Preface

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1 Introduction

The development of complex systems has been experiencing a paradigm shift in recent years, from the traditional planning and automation development paradigm to the new machine learning and pattern recognition paradigm. In the traditional way, we build a system by analysing the specification and establishing a mathematical model. Then, we compute the results based on the model. Consider a robot shooting a ball into a basket. We can develop a model based on the projectile motion theory. The model takes the following parameters as inputs: the distance and height from the ball position to the basket, the weight and size of the ball, and other parameters, such as the air resistance factor. The model then calculates the force and the angle needed to shoot the ball into the basket. We repeat this process for all possible locations that the robot can shoot the ball. For the same problem, the new approach is through machine learning. We do not need a precise projectile motion model. We make the robot learn to shoot by trial and error. The robot tries different forces and angles to shoot the ball towards the basket. It uses a camera for feedback. If a shot misses, it adjusts the force and angle based on the feedback. If a hit is seen, the robot records the location with the force and angle values. Then, it moves to the next location and continues the learning process.

For a small or medium sized system development, the planning and automation paradigm has worked well. For complex system development today, the model may become too complex to develop or to calculate. Machine learning becomes a better option. For example, an autonomous driving vehicle needs to recognise the combination of many traffic signs, road shapes and dynamic traffic, including other vehicles and pedestrians. It is hard or even impossible to develop a model to taken all these parameters into consideration. Thus, machine leaning becomes the only viable option for implementing an autonomous driving vehicle.

Today's machine learning and artificial intelligence are based on big data analysis and processing, which requires a training stage to collect and fit the data into a certain model and knowledge base. They also require continuous learning and improving of the model and knowledge during the supervised and unsupervised learning and operation stages. To support real-time big data analysis and processing in machine learning-based decision making, hardware and software co-design is necessary.

In this special issue on 'Machine learning and development of complex systems', we selected five papers, which cover three areas of system development based on machine learning and artificial intelligence. The first paper studies on image fusion for creating a multi-point focused image. The next two papers are on pedestrian gait pattern recognition and travel pattern recognition. Then, we move to the development of a complex system that implements pattern recognitions in health and disease transmission through distributed intelligence. The final paper explores circuit design using memristor, which is one of the fundamental circuit elements in computer hardware design that has potential applications in neural network, brain-computer interface, signal processing, and control systems.

2 Multi-focus image fusion

Image processing is a key area in machine learning that provides better images for decision making. An image from a physical camera has one focus point only. Multi-focus image fusion is a technique of combining two or more images to obtain an image with multiple focuses or even all-in-focus effect. The first paper of the special issue presents a sparse representation-based image fusion framework that facilitates the geometric dictionary construction. A geometric image patch classification approach is presented to group image patches from different source images based on the similarity of the images' geometric structure. The proposed method extracts a few compact and informative sub-dictionaries from each image patch cluster through principal component analysis. Then, these sub-dictionaries are combined into a full dictionary for sparse representation. Finally, the image patches are sparsely coded into coefficients by the trained dictionary through machine learning. For obtaining better edge and corner details of fusion results, the proposed solution also chooses the image block size adaptively and selects optimal coefficients during image processing.

3 Pedestrian indoor positioning based on gait recognition

The second paper of the special issue is on 3D pedestrian dead reckoning (PDR) method based on gait recognition using smartphone data. The current studies have been focused on a two-dimensional effective modelling method of the indoor space. This paper extends the current studies into a three-dimensional scenario by introducing the concept of step height. The proposed method includes two phases of gait recognition and step height calculation. It combines the steps by step detection, step estimation, and heading determination. The gait recognition process identifies the pedestrian current state, which falls into one of the three states: walking, upstairs moving and downstairs moving, step size, step height and heading calculation in different states. In this way, it can accurately find a pedestrian's location in a three-dimensional indoor space. The experiment shows that the positioning of the proposed 3D PDR model has a higher accuracy than that of the traditional PDR model. However, the maximum error becomes higher. This issue needs to be studied in future research.

4 Travel pattern and behaviour prediction

Automated fare collection systems using smart cards have been widely used in public transportation systems, among many other applications. They produce a large amount of very detailed data on travel patterns, which are useful for transit planners, from the day-to-day operation of the transit system to the strategic long-term planning of the network. The third paper of the special issue is on travel pattern learning and travel behaviour prediction. This paper aims at learning travel patterns and predicting future travel behaviour of a metro system's smart card holders. The study applies Gaussian mixture model (GMM) on time series extracted from each smart card. It proposes a new method based on the perplexity for finite GMM, and the expectation-maximisation is used to estimate parameters of GMM. In order to predict the probability of travelling at a certain unknown moment, the study fits the Gaussian process regression model by using the density function to represent the probability of travelling at that moment. Then, it takes the predictive test mean as the probability of the user travelling at that moment. Finally, it takes the reciprocal of predictive test variance as the reliability of the predictive result. The study in this paper remains at the individual level, and the group level studies are expected in the future research.

5 Distributed intelligence solution and application

The fourth paper of the special issue studies the simulation of ambient intelligence. It provides a generic simulation environment for interaction of different intelligent devices and their integration. It is also specifically design for implementing the applications such as disease surveillance systems (DSS) that can achieve faster and more accurate detection of disease outbreaks and epidemic propagation. The study is based various patterns and their recognitions in health and disease transmission. From the infrastructure point of view, the paper offers a simulation server solution (middleware) designed to meet the needs of parallel and distributed discrete event simulation. It implements a fully distributed triple space computing (TSC) paradigm to address the interoperability by sharing information represented in a semantic format through a common virtual space. The server defines a service oriented architecture (SOA) interface for the TSC operations, which ensures the interoperability with different simulation requirements. This interface also complies with DEVS formalism and focuses on simplicity, conviviality and modularity, so that a single or many simulations that support different models can still interact. To assess server, a tuberculosis epidemic model simulation in time-varying temporal network with a genetic programming immunisation strategy approach is implemented.

6 Exploring new hardware

Problem solving based on big data processing, machine learning and artificial intelligence requires extraordinary computation power. Software and hardware co-design is the current approach to address the need. New computer architecture design and circuit realisation are two directions for breaking the bottleneck at hardware level. Memristor is one of the fundamental circuit elements in hardware design that has the potential to revolutionise the hardware design for artificial intelligence applications, including neural network computing, brain-computer interface, signal processing, and various control systems. The fifth paper of the special issue studies the characteristics of a new type of circuit structure that is extended from simplified Lorenz system by taking a memristor as feedback. Based on Lyapunov stability theory, finite-time control, and considering of transmission time delay, the paper develops a particular kind of signal controller to guarantee the finite-time synchronisation of two memristive hyperchaotic circuits based on Lorenz system. Simulation results are given to verify the effectiveness of this method.