals, e.g. interfaces for eye-based applications, hands-free interfaces and wearable embedded systems. Their approach consists of a feature extraction stage and a classification stage. They explore various strategies for improving the analysis of EOG signals, investigating extraction of features using parametric methods in the frequency and time domains. Their methods range from straightforward time-based techniques that take the whole buffer content without any further operations to sophisticated wavelet decomposition based on Discrete Wavelet Transform-DWT to obtain specific features in a particular time and frequency resolution. For the classification stage, the authors employ Nearest Neighbour (NN) classifiers, Artificial Neural Network (ANN) and Linear Discriminant Analysis (LDA). Considering a virtual keyboard as the real life context for their study, they perform a comparison of the various feature extraction-classification combinations using data recorded from real user interactions. They particularly identify four promising strategies: template matching using NN and three DWT-based classifiers. Their results indicate that parametric Auto Regressive modelling using the Burg method, which does not retain the phase information, gives poor classification. In contrast, they find that the projection on the approximation space of the fourth level of Haar wavelet decomposition yields feature sets that enhance the class discrimination and reduce the feature dimensionality, making the method much more efficient in terms of computation. They also find that the computation cost for ANN and LDA is not significantly different when training is done off-line. Lastly, the authors implement a combination of DWT-based LDA classifier with a virtual keyboard acting as the user front-end and perform real time testing with a small sample of users getting some very promising detection rates.

*An Autonomous Multi-Agent Simulation Model for Acute Inflammatory Response*, by Wu, Ben-Arieh, and Shi, proposes an agent-supported system to enable computer simulation for acute inflammatory response-AIR. AIR is the initial stage of a typical sepsis episode, often leading to severe sepsis or septic shocks. The process of AIR has attracted the interest of clinicians because it affects more than 750,000 patients annually in the United State alone. Existing approaches employ mathematical models describing system dynamics and offer limited ability of capturing behavioural variations since they use deterministic scalar parameters. In order to model the inherent stochastic nature of the biological system and provide the ability to include the correct boundary conditions, the authors combine agent-based modelling with dynamic mathematical models. The proposed agent-supported system employs multiple agents that exploit knowledge of the variables describing the system dynamics and incorporate various indicators of AIR progression. This approach allows to link system dynamics and real AIR environment-related
information. Moreover, agents allow defining autonomous and probabilistic behaviours, capturing the stochastic nature of the AIR progression episode. Unlike the use of strict mathematical model, the agent-supported system simulation allows the designers and the users to simulate and observe the interactions among different agents; thus, it is more intuitive and flexible than the traditional mathematical models. Outcomes of this work can be useful to clinicians interested in predicting the sepsis pathogenesis for patients. Using the prognostic indicators from the simulation results, clinicians can plan appropriate therapeutic interventions, and visualise and capture potential AIR progression patterns.

In *Rough Set based Clustering Using Active Learning Approach*, Kandwal, Mahajan, and Vijay revisit the problem of active learning and decision making when a large number of unlabeled data is available but their labelling incurs a high cost. The main aim of a clustering approach that employs active learning would be to generate or sample the unlabeled instances in such a way that they self-organise into small groups with minimal overlapping. In this context, the authors extend the basic notion of Hamming distance to propose a dissimilarity measure, which helps finding the approximations of clusters in the given data set. Moreover, they introduce Rough sets as a tool to deal with inexact, imprecise, or vague knowledge in the real world data and identify rough clusters. Their algorithm partitions the dataset into k clusters and tries to maximise the intracluster similarity whilst minimising the intercluster similarity. Active learning is applied at each iteration with the learner actively selecting a batch of unlabeled samples for training to improve the internal model, i.e. make cluster adjustment as quickly as possible. Their algorithm compares the feature vector for a new instance with feature vectors for clusters centres, when there is a matching the feature vector is labelled, otherwise the distance is calculated and used to label the vector with the clusters where the similarity is maximum. The authors evaluate successfully the proposed algorithm using benchmark data sets from the UCI machine learning repository.

The issue of managing imprecision, inherent in the operation of living and artificial intelligence systems, is also investigated in the work of Danish Lohani, titled *Intuitionistic Fuzzy 2-Metric Space and Some Topological Properties* in the context of fuzzy topology. Fuzzy topology has a wide range of applications in quantum physics, nano technology, and brain research. It is a specialised domain of Fuzzy theory which has found applications in the field of science and engineering, e.g. population dynamics, chaos control, nonlinear dynamical systems and medicine. In this work, the focus is on the notion of intuitionistic fuzzy metric space and the concept of intuitionistic fuzzy normed space. The author studies the intuitionistic fuzzy 2-metric space, which provides a more suitable functional tool to deal with the inexactness of the metric, or 2-metric in some situations. He discusses analogues of precompactness and metrizability and establishes some theoretical results in this space.

*Folding Theory for Fantastic Filters in BL-Algebras*, by Lele, also contributes to fuzzy logic theory examining the notion of n-fold fantastic and fuzzy n-fold fantastic filters in BL-algebras. The work goes beyond the typical formulation of fuzzy logic as a system of formal deductive systems that support deduction under vagueness. It equips mathematical fuzzy logic with abstract algebraic semantics in a way analogous to the classical (Boolean) logic. The author shows that every n-fold (fuzzy n-fold) fantastic filter is a filter (fuzzy filter), but the converse is not true. Building on the concept of level set of a fuzzy set in a BL-algebra, the author characterises fuzzy n-fold fantastic filters and establishes an extension principle for n-fold and fuzzy n-fold fantastic filters in BL-algebras. These theoretical results are important not only for BL-algebra but also as foundations of methods of fuzzy logic in a broad sense.

Psillakis, Christodoulou, Giotis, and Boutalis’ work, titled *An Observer Approach for Deterministic Learning Using Patchy Neural Networks with Applications to Fuzzy Cognitive Networks*, contributes both to theory and applications by combining Fuzzy Cognitive Networks and dynamic systems with new
Neural Network models. The authors build on previous work that established Fuzzy Cognitive Networks (FCNs) as an alternative operational extension of Fuzzy Cognitive Maps-FCM. Their aim is to increase FCMs suitability for control and adaptive decision making applications by better representing interactions with the system they represent and dynamic behavioural patterns. In this work, the authors derive a new identification methodology that consists of designing a suitable observer that provides asymptotic estimation of the respective nonlinear vector field, and then employing a localised neural network to extract and store the information of this estimate. To this end, a new class of localised neural networks, called Patchy Neural Networks (PNNs), are introduced. PNNs employ basis functions that are “patches” of the state space and are used to identify the unknown nonlinearity from the observer’s output and the state measurements. The authors propose a scheme that achieves learning in a single pass from the respective patches and does not need standard persistency of excitation conditions. Furthermore, PNNs weights are updated algebraically, reducing the computational load of learning significantly. This identification procedure is applied to the learning problem of the dynamics of FCNs and a Duffing oscillator providing evidence for the effectiveness of the proposed approach.

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