Scholar Publishing Group
Kinetic Mechanical Engineering
https://doi.org/10.38007/KME.2023.040106
ISSN 2790-2676 Vol. 4, Issue 1: 48-56

Fusion Particle Swarm Optimization Algorithm in Automobile Engine Fault Diagnosis

Sridevi Sujata*

Universiti Teknologi MARA, Malaysia

**corresponding author*

Keywords: Particle Swarm Optimization, Automobile Engine, Fault Diagnosis, Automobile Fault

Abstract: The automobile engine is a high-speed vehicle. Its working principle and process are to generate gas through fuel burning, and then convert the chemical energy contained in the exhaust gas into heat energy. However, in reality, due to various reasons, serious wear and tear inside the engine and sharp reduction of mechanical strength have occurred. This paper mainly introduces a method based on particle swarm optimization algorithm to simplify the complex structure between various systems in the car and outside. The analysis shows that this method has the advantages of accuracy and reliability, and can effectively diagnose and predict it. The advantage of large workload and small space is very prominent. After that, this paper designs a fault diagnosis model of automobile engine based on particle swarm optimization algorithm, and tests the model. The test results show that the fault diagnosis time of this model is short, and the fault diagnosis accuracy is high, which can meet the user needs.

1. Introduction

The fault phenomenon of automobile engine is extremely common and difficult to solve, which affects production and work in people's life. There are many reasons for its failure. For example, the temperature is too high, the fuel supply is insufficient, or a series of problems are caused by the aging of mechanical parts and components, such as serious wear of piston rings and rupture of cylinder heads, and some phenomena are caused by the failure of various components in the automobile system or other aspects due to some uncertain factors in the engine, Thus, the working performance and reliability of the whole machine are reduced [1-2].

The application scope of fault diagnosis technology is very wide, and in the aspect of aeroengine, many fields are involved, such as automotive electronics, instrument detection, etc. Foreign scholars

have conducted research and development on large aircraft. At present, artificial neural network algorithm is mainly used to realize online fault prediction and analysis, and fuzzy theory is used to model and optimize the diesel engine system to get the final result. Others use the intelligent way of fuzzy diagnosis experts to solve traditional problems, such as traffic accidents caused by high driver uncertainty. In China, with the development and application of fault diagnosis technology, Chinese scholars have also conducted a lot of research on it [3-4]. Some scholars, based on the intelligent pusher system of particle swarm optimization algorithm, proposed to introduce the artificial neural network method into the automobile engine fault diagnosis to solve the problems that the traditional classification method of automobile power system is difficult to deal with complex, non real-time features and other shortcomings. At the same time, they designed hierarchical and progressive hybrid vehicle fault troubleshooting by improving the BP optimization principle, and used genetic algorithm to identify and locate each component online [5-6]. Therefore, this paper studies the fault diagnosis technology of automobile engine based on particle swarm optimization algorithm.

With the rapid development of computer technology, in all walks of life, machine fault diagnosis has also achieved some results. This paper mainly introduces the method of automobile engine fault diagnosis based on particle swarm optimization algorithm. This paper first briefly describes the basic theories of conceptual neural network and genetic algorithm, and then proposes to use the system load index calculated by PSO to process and analyze the driver test results to obtain the critical speed, valve opening and ignition timing under the real operating conditions of the system. Finally, the technical manual of automobile engine fault diagnosis and relevant conclusions are given.

2. Research on Automobile Engine Fault Diagnosis Based on Particle Swarm Optimization

2.1. Working Principle of Engine Fault Diagnosis

In actual work, cars will encounter many common complex situations and phenomena, which will lead to various interference factors affecting normal operation. Engine fault diagnosis is to analyze and judge these parameters according to the basic information of the car, such as various sensor elements, ignition timing signals and fuel systems, and to detect these parameters and analyze their characteristic curves as well as their causes and change trends, Then convert their numerical values into corresponding digital waveforms (or images) displayed in the oscilloscope through calculation methods, and then use MATLAB software to develop an algorithm program to realize the engine fault diagnosis process [7-8]. This mainly includes checking whether all systems of the vehicle are normal, fuel consumption, ignition timing, etc. The fuel consumption and emissions exceed the standard. The test shows that there are abnormal conditions or excessive reactive power output in the combustion chamber caused by exceeding a certain value, or the internal component parameters of the engine do not conform to the actual operating conditions or the sensor fault in the vehicle driving makes it deviate from the design requirements. In the daily driving of cars, the engine is a very important, irreplaceable and key component. Its failure will directly affect the vehicle performance and comfort. Therefore, it is of great significance to scientifically diagnose the automobile engine, which can help people master the actual running conditions and laws of the vehicle, help improve the maintenance level and safety factor to meet the needs of users, and can also find potential hazards and eliminate them in time to ensure driving safety and smooth roads. Under normal driving conditions, engine failure occurs due to different operating temperatures of various parts or unstable vehicle performance. In case of vehicle failure, various parts of the engine will be damaged to a certain extent due to various reasons, and these parts may cause a certain kind of damage due to some factors, or cause another kind of damage under some irresistible conditions. In this case, we can use signal description, principle analysis,

method detection and other methods for diagnosis and maintenance [9-10]. There are various and complex vehicle driving conditions, and the failure phenomena in different environments may also be different. For example, the mechanical components of the engine are damaged or failed, and the vehicle vibration system causes collisions between various parts of the engine. Figure 1 shows the process of vehicle fault location.

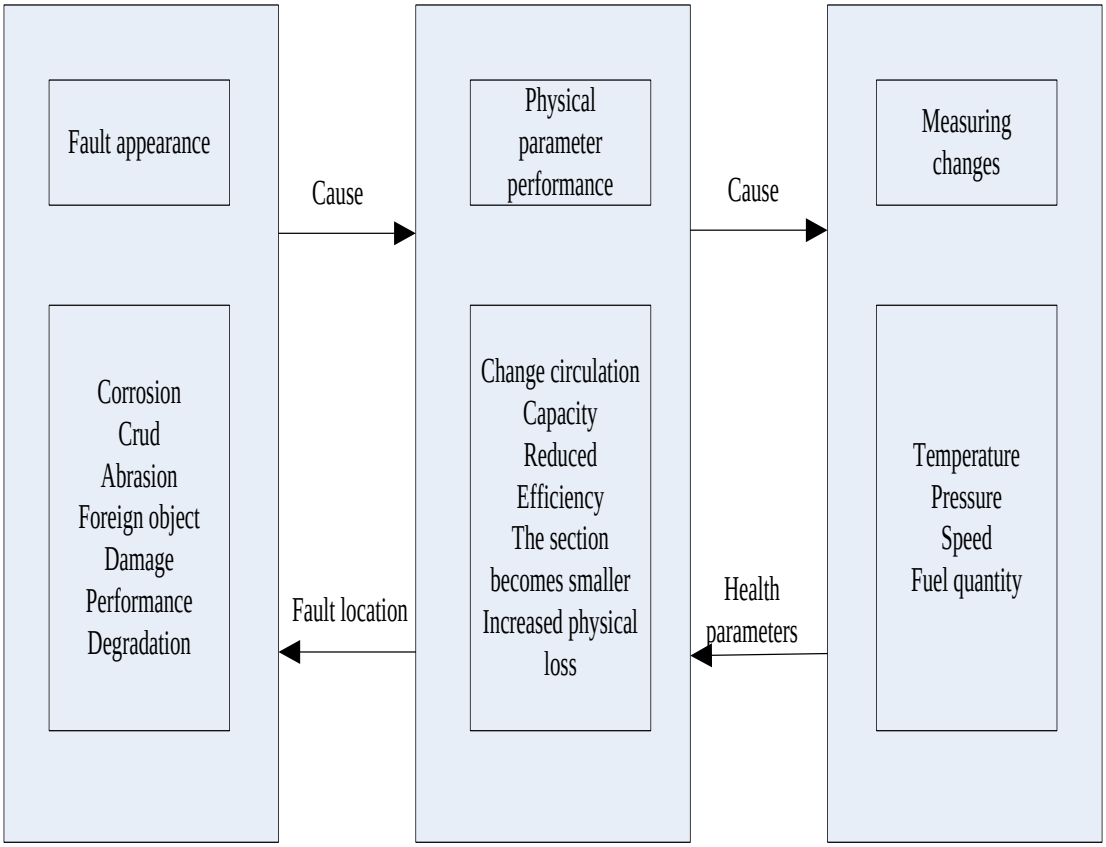

Figure 1. Vehicle fault positioning process

2.2. Importance of Automobile Engine Fault Diagnosis

With the continuous development and progress of science and technology, as well as the gradual enhancement of people's safety awareness, the increasing traffic demand and the increasingly high requirements for fuel consumption rate, more and more traffic accidents have caused serious casualties, while the consequences of accidents are often quite heavy and losses due to overheating of the engine or external forces and other reasons, as well as problems of vehicle systems or parts. People have put forward higher and higher requirements for automotive products. While meeting the basic functional requirements, they also need to ensure their safety, reliability and emissions. Therefore, engine fault analysis and diagnosis technology must keep up with the pace of the times to achieve significant development [11-12]. The automobile engine is the necessary equipment to ensure the safe and stable driving of the vehicle, and the fault diagnosis is to analyze the fault inside the whole vehicle body under the condition that the system fully understands the basic conditions. The automobile engine is the power source of the whole vehicle, and it directly affects the vehicle performance when driving, so it is very important to study its fault diagnosis. It can provide technical support for further determining the whole vehicle and assembly by detecting the failure causes of various possible different parts and operating conditions. Automobile engine is one of the most important parts of power assembly in the whole mechanical system. Because it is directly

related to the mutual cooperation and working quality of various parts in the machine, and because it accounts for a large proportion in the overall performance index, it is necessary to conduct fault identification and prediction in this process. The importance of automobile engine fault diagnosis is mainly reflected in the following aspects: First, it is a very important and indispensable part in the entire system, Because it directly affects whether the whole vehicle and its components can work normally. Therefore, in order to ensure the safe driving of the vehicle, the engine mechanism must be comprehensively and carefully inspected and analyzed. If problems cannot be handled or solved in time when they are found, or the irreparable situation is caused by incalculable losses caused by accidents caused by faults, it will bring huge economic losses to vehicle users and even endanger personal life and property safety. Second, the automobile engine is a complex, diverse and extremely important system, which works under various functions, including fuel supply, ignition timing and fuel saving. Fault diagnosis and analysis play an important role in the normal and smooth operation of the whole vehicle [13-14]. Third, through comprehensive and detailed inspection and maintenance of the automobile engine, we can find out the problem in time and take corresponding measures to reduce or avoid some unnecessary losses. For example, shortening the overhaul time can effectively improve production efficiency, reduce costs, and obtain greater benefits.

2.3. Particle Swarm Optimization

For the traditional algorithm, the particle swarm optimization algorithm is a new method based on the simulation of the response mechanism of the biological world to the external environment in nature. It imitates the individual differences of the generation and evolution laws of species in the evolutionary process [15-16]. A three-dimensional space has been established between birds and insect groups to enable them to work together to reduce noise pollution, improve efficiency and avoid competition leading to foraging behavior. The food chain uses the food chain to exchange information to find the most suitable substitute. It is a simulation of the evolution process of natural organisms, and the results are obtained by optimizing a complex system. Look for or create a biological pattern in the nature. Its purpose is to make the problem simple, easy to solve and easier to propose new schemes, which are widely used in various nonlinear programming designs. This method, also known as parallel search method or approximate optimization tool SPSL technology, is one of the marginal algorithms applying evolutionary theory. It is based on strong adaptability to the environment and strong global convergence characteristics. The solution process is that particle swarm optimization algorithm simulates biological evolution on the computer, uses random search and classification, and arranges and combines all the individuals involved in the problem according to certain rules, And finally apply it to solve the corresponding problems. This method can get the required results quickly and accurately.

Figure 2 is the flow chart of the particle swarm optimization algorithm. It can be used to solve some data that is not easy to obtain the complete or partial decomposition property of the solution but can not be expressed clearly, the number of variables is too large or it is difficult to describe with numerical calculation, and it has good operability and other characteristics [17-18]. The failure of engine gas path components can be diagnosed by quantitative performance parameter estimation. In this paper, the health parameter h is introduced to measure the change degree of component performance after the failure and the degradation degree of components during the service life of the engine.

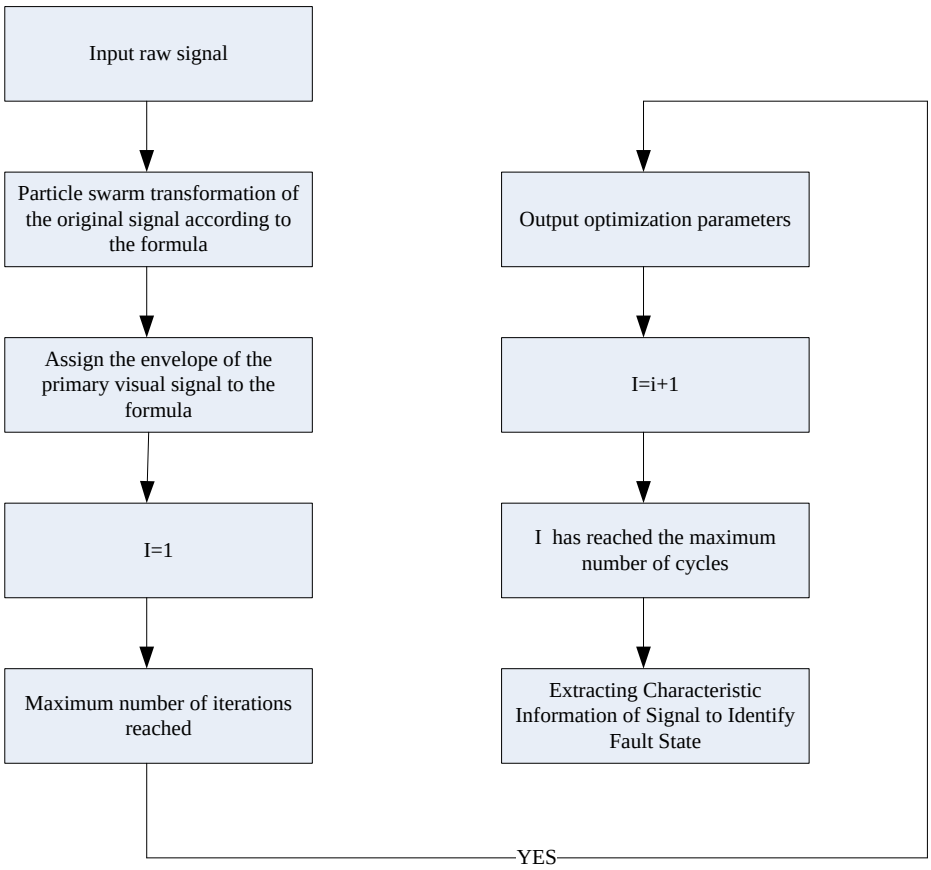

Figure 2. Application of the particle swarm algorithm in fault identification

The efficiency change coefficient SE of rotating components is selected as the health parameter, which is defined as follows:

$$\Delta SE_i = \frac{\eta_i}{\eta_i^*} - 1 \tag{1}$$

Where, η is the actual efficiency of the component, η is the ideal value of component efficiency. On the premise of meeting the system observability, the health parameter in this paper is selected as the coefficient of change of the efficiency of the fan, compressor, high-pressure turbine and low-pressure turbine. There are four health parameters, they can be seen from Formula 1 that the occurrence of gas circuit failure and the degradation of component performance during service life will cause the engine to deviate from the rated working state. In order to more truly describe the dynamic characteristics of the engine, the health parameters representing the degradation degree of component performance are added to the state variable model to obtain the augmented engine state variable model:

$$\begin{aligned} x(k+1) &= Ax(k) + Bu(k) + Lh(k) + o(k) \\ y(k) &= Cx(k) + Du(k) + Mh(k) + v(k) \end{aligned} \tag{2}$$

Equation (2) reflects that the state quantity and output quantity of the model will change with the component health parameters, and the health parameters cannot be directly measured. Therefore, the health parameters are taken as the state variables of the model, and then the state estimation algorithm is used to estimate the health parameters.

3. Experimental Process of Automobile Engine Fault Diagnosis Based on Particle Swarm Optimization

3.1. Fault Diagnosis Model of Automobile Engine Fault Diagnosis Based on Particle Swarm Optimization

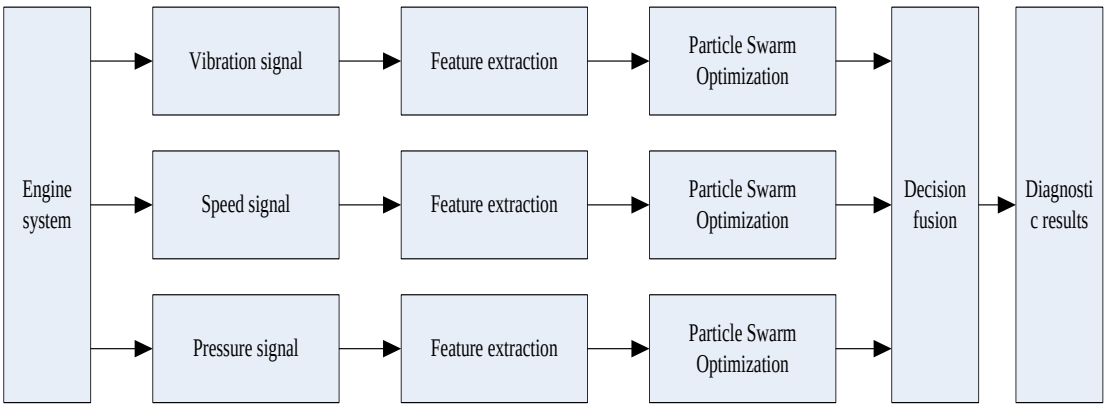

Figure 3. Fault diagnosis model

In the research of automobile engine fault diagnosis, the traditional method is mainly based on qualitative analysis and empirical judgment, but with the development of computer technology, information processing and memory technology and the deepening of intelligence. Intelligent algorithms are mainly used to solve various problems through comprehensive operations on complex data. The basic idea is to transform complex problems into simple, easy to explain and understand problems that can be expressed by digital description or simulation, and then establish a mathematical model (as shown in Figure 3) and use this model to calculate the relationship between various components and the working state of each part of the system when a fault occurs.

3.2. Function Test of Automobile Engine Fault Diagnosis Based on Particle Swarm Optimization

Automobile engine fault diagnosis research is a complex mathematical model analysis, calculation and reasoning. Its basic principle is to use digital signal processing technology to classify the collected information and integrate these different types of data through a certain algorithm. In practical application, what needs to be solved is how to use the same characteristic quantity (such as engine parameters) in the same time series as test samples. At present, there are some models and methods for automobile engine fault diagnosis based on particle swarm optimization algorithm. For example, the single target one-dimensional discrete mathematical method is used to conduct simulation experiments. In the process of system testing, we need to diagnose the faults of the automobile engine and feed back the results to the user. In order to ensure that the diagnostic model can accurately and quickly reflect whether the characteristic parameter values such as the problem state and the distribution of characteristic points meet the actual application requirements and whether the reliability requirement indicators can fully quantify the analysis and processing of these information, the mathematical model established to solve the above difficulties or uncertainties can correctly and reasonably describe the problem mode and prediction methods.

4. Experimental Analysis of Automobile Engine Fault Diagnosis Based on Particle Swarm Optimization

4.1. Functional Test Analysis of Automobile Engine Fault Diagnosis Based on Particle Swarm Optimization

Table 1 shows the function test data of automobile engine fault diagnosis model.

Table 1. Automotive engine troubleshooting model function test

Test times	Failure diagnosis time (s)	Fault diagnosis accuracy rate(%)	Failure result upload time(s)
1	4	97	4
2	3	96	7
3	5	94	4
4	6	95	5
5	5	98	3

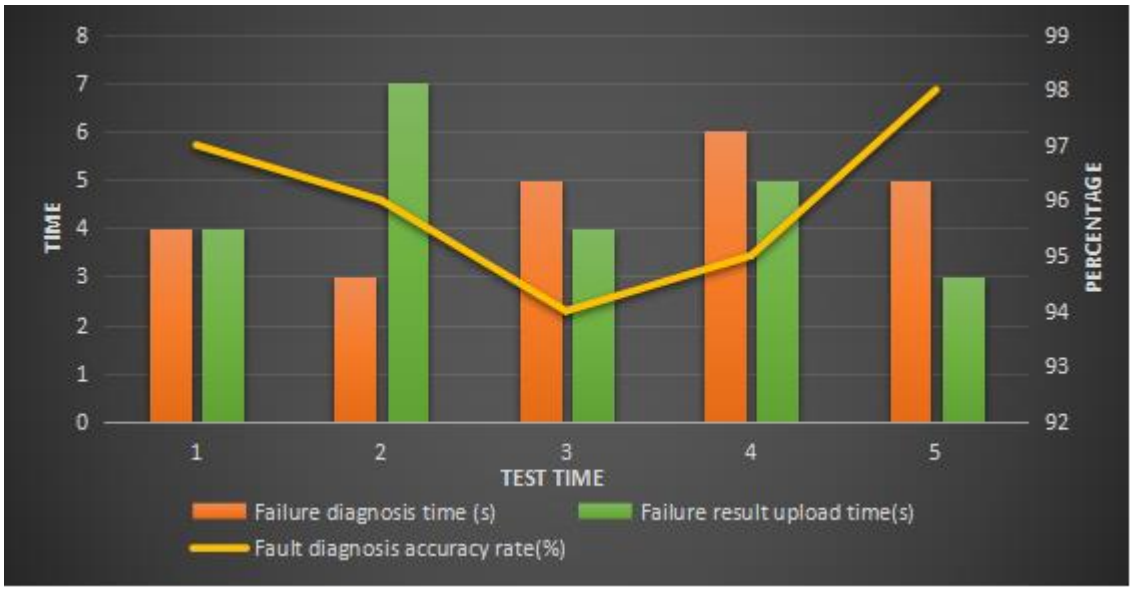

Figure 4. Fault performance test

In the research of automobile engine fault diagnosis, the functional test of model is very important, which is also called functional test. Through the simplification of the actual object and simulation experiments to determine its specific application program. For different types, sizes or the same category of automotive engines or systems, the same principle method can be used to design test procedures and obtain verification results. For different types of vehicle models, it is necessary to adopt fault diagnosis models applicable to different working conditions, and then build them based on the models to reflect the actual object operation status and characteristics to a certain extent. It can be seen from Figure 4 that the fault diagnosis time of this model is short and the fault diagnosis accuracy is high, which can meet the user's needs.

5. Conclusion

With the continuous improvement of people's living standards, there are higher requirements for

vehicle performance, and it also promotes the development of fault diagnosis technology. This paper mainly introduces the specific application of the fusion particle swarm optimization algorithm in the engine integrated electrode system. Firstly, the principle and basic steps are described. Secondly, the composition and functions of automotive electronic components and subsystems are briefly described. Finally, a simple, economical and feasible method based on genetic algorithm is proposed to solve the short-term discrete variable set model for calculating engine operating conditions.

Funding

This article is not supported by any foundation.

Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

References

[1] Elnaz Pashaei, Elham Pashaei:A fusion approach based on black hole algorithm and particle swarm optimization for image enhancement. Multim. Tools Appl. 82(1): 297-325 (2023).

[2] Gabriel Hermosilla Vigneau, Mauricio Rojas, Jorge Mendoza, Gonzalo Farias Castro, Francisco Pizarro, César San-Martín, Esteban Vera:Particle Swarm Optimization for the Fusion of Thermal and Visible Descriptors in Face Recognition Systems. IEEE Access 6: 42800-42811 (2018).

[3] Sethembiso Nonjabulo Langazane, Akshay Kumar Saha: Effects of Particle Swarm Optimization and Genetic Algorithm Control Parameters on Overcurrent Relay Selectivity and Speed. IEEE Access 10: 4550-4567 (2022).

[4] Morteza Alinia Ahandani, Jafar Abbasfam, Hamed Kharrati: Parameter identification of permanent magnet synchronous motors using quasi-opposition-based particle swarm optimization and hybrid chaotic particle swarm optimization algorithms. Appl. Intell. 52(11): 13082-13096 (2022).

[5] Marziyeh Dadvar, Hamidreza Navidi, Hamid Haj Seyyed Javadi, Mitra Mirzarezaee:A cooperative approach for combining particle swarm optimization and differential evolution algorithms to solve single-objective optimization problems. Appl. Intell. 52(4): 4089-4108 (2022).

[6] Dharmendra Kumar, Mayank Pandey: An optimal and secure resource searching algorithm for unstructured mobile peer-to-peer network using particle swarm optimization. Appl. Intell. 52(13): 14988-15005 (2022).

[7] Bhawna Dhruv, Neetu Mittal, Megha Modi: Improved Particle Swarm Optimization for Detection of Pancreatic Tumor using Split and Merge Algorithm. Comput. methods Biomech. Biomed. Eng. Imaging Vis. 10(1): 38-47 (2022).

[8] Clement Nartey, Eric Tutu Tchao, James Dzisi Gadze, Bright Yeboah-Akowuah, Henry Nunoo-Mensah, Dominik Welte, Axel Sikora:Blockchain-IoT peer device storage optimization using an advanced time-variant multi-objective particle swarm optimization algorithm.

EURASIP. Wirel. Commun. Netw. 2022(1): 1-27 (2022).

[9] Abhishek Dixit, Ashish Mani, Rohit Bansal:An adaptive mutation strategy for differential evolution algorithm based on particle swarm optimization. Evol. Intell. 15(3): 1571-1585 (2022).

[10] Narinder Singh, S. B. Singh, Essam H. Houssein:Hybridizing salp swarm algorithm with particle swarm optimization algorithm for recent optimization functions. Evol. Intell. 15(1): 23-56 (2022).

[11] Jay Teraiya, Apurva Shah:Optimized scheduling algorithm for soft Real-Time System using particle swarm optimization technique. Evol. Intell. 15(3): 1935-1945 (2022).

[12] María Guadalupe Bedolla-Ibarra, María del Cármen Cabrera-Hernández, Marco Antonio Aceves-Fernández, Saúl Tovar-Arriaga:Classification of attention levels using a Random Forest algorithm optimized with Particle Swarm Optimization. Evol. Syst. 13(5): 687-702 (2022).

[13] Nitin Kumar Saxena, David Wenzhong Gao, Ashwani Kumar, Saad Mekhilef, Varun Gupta:Frequency regulation for microgrid using genetic algorithm and particle swarm optimization tuned STATCOM. Int. J. Circuit Theory Appl. 50(9): 3231-3250 (2022).

[14] Imen Hamdi, Imen Boujneh: Particle swarm optimization based-algorithms to solve the two-machine cross-docking flow shop problem: just in time scheduling. Comb. Optim. 44(2): 947-969 (2022).

[15] Houda Abadlia, Nadia Smairi, Khaled Ghédira:Comparative performance evaluation of island particle swarm algorithm applied to solve constrained and unconstrained optimization problems. Intell. Fuzzy Syst. 43(3): 2747-2763 (2022).

[16] Johny Renoald Albert, Aditi Sharma, B. Rajani, Ashish Mishra, Ankur Saxena, C. Nandagopal, Shivlal Mewada:Investigation on load harmonic reduction through solar-power utilization in intermittent SSFI using particle swarm, genetic, and modified firefly optimization algorithms. Intell. Fuzzy Syst. 42(4): 4117-4133 (2022).

[17] Satish Kumar Ramaraju, Thenmalar Kaliannan, Sheela Androse Joseph, Umadevi Kumaravel, Johny Renoald Albert, Arun Vignesh Natarajan, Gokul Prasad Chellakutty:Design and experimental investigation on VL-MLI intended for half height (H-H) method to improve power quality using modified particle swarm optimization (MPSO) algorithm. Intell. Fuzzy Syst. 42(6): 5939-5956 (2022).

[18] Jhansi Rani Challapalli, Nagaraju Devarakonda:A novel approach for optimization of convolution neural network with hybrid particle swarm and grey wolf algorithm for classification of Indian classical dances. Knowl. Inf. Syst. 64(9): 2411-2434 (2022).