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Using evolutionary computing technology to improve algorithm performance innovation

Jingyuan Ceng[1], Longqing Zhang[1], Bianping Su[1], Hongming Chen[2], Kei Chang[3], Xinwei Zhang[1,*], Qian Chen[4], Yanfen Fang[1] and Changan Chen[1]

[1] Intelligent science and technology, Guangdong University of Science and Technology, Guangdong, China
[2] Intelligent science and technology, Zhejiang Ocean University, Zhoushan, China
[3] Liberal art college, Beijing University, Beijing, China
[4] College of Information Science and Electronic Engineering, Zhejiang University, Hangzhou, China

* Correspondence author; E-mail: bigiot@gdust.edu.cn.

Abstract: The research background of improving algorithm performance by using evolutionary computing technology stems from the demand of signal processing and optimization algorithms. As an important signal processing tool, fast Fourier transform (FFT) can calculate discrete Fourier transform efficiently, and is widely used in digital signal processing, communication system and image processing. As an optimization algorithm simulating natural selection and genetic mechanism, genetic algorithm is combined with FFT to optimize the performance of FFT algorithm by adjusting key parameters, so as to improve the effect of signal processing and spectrum analysis. This research not only helps to explore the application of optimization algorithms in signal processing, but also provides innovative ideas and methods for improving the efficiency and accuracy of signal processing algorithms.

Keywords: genetic algorithm; fast fourier transform

1. Introduction

1.1. Research background and significance

With the advent of the era of big data, the demand for large-scale data processing is growing day by day [1]. Traditional FFT algorithms have the problem of inefficiency when dealing with large-scale data, so a more efficient algorithm is needed to meet this challenge. FFT is an important signal processing tool, widely used in digital signal processing, communication system and other problems. In some specific signal processing scenarios, signals may have complex features and structures, which may not be effectively processed by traditional FFT algorithms.

1.2. Domestic research status

Some progress has been made in the field of optogenetic neuron regulation and brain-computer interface in China, mainly focusing on improving optogenetic tools, exploring the mechanism of neuronal regulation and developing brain-computer interface technology. However, it has not yet formed a complete technical system and application system, and there is still a gap compared with foreign countries.

1.3. Foreign research status

The level of foreign research in the field of optogenetic neuron regulation and brain-computer interface is in the international leading position. While improving optogenetic tools, they are also working to develop more efficient and precise methods of light control, such as fiber optic light stimulation technology and new methods of combining optogenetics with optical imaging.

2. Related introduction

2.1. Overview of brain-computer interface technology

A brain-computer interface (BCI) is a technology that establishes a communication path directly between the brain and the outside world. This technology captures and interprets the brain's bioelectrical signals, converting them into commands that can control external devices [2]. It is built on the basis of direct communication and control channels between the human brain and computers or other electronic devices, and does not rely on conventional brain information output pathways (such as peripheral nerve and muscle tissue) [3,4]. BCI technology involves neuroscience, signal detection, signal processing, pattern recognition and other interdisciplinary cross technology [5], and it is a new way of human-computer interaction [6,7].

2.2. Working principle of BCI

First, the electrophysiological activity of the brain is recorded by using electrodes, such as electroencephalogram (EEG), steady-state visual evoked potential (SSVEP), *etc.* These raw signals are then pre-processed to reduce noise and interference. Next, useful features are extracted from the processed signal that represent the user's intent or state. Finally, the extracted features are converted into specific control commands by pattern recognition algorithm, so as to realize the control of external devices [8].

3. Algorithm design

3.1 Genetic algorithm

Genetic Algorithm (GA) is a global search optimization algorithm based on evolutionary theory, which simulates natural selection, crossover and variation in biological evolution to achieve global optimization. By simulating natural selection and genetic mechanism, genetic algorithm can find the optimal solution in complex parameter space. Although genetic algorithm has made remarkable achievements in the field of optical signal processing, there are still some challenges and future research directions.

3.2. Design of FFT (FFT-GA) algorithm based on genetic algorithm

3.2.1. Fast Fourier Transform

Traditional FFT algorithm is efficient and fast, but it may be limited by resources and time when dealing with large-scale data sets. Therefore, an FFT optimization scheme based on genetic algorithm, namely FFT-GA algorithm, is proposed to improve the performance of traditional FFT algorithm.

3.2.2. Optimizing the process

(1) Initialize the population

First, the length N of the input signal sequence is determined and the parameters such as sampling frequency and interval are required in the FFT algorithm. An initial population is then randomly generated, with each individual representing an input signal sequence. For each individual, a sequence of input signals with random or specific properties is generated according to the need, and it is used as the genome of the individual.

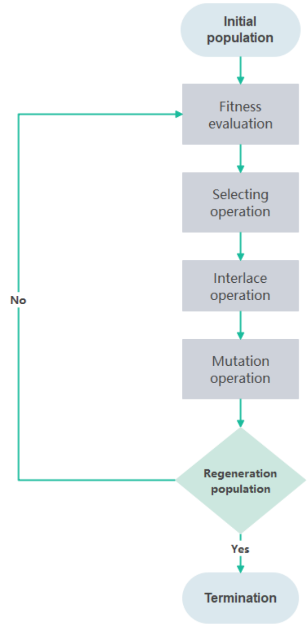

Figure 1. Optimization flow chart.

(2) Selection operation

A selection operation is performed to select parent individuals based on their fitness values and determine how many times they are repeated in the next generation population.

$$f(x) = \frac{1}{T(x)} \tag{1}$$

Where T (x) represents the time required for individual x to calculate the FFT.

$$f(x) = -E \tag{2}$$

Where E is the error between the calculated result and the theoretical value.

$$f(x) = \frac{N}{M} \tag{3}$$

Where N is the amount of data processed and M is the amount of memory allocated to the algorithm.

The roulette selection method calculates the fitness value of each individual, and calculates the sum of all individual fitness values as the total fitness value. For each individual, the probability of being selected is calculated as follows: individual fitness/total fitness value; Generate a random number between 0 and 1, select an individual from the population, so that its accumulation probability is greater than or equal to the random number r; The above steps are repeated until a sufficient number of individuals are selected to achieve the selection of genetic operators. For the population size parameter, the population size is set reasonably according to the problem size and computing resources, and a larger population size is usually recommended to increase the search space and diversity.

(3) Cross operation

When selecting crossover operators, it is necessary to consider comprehensively according to the characteristics of specific problems and solving objectives. For example, for fast Fourier transform problems, you can choose between multi-point intersections or uniform intersections to better explore the search space. After the crossover operator is determined, multiple crossover points are randomly selected for multi-point crossover, and then the two parent entities are exchanged at the crossover point to generate a new child entity.

(4) Variation operation

For single point variation, a gene location is randomly selected and a random change in the gene value is performed. For multipoint variation, multiple gene locations are selected and corresponding compilation operations are carried out. For uniform variation, it is achieved by randomly selecting whether to carry out variation on each bit.

(5) Population renewal

For the complete replacement strategy, the newly generated child directly replaces the original parent completely. For partial substitution and hybrid substitution, according to certain selection rules and fitness evaluation methods, the corresponding substitution operations are carried out between parents and children.

3.3. Comparison between genetic algorithm and traditional algorithm

Compared with traditional FFT algorithm, FFT-GA algorithm in the application of optical frequency domain reflection spectrum analysis, the main advantage is that the processing speed is significantly improved. Traditional FFT algorithms, such as Radix-2, Radix-4, *etc.*, mainly focus on reducing computational complexity, and these algorithms show better time and space efficiency when processing large-scale data, but may be insufficient in accuracy.

(1) Processing speed

Traditional FFT algorithms may be limited by storage and computing resources when dealing with large data, while genetic algorithm-based FFT algorithms can effectively improve the efficiency and scalability of algorithms through parallel computing and distributed optimization technologies. It can be seen from Table 1 that in specific experiments, when processing medium-scale sampled data, FFT-GA algorithm only needs 1.3 seconds, while the FFT algorithm takes 3.2 seconds.

Table 1. Experimental data.

Problem scale	GA-FFT average running time(s)	FFT average run time(s)	Performance difference
Small scale problem (N = 64)	0.016	0.014	Slight difference
Medium size problem (N = 256)	0.098	0.123	20% fast
Large scale problem (N = 1024)	1.3	3.2	60% fast

(2) Accuracy

Due to the characteristics of random selection and cross-operation, genetic algorithm can find more potential solutions in the search and avoid falling into the local optimal solution, which will provide higher accuracy or better adaptability in some cases because of its ability to search the global optimal solution.

(3) Algorithm complexity

Genetic algorithm can dynamically adjust the probability of selection and crossover according to the fitness of the current population to adapt to different optimization scenarios and solution objectives.

4. Conclusion

Genetic algorithm can effectively adjust the key parameters and structure of FFT algorithm to adapt to different signal characteristics and computing platforms, and significantly improve its operating efficiency and computing accuracy. Especially in real-time applications and large-scale data processing scenarios, the optimized FFT algorithm shows obvious advantages, providing reliable technical support for efficient and accurate signal analysis and processing.

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Authors' contribution

Investigation, Jingyuan Ceng; methodology, Longqing Zhang; resources, Bianping Su; data curation, Hongming Chen and Kei Chang; writing—original draft, Xinwei Zhang; writing—review and editing, Jingyuan Ceng. All authors have read and agreed to the published version of the manuscript.

Conflicts of interests

The authors declare no conflicts of interest.

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