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Recent Trends in Signal and Image Processing

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Siddhartha Bhattacharyya would like to dedicate this book to his father Late Ajit Kumar Bhattacharyya, his mother Late Hashi Bhattacharyya, his beloved and evergreen wife Rashni, his cousin brothers Prithwish, Santi, Smritish, Palash, Pinaki, Kartick and Atanu

Anirban Mukherjee would like to dedicate this book to Late Mr. P. K. Sen, former Head, Department of IT, RCCIIT

Hrishikesh Bhaumik would like to dedicate this book to his late father, Major Ranjit Kumar Bhaumik, his greatest inspiration and to his mother Mrs. Anjali Bhaumik who has supported and stood by him in all ups and downs of life

Swagatam Das would like to dedicate this book to his beloved wife Sangita Sarkar

Kaori Yoshida would like to dedicate this book to everyone who is passionate to image and signal processing research

Preface

In this era of technology, almost every modern tools and gadgets resort to signal processing in one way or the other. The algorithms governing mobile communications, medical imaging, gaming, and host of other technologies all encompass some kind of signal processing. The signals might be speech, audio, images, video, sensor data, telemetry, electrocardiograms, or seismic data among others. The possible application areas include transmission, display, storage, interpretation, classification, segmentation, or diagnosis. The signals generally handled in real-life situations are often uncertain and imprecise, often posing a challenge and requiring advanced computational techniques to process and analyze. Scientists and researchers all over the world are extensively investing efforts in developing time-efficient, robust, and fail-safe signal processing algorithms for the benefit of mankind.

2017 First International Symposium on Signal and Image Processing (ISSIP 2017) organized at Kolkata during November 01–02, 2017, was aimed to bring together researchers and scholars working in the field of signal and image processing. This is a quite focused domain yet broad enough to accommodate a wide spectrum of relevant research work having potential impact. The symposium showcased author presentations of 21 high-quality research papers carefully selected through a process of rigorous review by experts in the field. In the present treatise, all these 21 research papers have been meticulously checked and compiled with all necessary details following the Springer manuscript guidelines. It is indeed encouraging for the editors to bring out this collection under the Springer book series of Advances in Intelligent Systems and Computing (AISC). The organization of this book containing 21 papers as separate chapters is as follows:

A novel hybrid algorithm is presented by the authors of Chapter "Design of Higher Order Quadrature Mirror Filter Bank Using Simulated Annealing-Based Multi-swarm Cooperative Particle Swarm Optimization" for obtaining prototype filter that leads to near-perfect reconstruction for lower- and higher-dimensional filter banks. A comparison of the algorithm made with other existing methods reveals a significant increase in stop-band attenuation and reduction in perfect reconstruction error (PRE) of 82-tap filter bank.

Chapter "Medav Filter—Filter for Removal of Image Noise with the Combination of Median and Average Filters" also deals with a hybrid filter for removal of image noise. It is better than the primitive filters in terms of edge preservation and signal-to-noise ratio (SNR) when the intensity of disrupted noise is very high.

A neural network-based classifier is proposed in Chapter "Classification of Metamaterial-Based Defected Photonic Crystal Structure from Band-Pass Filter Characteristics Using Soft Computing Techniques" that deals with the classification problem of metamaterial-based photonic crystal from its band-pass filter characteristics. High accuracy of the classifier must attract the attention of the researchers.

Chapter "Sparse Encoding Algorithm for Real-Time ECG Compression" deals with encoding algorithm of ECG signals. Here, the authors propose and validate a sparse encoding algorithm consisting of two schemes, namely geometry-based method (GBM) and the wavelet transform-based iterative thresholding (WTIT).

The authors of Chapter "Wavelet Based Fractal Analysis of Solar Wind Speed Signal" have studied the presence of multi-fractality of solar wind speed signal (SWS). Wavelet-based fractal analysis has been employed for this purpose, and qualitative evaluation is also shown.

Clinical importance of electromyogram (EMG) signals is immense for diagnosis of neuromuscular diseases like neuropathy and myopathy. Authors in Chapter "Class Discriminator-Based EMG Classification Approach for Detection of Neuromuscular Diseases Using Discriminator-Dependent Decision Rule (D3R) Approach" have demonstrated a new method of classification of EMG signals, based on SVM, which can be reliably implemented in clinical environment.

Real-life signal and image processing applications often entail medium- to large-scale multi-objective and many-objective optimization problems involving more than hundred decision variables. Chapter "A Cooperative Co-evolutionary Approach for Multi-objective Optimization" proposes an evolutionary algorithm (EA) that can handle such real-world optimization problem with reasonable accuracy.

Vehicle tracking through smart visual surveillance is an important part of intelligent traffic monitoring system that is gaining wider application day by day. Authors in Chapter "Automatic License Plate Recognition" have addressed this important practical issue by proposing a novel technique of automated license plate recognition of moving vehicles. They have worked on two different databases of traffic video justifying impressive performance of their proposed technique primarily with respect to recognition accuracy.

Quality of classification depends on accuracy of selection of prominent features after removing irrelevant and redundant data from a high-dimensional data set. The authors of Chapter "S-shaped Binary Whale Optimization Algorithm for Feature Selection" have proposed and evaluated an effective algorithm for finding optimal feature subset from a given data set.

Chapter "Motion Artifact Reduction from Finger Photoplethysmogram Using Discrete Wavelet Transform" deals with noise reduction from photoplethysmogram (PPG) signal obtained at fingertip. Motion artifact is injected into the clean PPG signal artificially, and denoising is done using discrete wavelet transform. Comparative analysis shows that the performance of the proposed method is better than the existing ones.

Precision of automatic target recognition and striking has become an important area of modern defense research and development. Real-time target classification and recognition require real-time processing of high-frequency and higher-precision THz signals over an ultra-wide bandwidth. Authors in Chapter "Analysis of Picosecond Pulse for ATR Using Ultra-Wideband RADAR" have taken up this very sensitive work of spectrum analysis of THz pulses for detecting radar target.

Authors in Chapter "Detection of Endangered Gangetic Dolphins from Underwater Videos Using Improved Hybrid Frame Detection Technique in Combination with LBP-SVM Classifier" have taken up a very interesting problem of detecting aquatic organisms like fish and dolphins in underwater poor lighting condition. Underwater video is analyzed and processed to recognize endangered Gangetic dolphin class using the hybrid of traditional SVM classifier and local binary pattern feature extractor.

Lip contour detection and extraction is the most important criterion for speech recognition. Chapter "Automatic Lip Extraction Using DHT and Active Contour" presents a new lip extraction algorithm that works good in case of uneven illumination, effects of teeth and tongue, rotation, and deformation.

Noise classification is very crucial in medical image processing mainly because of the associated medical implication. Chapter "Early Started Hybrid Denoising Technique for Medical Images" deals with a hybrid denoising technique for brain images obtained by PET and CT scans, and authors share some of their impressive findings in this regard.

Chapter "Intelligent Tutoring by Diagram Recognition" demonstrates a nice application of digital diagram recognition and analysis in facilitating student's learning of geometry. The authors have reported a case study of elementary geometry of primary school level and have shown how intelligent handling of digital image can replace traditional teaching.

Quantum computing is a new paradigm of intelligent computing. Authors in Chapter "Color MRI Image Segmentation Using Quantum-Inspired Modified Genetic Algorithm-Based FCM" have deployed quantum-inspired modified genetic algorithm for color MRI image segmentation that has enhanced the speed, optimality, and cost-effectiveness of the conventional GA or modified GA.

Processing and digitization of handwritten documents is an important application of clustering algorithms. Chapter "Multi-verse Optimization Clustering Algorithm for Binarization of Handwritten Documents" presents an automatic clustering algorithm for binarization of handwritten documents based on multi-verse optimization. The proposed approach is tested on a benchmark data set.

Effectiveness of 3D object reconstruction and recognition from a set of images is evaluated in Chapter "3D Object Recognition Based on Data Fusion at Feature Level via Principal Component Analysis." Different feature extraction, matching, and fusion techniques and discrete wavelet transform are used to reconstruct different 3D models from a given set of images.

With newer techniques evolving for signal and image processing, unauthorized manipulation and corruption of digital audio, image, and video data is becoming easier, thereby requiring robust watermarking technique. Authors have offered a new watermarking technique for digital image (for copyright protection) using discrete wavelet transform (DWT) and encryption in Chapter "Digital Image Watermarking Through Encryption and DWT for Copyright Protection."

Extraction of textural and acoustic features from speech and non-speech audio files and classification of audio files comes under the purview of Chapter "Speech and Non-speech Audio Files Discrimination Extracting Textural and Acoustic Features." This is a new interesting area of research of audio signal recognition.

Another interesting area of audio signal recognition is speech recognition. Chapter "Speaker Recognition Using Occurrence Pattern of Speech Signal," the last chapter, addresses speaker identification problem that has potential application in forensic science, tele-banking, smart devices, etc. Authors have shown how their method correctly classifies speech sample and identifies the speaker.

This treatise contains 21 chapters encompassing various applications in the domain of signal and image processing. The applications range from filtering, encoding, classification, segmentation, clustering, feature extraction, denoising, watermarking, object recognition, reconstruction, fractal analysis on a wide range of signals including image, video, speech, non-speech audio, handwritten text, geometric diagram, ECG and EMG signals, MRI, PET, and CT scan images, THz signals, solar wind speed signals (SWS), and photoplethysmogram (PPG) signals. The authors of different chapters share some of their latest findings that can be considered as novel contributions in the current domain. It is needless to mention that the effort by the editors to come out with this volume would not have been successful without the valuable contribution and the effort and cooperation rendered by the authors. The editors also would like to take this opportunity to express their thanks to Springer as an international publishing house of eminence to provide the scope to bring out such a concise and quality volume. The editors would also like to express their heartfelt thanks to Mr. Aninda Bose, Senior Editor, Springer, for his support and guidance right from the planning phase. The editors also express their gratitude to the respected reviewers who have shared their valuable time and expertise in meticulously reviewing the papers submitted to the symposium and finally selecting the best ones that are included in this volume. We sincerely hope that this book volume becomes really useful to the young researchers, academicians, and scientists working in the domain of signal and image processing and also to the postgraduate students of computer science and information technology.

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Kaori Yoshida studied Electrics and Computer Engineering at Kyushu Institute of Technology and received her bachelor and master's degrees. From 1996 to 1999, she has worked as intern at Electrotechnical Laboratory, AIST, MITI in Tsukuba City, Japan. She has obtained JSPS Research Fellowship from 1998 and achieved doctoral degree at Kyushu Institute of Technology in 1999. She is currently an Associate Professor in the Department of Brain Science and Engineering at Kyushu Institute of Technology. Her research interests include Kansei Information Processing, Human–Computer Interaction, and Soft Computing. She has published more than 100 research papers in these fields.

Design of Higher Order Quadrature Mirror Filter Bank Using Simulated Annealing-Based Multi-swarm Cooperative Particle Swarm Optimization

Supriya Dhabal, Roshni Chakrabarti and Palaniandavar Venkateswaran

Abstract This paper presents a novel hybrid algorithm based on Multi-swarm Cooperative Particle Swarm Optimization (MCPSO) and Simulated Annealing (SA) for the design of higher order Quadrature Mirror Filter (QMF) bank. The optimization of lower order filters can be carried out easily by traditional optimization methods, but these approaches failed to find higher order filter coefficients due to nonlinear and multimodality problem space. Most of the optimization algorithms are easily trapped into local optimum which yields few unwanted characteristics in filter magnitude responses like ripples in transition region, lower stop-band attenuation. The proposed algorithm, named Simulated Annealing-based Multi-swarm Cooperative PSO (SAMCPSO), is presented here to obtain prototype filter that leads to near-perfect reconstruction for both lower and higher dimensional filter banks. Comparison with other existing methods in the literature demonstrates that the proposed algorithm exhibits an average increase of 17.39% in stop-band attenuation and 47.35% reduction in Perfect Reconstruction Error (PRE) of 82-tap filter bank.

Keywords QMF · Filter bank · NPR · PSO · Metropolis criterion · SAPSO

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1 Introduction

During the last few years, QMF bank has been widely employed in the processing of biomedical signals, design of wavelet bases, noise cancellation, discrete multi-tone modulation systems, wideband beam-forming, and so on [1–5]. Few applications of filter bank like echo cancellation, cross talk suppression, ECG signal processing, three-dimensional audio reduction systems, and efficient realization of the higher order filter banks are necessary as they necessitate high attenuations at stop-band. Therefore, several design approaches are developed for efficient realization of the filter bank. Due to the complex optimization and high degree of nonlinearity, the techniques provided in [1–3, 6–12] are not applicable for the design of higher order filter banks and do not have precise control at transition band of the magnitude response which yields in sub-optimal solutions. The above-mentioned limitations can be tackled effectively by integrating SA with MCPSO.

Although PSO is considered as a robust algorithm exhibiting fast convergence in many practical applications, it suffers from the premature convergence problem and can be easily trapped in local optima. Therefore, several attempts have been made by researchers to improve the performance of PSO. One such method is the hybridization of PSO with other local search methods like SA. By hybridizing SA with PSO, significant performance improvement is achieved for different practical problems. Besides this, the recent development in optimization paradigm shows that the multi-swarm-based methods can perform better with the higher dimensional and multimodal problems [13–17]. Thus, by exploiting improved features of SA and multi-swarm PSO, a new SAMCPSO algorithm has been proposed in this paper towards the efficient design of higher order QMF bank.

The remaining of the paper is arranged as follows: the formulation of design problem to obtain prototype filter is discussed in Sect. 2. The proposed design method using hybrid SAMCPSO is presented in Sect. 3. The simulation results with different design examples are demonstrated in Sect. 4. Further, comparative study of the performance of QMF bank with other existing methods is also analysed and presented. Finally, conclusions and further research scopes are given in Sect. 5.

2 Design Problem Formulations

QMF is a two-channel filter bank, consisting of analysis filters followed by down-samplers in the transmitting part and up-samplers with synthesis filters in the receiver section, as presented in Fig. 1. The design problem of QMF can be solved by considering mean square errors in passband $\left(E_p\right)$, stop-band (E_s), transition band (E_t), and ripple energy of filter bank, i.e. Measure of Ripple (MOR) [7]. During the design of filter bank, it is assumed that the prototype filter should be ideal in passband and stop-band, and there exists lowest possible reconstruction error at

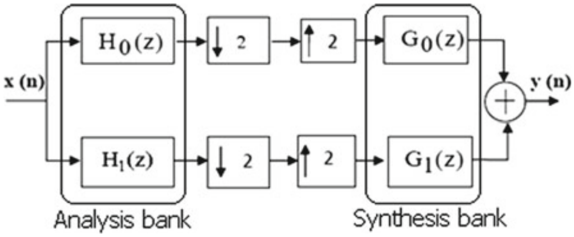

Fig. 1 Basic structure of QMF bank

$\omega = \pi/2$. Consequently, the objective function (φ) is formulated using a weighted sum of these four parameters as given by [2–7]:

$$\varphi = \alpha E_p + (1-\alpha)E_s + E_t + \beta\,\mathrm{MOR} \tag{1}$$

where $0 < \alpha \le 1$ and β are the weight of MOR.

3 The Proposed Hybrid SAMCPSO Algorithm

Multi-swarm cooperative PSO (MCPSO) is an important variant of the basic PSO algorithm, based on the use of multiple swarms instead of a single swarm [14–17]. In MCPSO method, the whole population is divided into a number of sub-swarms which can execute independently following the principle of master–slave model: it consists of one master swarm and several slave swarms. Each slave swarm executes a single PSO or its variants. When all the slave swarms are equipped with the new solutions, each of them sends the best local solution to the master. Thereafter, master swarm selects the best of all received solutions and evolves velocity and position according to the following modified equations:

$$\begin{aligned} V_{iD}^{M} = \chi \Big(& \omega * V_{iD}^{M} + c_1 * \frac{r_1}{r} * (pbest_{iD}^{M} - X_{iD}^{M}) \\ & + \psi * c_2 * \frac{r_2}{r} * \left(pbest_{gD} - X_{iD}^{M}\right) \\ & + \psi * c_3 * \frac{r_3}{r} * \left(pbest_{gD}^{M} - X_{iD}^{M}\right) \\ & + (1-\psi) * c_4 * \frac{r_4}{r} * (pbest_{gD}^{S} - X_{iD}^{M}) \Big) \end{aligned} \tag{2}$$

$$X_{iD}^{M} = X_{iD}^{M} + V_{iD}^{M} \tag{3}$$

where $c_{1-4} = 2.05$, $r_{1-4} \in [0, 1]$ are random numbers related as $r = r_1 + r_2 + r_3 + r_4$, and ψ is a migration factor given by

$$\psi = \begin{cases} 0 \ pbest_g^S \le pbest_g^M \\ 1 \ pbest_g^S > pbest_g^M \end{cases} \quad (4)$$

Here, ψ is responsible for supplying best slave swarm to the master swarm as the generation proceeds. The best performed slave and master particles are represented by $pbest_g^S$ and $pbest_g^M$, respectively. As inertia weight (ω) plays a significant role in balancing act of exploration and exploitation behaviour of particles, a new adaptive inertia weight is introduced here for the adjustment of ω as:

$$\omega = \begin{cases} \omega_{max} & \text{if} \quad f \ge f_{avg} \\ \omega_{max} - (f - f_{min}) * (\omega_{max} - \omega_{min})/(f_{avg}/4 - f_{min}) & \text{if } f \ge f_{avg}/4 \,\&\, f < f_{avg} \\ (\omega_{max} - \omega_{min}) \times \frac{(iter_{max} - iter)}{iter_{max}} + \omega_{min} & \text{if} \quad f < f_{avg}/4 \end{cases} \quad (5)$$

where "f" denotes the fitness of current particle, f_{avg} is the mean fitness of the swarm selected, and f_{min} indicates the fitness of global best solution achieved so far. In our proposed approach, two modifications are performed to escape from local minima while maintaining the diversity of particles in the swarm: (a) the SA is introduced inside the search process because SA employs high probability to jump out from local optima [10, 13], and (b) instead of single swarm, the cooperative multi-swarm scheme with modified search equation and inertia weight is employed which helps in better balancing the exploration and exploitation performance of particles in the swarm [15]. Thus, the effective combination of SA and multi-swarm cooperative PSO scheme reduces the computational complexity for searching the lower order filter coefficients, and at the same time, it also has the sufficient ability to avoid premature convergence for the design of higher order filters. The summary of proposed SAMCPSO is introduced as follows:

Step 1: **Initialization stage**—Specify number of filter taps, the passband frequency (ω_p), stop-band frequency (ω_s), α, and β . **PSO**: Initialize number of slave swarms and size of each swarm; create initial swarms by randomly generating position and velocity vectors for each particle assuming first (MM) entries are zero; initialize ω_{max}, ω_{min}, c_1, c_2, maxNOI (maximum number of iterations) and NOI = 0, ite_M = no. of iterations after which MM will be reduced. **SA**: Assume *LS*—local search interval, initial temperature (T_0) , minimum temperature $\left(T_{min}\right)$. For simplification purpose, cooling schedule for SA is chosen as $T(k) = 0.99 * T(k-1)$.

Step 2: **Computation for PSO and SA**—Evaluate the fitness of all particles in each swarm; find out $pbest_g^s$ from each slave swarm, $pbest_g^M$ from master swarm and $gbest$ for the entire swarm. Repeat until evaluations < maxNOI or $T(k) < T_{min;}$ select a random particle from each swarm and update velocity and position of slave and master particles. Calculate fitness of newly generated slave and master particles. Update best slave $pbest_g^s$ from each group and best master $pbest_g^M$. Update $gbest$ based on Metropolis criterion [13]. If $gbest$ is modified, then reduce temperature using the cooling schedule. After every *LS* evaluation, perform SA for $gbest$ particle.

If $MM \neq 0$ and mod (iterations, ite_M) = 0, then reduce $MM = MM - 1$ and NOI = NOI + 1.

Step 3: **Output optimization results**—Design the prototype filter using best solution of the whole swarm, i.e.*gbest*, and obtain all other filters of QMF bank from the prototype filter.

4 Simulation Results and Discussion

In this section, the proposed SAMCPSO method is used for the design of prototype filter of QMF bank. The unknown parameters of cost function, i.e. α and β are selected by trial and error methods to obtain the best possible solutions. The complete simulation work is carried out using MATLAB 2012a on Genuine Intel(R) Core (TM) i5-2450 M @2.5 GHz, 4 GB RAM. In the design, following performance parameters are measured: square errors in passband (E_p), stop-band (E_s), transition band (E_t),

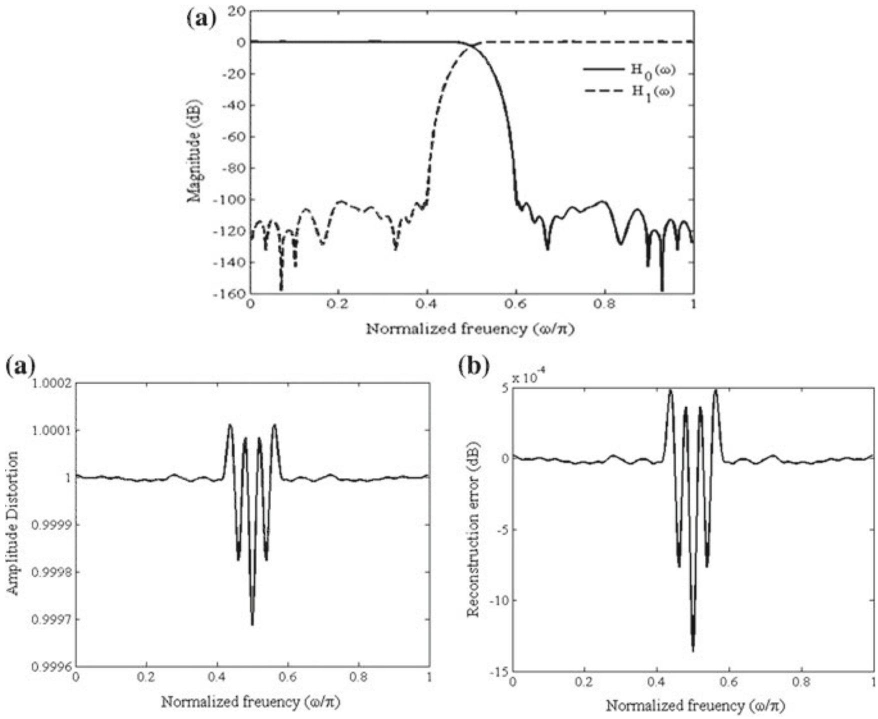

Fig. 2 Frequency response of QMF for N = 100: **a** amplitude response of analysis filters, **b** variation of amplitude distortion, **c** reconstruction error in dB

overall amplitude distortion $e_{am}(\omega)$, Peak Reconstruction Error (PRE), and stop-band attenuation (A_s) in dB [7].

4.1 Design Problem

Here, the filter bank is designed with the set of specifications: N = 100, $\omega_p = 0.4\pi$, and $\omega_s = 0.6\pi$. The magnitude response for analysis filters and amplitude distortion function are plotted and shown in Fig. 2a and Fig. 2b, respectively. Figure 2c illustrates the reconstruction error of QMF bank. The calculated values of A_s and PRE are 122.23 dB and 0.000334 dB, respectively. The remaining performance results are as follows: $E_p = 2.94 \times 10^{-12}$, $E_s = 8.57 \times 10^{-14}$, and $E_t = 2.65 \times 10^{-19}$.

4.2 Performance Analysis for Designing Higher Order Filter Banks

For higher values of N, the performance results are shown in Table 1. The values of α, and β are selected based on the minimum of fitness function achieved. It is obvious that with the increase of filter taps (N), the values of E_p, E_s, E_t, e_{am}, and PRE are reduced gradually while A_s is increased.

4.3 Comparison of Results with Other Algorithms

Table 2 indicates the improvement in performance for higher order filter banks in comparison with recently available methods given in [4, 5, 11, 18–20]. For N = 48, keeping E_p, E_s, and E_t almost at the same level, the percentage improvements in A_s are 17.27%, 15.38%, 7.63%, 23.04%, 2.68%, and 4.02%, respectively. In addition to A_s, large amount of reduction in PRE are noticed using proposed method which are 65.62%, 38.8%, 67.10%, 99.53%, 7.55%, and 42.7%, respectively.

5 Conclusions

In this paper, a new algorithm based on multi-swarm PSO is presented to design the linear phase prototype filter of QMF bank. To avoid the premature convergence in higher order filter design, SA is hybridized with multi-swarm PSO. The performance of the proposed SAMCPSO algorithm is compared with that of different PSO variants, ABC, BAT algorithm, and other well-known recently reported methods.

Table 1 Performance parameters obtained using proposed SAMCPSO for higher order filter banks

N	α	β	E_p	E_s	E_t	e_{am}	PRE (dB)	A_s (dB)
48	0.8	10^{-06}	3.9×10^{-09}	1.6×10^{-08}	1.4×10^{-11}	2.1×10^{-03}	0.00305	59.28
56	0.6	10^{-06}	1.6×10^{-09}	1.6×10^{-09}	4.8×10^{-12}	1.2×10^{-03}	0.00135	67.16
64	0.5	10^{-06}	1.1×10^{-09}	6.5×10^{-10}	1.9×10^{-11}	9.1×10^{-04}	0.00105	77.135
76	0.5	10^{-07}	2.7×10^{-10}	6.4×10^{-11}	7.5×10^{-12}	7.7×10^{-04}	0.00096	102.83
82	0.3	10^{-08}	1.4×10^{-11}	2.7×10^{-13}	1.1×10^{-18}	6.8×10^{-04}	0.00082	112.88
90	0.01	10^{-09}	1.4×10^{-11}	9.6×10^{-14}	7.7×10^{-19}	5.7×10^{-04}	0.00042	119.46
100	0.01	10^{-09}	2.9×10^{-12}	8.6×10^{-14}	2.7×10^{-19}	4.8×10^{-04}	0.00033	122.24

Table 2 Performance comparison of proposed SAMCPSO for higher order (N = 48 and 82) filter bank

N	Method	A_s (dB)	e_{am}	E_p	E_s	E_t	PRE (dB)
48	[4]	50.55	–	2.54×10^{-09}	6.62×10^{-08}	3.87×10^{-27}	0.0089
	[5]	51.38	–	2.70×10^{-08}	8.91×10^{-08}	1.93×10^{-22}	0.0050
	ABC [11]	55.08	–	3.16×10^{-10}	2.95×10^{-08}	–	0.0093
	BAT [18]	48.18	0.1618	$4.40 \times 10^{+02}$	$9.00 \times 10^{+02}$	6.49	0.6445
	COABC [19]	57.73	3.87×10^{-03}	5.08×10^{-10}	1.77×10^{-08}	3.17×10^{-13}	0.00331
	CPSO [20]	56.99	3.9×10^{-03}	3.58×10^{-10}	1.76×10^{-10}	2.26×10^{-13}	0.00534
	SAMCPSO	**59.28**	$\mathbf{2.08 \times 10^{-03}}$	$\mathbf{3.93 \times 10^{-09}}$	$\mathbf{1.63 \times 10^{-08}}$	$\mathbf{1.36 \times 10^{-11}}$	**0.00306**
82	[4]	96.16	–	1.31×10^{-13}	8.30×10^{-13}	2.01×10^{-20}	0.0037
	[5]	96.54	–	3.37×10^{-11}	4.18×10^{-12}	2.07×10^{-14}	0.0010
	ABC [11], BAT [18], COABC [19], CPSO [20]				No feasible solution found		
	SAMCPSO	**112.88**	$\mathbf{6.86 \times 10^{-04}}$	$\mathbf{1.37 \times 10^{-11}}$	$\mathbf{2.66 \times 10^{-13}}$	$\mathbf{1.37 \times 10^{-18}}$	**0.000829**