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Realization of superhuman intelligence in microstrip filter design based on clustering-reinforcement learning

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Abstract

Microstrip filters are widely used in signal processing because of their light weight, compact structure and high reliability. Designing these filters is very time consuming, and a designer generally needs much knowledge of electromagnetic theory. In recent years, artificial intelligence (AI) technology has been used to accelerate the design process. However, current AI models retain the human design mindset (adopt a regular structure) and thus cannot be applied to the automatic design of irregular structures. We proposed a clustering-reinforcement learning model named parallel advantage actor-critic with K-means (PAAC-K). The PAAC-K model is based on a reinforcement learning model, in which the size of the overlapping area is used as the reward function, and a clustering algorithm was added to extract characteristics for learning. We used the stepwise training method to avoid repeated exploration in a design with different frequencies. The PAAC-K model realized superhuman intelligence that automated the design of irregular structures, which was proven with four application examples. This work presents an AI model and a design mindset for irregular structures, which is of great significance in promoting the development of filter devices.

Keywords Microstrip filter · Parallel advantage actor-critic · Reinforcement learning, K-means · Electromagnetic simulation

1 Introduction

Filters are frequency selectors that allow the specific frequency components of a filter to pass through or eliminate the signal at a particular frequency. As an essential type of filter, microstrip filters, whose advantages include their light weight, compact structure and high reliability, have been widely used in signal processing. The performance of filters has an important influence on signal processing systems. However, filters [1–3] have highly complex relationships with physical size parameters. For example, multivariate, nonlinear, and strongly coupled characteristics are usually analysed using computer-aided design (electromagnetic simulation tools). Electromagnetic(EM) simulations are based on Maxwell's system of equations and solved by numerical calculation methods. Examples include the method of moments [4] and the finite element method [5]. Moreover, the higher the meshing density in the numerical analysis methods, the more intensive computation [6]. Manually tuning physical parameters to optimize filter performance using EM wave theory is tedious and complex. Artificial neural networks (ANNs), such as those in [7–9], have been found to be robust modelling method substitutes to EM/physics models. This supervised learning approach still has the disadvantage that human involvement is necessary to extract the training data. For designs, engineers must have high theoretical knowledge of electromagnetic waves to find physical dimension parameters that meet design standards, and adjusting parameters by the sweep frequency is time consuming. This process is usually designed to fit a specific size, which does not account for the optimal circuit performance.

A high-performance filter with many action spaces makes it difficult to obtain valid results directly using reinforcement learning. One of the reasons is that reinforcement learning

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