Research Article

A novel approach adaptive filtering method for electromyogram signal using Gray Wolf optimization algorithm

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Abstract
The proposed paper, presents the construction of adaptive noise cancellation filter based on gray wolf optimization (GWO) optimization technique.The relative investigation of different strategies uncovers that the presentation of GWO calculation is better in boisterous condition. The objective of proposed paper is structure ANC channel utilizing GWO method that improves association involving output with pure EMG signal.The results of proposed strategy are contrasted through gray wolf optimizer (GWO) and other evolutionary algorithms.The presentation of these calculations is assessed regarding signal-to-noise ratio (S_{SNR}), mean square error (S_{MSE}), maximum error (S_{ME}) mean, convergence rate (CR) plus correlation feature (S_r). The noise attenuation capability is tested on EMG signal contaminated with power line and ECG noise at different SNR levels. The ANC filter based on GWO technique provides 28 dB improvement in output SNR, 81% reduction in MSE, and 84% lower ME as compared to reported ANC filter based on RLS algorithm. Further, ANC filter based on GWO technique provides 7 dB improvement in output SNR, 59.5% reduction in MSE, and 69.2% lower ME as compared to recently reported ANC filter based on ABC-MR algorithm.

Keywords GWO · ABC-MR · Gradient methods · SNR · MSE · ME and ANC

1 Introduction

The information generated by electromyogram (EMG) is popularly utilized for conducting study of motor function and movement disorders including dystonia. The dystonia is medically identified by sustained muscle contractions pain along with twisting and abnormal posture. We aim to denoise EMG signal which include power line interference and electrocardiogram (ECG) coupling. The objective behind the proposed work is to design an ANC filter based on GWO algorithm, that generates better result and fidelity paramerets.The GWO calculation applies a similar natural system, so pursues collection order for arranging various jobs involved with wolves collection. The ANC recommend channel configuration be a viable method for de noising EMG that enhance signal to noise ratio (SNR), mean-square-error (MSE), maximum error (ME) furthermore relationship dynamic essentially. The work of this paper is organised as follows. In Sect. 2 related research review and gaps are presented The proposed work is described in Sect. 3. In Sect. 4 the algorithm of GWO and optimizer is discussed. The performance of proposed work is evaluated in Sect. 5. Finally, concluding remarks are presented in Sect. 6.

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2 Research review and gaps

The electromyogram (EMG) represents a superposition of electrical activity from motor unit action potentials located subcutaneous to the detecting electrodes. EMG gives important data identifying with peripheral and central motor function that has been generally adopted in the investigation of motor function and movement disorders consisting dystonia [1, 2]. The clinical disorder is dystonia portrayed via bending, anomalous stance, tedious developments and pain resulting from sustained muscle contractions. The surface EMGs got from patients amid dystonia are characteristically non-stationary because of unstable and blended indications that include considerable degrees of noise in [2]. The beside this, there are several other popular artefactual sources that should be recognized as well.In the past, surface EMGs.

Have been applied to assess muscle activity in dystonia and to analyse its patho physiological characteristics in [2, 3]. It is observed that brief brusting activity is superimposed on persistent tonic activity in dystonic patients surface EMGs [2–4]. Recently, new measures indicate that patients with a dominant pattern of EMG activity burst faster and better after pallidal deep brain stimulation (DBS) and an intrusive neurosurgical stereotactic procedure [5]. Research proposed with aim to dystonic movement might expected with high-synchronized pallidal motions here 3–20 Hz range [5, 6]. In any case, apparent partition through mechanism in charge of blasting and supported sustained muscular activation remains elusive [3]. The restriction were imposed on discoveries by the tainting EMG accounts because of ECG artefacts that particularly articulated through shoulder along with neckline muscles of sufferer through cervix dystonia. Along these lines, undesirable signal during EMG incorporate power line interference and ECG coupling. The power line interference can be effectively evacuated utilizing appropriate notch filters [7]. Though, separation of ECG via surface EMG recordings is a difficult task because of their inherent overlap in frequency and temporal domains. A few investigations encompass moreover accounted for exclusion of ECG noise from the surface EMGs via appropriate high-pass filters, substraction otherwise gating operation methods [6]. Karan et al. [8] examining impact pro changing discontinued recurrence via high-pass filter moreover recommended that cut-off frequency of around 30 Hz might exist ideal pro removing ECG contamination in EMG signal. Abstraction method announced here [6–10] gives a substitute arrangement by recognizing and adjusting QRS complexes, averaging the adjusted action and subtracting the averaged artefacts from EMG by means via least square fit. Presented stategy viability depends upon precision related QRS composite identification furthermore level based upon the degree of stationary EMG signal. Then again, proposed strategy gives an over simplified at this point possibly compelling technique for removing ECG artefact [11–13].

This form, however, suffers from the loss of portions of the EMG signal overlapping in amplitude with QRS complexes [11]. Recently, more sophisticated algorithms for signal processing including nonlinear state space projections [12], wavelet-threshold de-noise in [3], independent components analysis (ICA) [1] and Neural-ICA combinations were used to remove artefact in the surface EMGs. Weiner and Kalman filters [13] were later used model ANC filter based on ECG and EMG's relative characteristics i.e. the frequency overlap, non-stationary, varied temporal shape and low signal-to-noise ratio (SNR) to achieve optimal denoising performance. The Literature survey investigates to facilitate different kinds of calculations else error inference techniques were exploited via adaptive filter to alter loads pro filter, furthermore error inference as indicated by EMG moreover noise features [4, 5]. Best inclination supported calculations be least mean square (LMS), recursive least mean (RLS) along with various variations based on them [14]. Discussed methods experience a few issues of convergence, analyzing the non-linear and non-stationary processes, and partial overlap of signal and noise bandwidths. Currently, Swarm intelligence (SI) [15] is another incredible type of the SI used to take care of the optimization issues. The SI calculations simulate and imitate the common swarms or networks or frameworks, for example, fish schools, winged animal swarms, bacterial development, creepy crawlies provinces and creature crowds. The vast majority of the SI calculations focus taking place conduct based upon flock's individualsas well as intrinsic way of living other than collaborations, moreover connection among flock's individuals towards find sustenance basis. The SI calculations incorporate numerous calculations such ant colony optimization technique (ACO) [16], particle swarm optimization (PSO) [17], cuckoo search (CS) [18], krill herd optimization (KH) [19], firefly scheme (FS) [20], artificial bee colony (ABC) [21], multi-verse optimizer (MVO) [22], ant lion optimizer (ALO) [23], sine cosine scheme (SCS) [24], dragonfly scheme (DS) [25], whale optimization scheme (WOS) [26], moth-flame optimization scheme (MFOS) [27], gray wolf optimizer technique (GWO) [28] and numerous former. The latest flocked knowledge is GWO, that's created via Mirjalili et al. [28] during 2014. GWO calculation be propelled via dim deceivers looking for the ideal path for chasing preys. GWO calculation applies a similar natural system, so pursues collection order pro arranging various jobs involved amid wolves collection. Here GWO, collection individuals be isolated keen on four gatherings dependent upon sort belongs wolf's job helped during propelling along chasing procedure. Along four gatherings termed alpha, beta, delta

furthermore omega, here alpha speaks to finest arrangement establish pro chasing up until this point. The splitting up populace towards four gatherings best studied in first GWO manuscript near conform to the pre dominance chain of command of dark scoundrels. The creators of this calculation led a broad analysis and saw that considering four gatherings brings about the best normal presentation on benchmark issues and a lot of low-dimensional true contextual analyses. In any case, considering pretty much gatherings can be explored as a future work when taking care of enormous scale testing issues. As far as we could possibly know, the ANC channel dependent on GWO isn't accounted in literature. Hence, the inspiration for present exploration be proposal of ANC channel configuration dependent pro AMC-MR calculation intended via productive de-noising of EMG. As shown ANC channel dependent on GWO calculation displays better fidelity parameters when contrasted with the detailed ANC channel planned with ABC, CS, MCS, QPSO, PSO and RLS strategies.

3 GWO based ANC filter devlope

The explaining chronological research including research design, the adaptive filter research procedure works as a noise canceller due to its selflearning process in which filter coefficients are adjusted in iterations to minimize error in [29, 30]. The ANC filter configuration be accounted for utilizing inclination based strategies, for example, LMS, also RLS techniques [14] utilized toward filter including power line also electroculogram (EOG) noise since ECG. As of late, developmental procedures, for example, QPSO, PSO, CS, MCS furthermore ABC, ABC-MR be utilized toward upgrade ANC channel aspects for effectively recreating ECG in [30]. None the less, present calculations be no more connected for structuring ANC filter for de-noising EMG. The consequently, recommended effort, structures ANC channel utilizing QPSO, PSO, CS, MCS, ABC, ABC-MR furthermore GWO along side slope based procedures is proposed. The square chart of ANC channel utilizing GWO is appeared here Fig. 1. The noisy EMG (d(n)) signal incorporates the simple EMG (s(n)) and q(n) signal. The q(n) consists of high frequency (power line noise) and low frequency (ECG noise) components that are additive and uncorrelated to s(n) in the case of EMG signal. The The noisy EMG (d(n)) signal contains the pure EMG (s(n)) and q(n) signal. The q(n) consists of high frequency (power line noise) and low frequency (ECG noise) components that are additive and uncorrelated to s(n) in the case of EMG signal.Signal d(n) from the MITBIH database is taken from this work [31]. In Fig. 1, $q_1(n)$ moreover $q_2(n)$ be high furthermore low frequency noise, separately created utilizing Matlab. As noticed to facilitate q_1(n) along q_2(n) are correlated with $q(n)$ yet uncorrelated with $s(n)$. The reference nosie q_1(n) moreover q_2(n) are fed toward ANC channel just deliver yield $y_1(n)$ and $y_2(n)$, separately. In each iteration, the error signal ($e_1(n)$) is measured as the difference between $d(n)$ and $y_1(n)$, which is returned to the ANC filter. The process of iteration will continue till $e_1(n)$ or at the first stage the high frequency noise is reduced. The yield signal, $s(n)+q'(n)$ enclosing low frequency noise be allowed to the second phase of ANC filter when error signal ($e_2(n)$) be registered while distinction of $s(n)+q'(n)$ moreover $y_2(n)$. The $e_2(n)$ be backward fed to ANC filter during each iteration.

Till $e_2(n)$ is limited. The last yield signal ($s'(n)$) is almost equivalent to $s(n)$. The objective function for $e_1(n)$ and $e_2(n)$ is spoken to [30]:

$$S_{\text{objective function}} = \frac{1}{M}\sum_{i=1}^{M} e_{ij}^2(m) \tag{1}$$

where e_{ij} (m) is jth error of ith sample for mth iteration moreover M the total number of samples of input signal

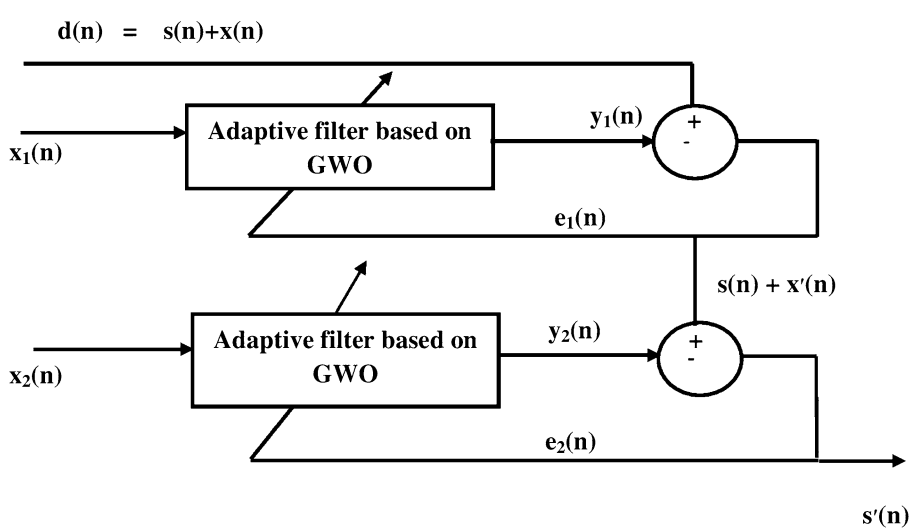


Fig. 1 Cascsde structure of an ANC filter

applied. After each iteration [13, 14] a traditional adaptive filter optimization algorithm offers only one solution. The different algorithms are used to formulate the ANC problem as an optimization problem to obtain a range of possible solution in each iteration, so that the likelihood of of achieving the global optimum is increased [16–20].

4 Gray Wolf optimizer

The Gray wolf (canis lupus) has an area with canidae own kin. Dark wolves be considered peak marauders, involveing that they're at the very best point of the life evolution. Dark wolves for the most part liked to stay in grouped flocks. The collection length is 5–12 by and huge. The specifically persuasive a severe communal widespread pecking order presented in Fig. 2.

The pioneers are a male and a woman, known as alphas. The alpha is for the maximum element in charge of deciding on alternatives about chasing, resting vicinity, time to wake etc. alpha's selections management for flocks. None the less, protocol laid conduction additionally watched alpha pursues different deceivers. Social events, the entire percent recognizes the alpha through maintaining their tails down. Additionally alpha devours termedas predominant devour iven that his/her requests ought to be trailed via the flock [32]. Alpha devours are simply accepted to mate inside the flock. Strangely, The alpha is not clearly the maximum grounded character from the flock however finest as far as whole flock. That exhibits alliance control of flock which significantly addedinits excellence. Next echelon in chain of importance of dark devours is β. The β_s represents subordinate devours which help alpha in fundamental leadership or different flock fitness. The beta wolf may be either male or lady, and he/she is in all likelihood the first-class contender to be the alpha within the event that one of the alpha wolves passes away or seems to be extremely antique. The beta wolf ought to regard the alpha, however directions, the other lower-level wolves also. It assumes the job of a counselor to the alpha and discipliner for the flock. The beta strengthens the alpha's instructions for the duration of the flock and gives enter to the alpha. The least positioning dark wolf is omega. The omega assumes the activity of alternative. Omega wolves continually want to submit to the numerous winning wolves. They're the remaining wolves which can be approved to eat. It'd seem the omega isn't always a substantial person within the percent, yet it's been visible that the entire percent face indoors struggling with and troubles within the event of dropping the omega. This is because of the venting of savagery and disappointment of all wolves by the omega(s).

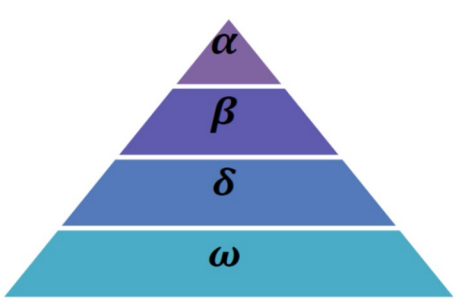


Fig. 2 Social hierarchy of grey wolves

This facilitates pleasant the whole percent and keeping up the predominance shape. Sometimes the omega is likewise the sitters within the flock. In the event that a wolf isn't an alpha, beta, or omega, he/she is referred to as subordinate (or delta in sure references). Delta wolves need to put up to alphas and betas, but they weigh down the omega. Scouts, sentinels, seniors, trackers, and caretakers have an area with this class. Scouts are in rate of viewing the bounds of the area and cautioning the flock if there must get up an incidence of any peril. Sentinels make sure and make certain the security of the flock. Older parents are the finished wolves who was alpha or beta. Trackers assist the alphas and betas when chasing prey and giving sustenance to the flock. At lengthy remaining, the overseers are in charge of considering the feeble, unwell, and injured deceivers. No longer supporting communalstring of command of devours, bunch driving another fascinating communal accomplishment regarding dim devours. Mentioned by Muro et al. [33] the standardepochs with dark devourdriving as: Tracking, ensuring, along stiring in direction of quarry, pursuing, encompassing, moreover pestering quarry awaiting it relinquishs moving and attack direction of quarry. The steps are represented in Fig. 3. The proposed driving procedure moreover communal progressive system of dark devours be methodically demonstrated so as to plan GWO and perform streamlining.

The strides involved GWO algorithm are tag alonged:

Step 1: Initialization Assign random input weights and vectors coefficient like a, A and C.
Step 2: Evaluating fitness function The fitness output is evaluated on the basis Eq. (6) and the result is the following.
Step 3: Separate the solution based on the fitness. We now evaluate the dissimilar results on the basis of the fitness value. Let the initial finest fitness be w_α, the second finest fitness be w_β and the third finest fitness be w_δ.
Step 4: Position Updation It is presuming that α, β and δ contain the information about the prey's anticipated position. Because of outcome, we a mass the necessary three best impacts acomplished up to this point and also allow additional hunting effect to refresh their circumstance as well. For replication, the innovative weight $w_p(t+1)$ is predicted for replication by stated formulae. An example of grey wolf's possible positions

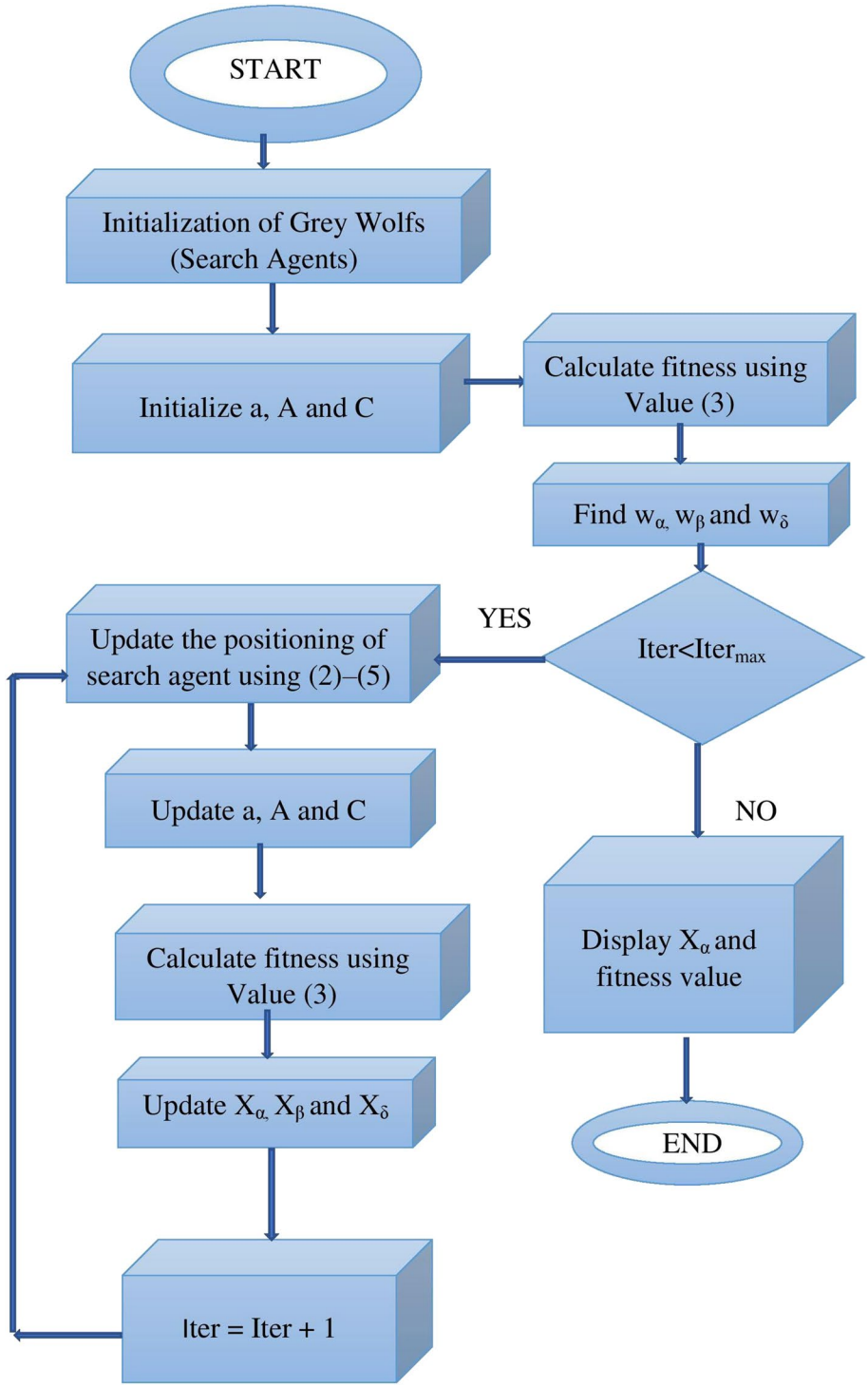


Fig. 3 The deplove of ANC filter using GWO Scheme

on a prey is shown in Fig. 4. The concepts of alpha, beta, delta and omega are terms are shown in Fig. 5.

Stride 5: Calculating the fitness The wellness of the new inquiry weight will be calculated by using Eq. (1). Then the best solution is stored.

$$\left|\vec{Z} = \vec{N}\overrightarrow{X_p}(t+1) - \overrightarrow{X_p}(t)\right| \tag{2}$$

$$\overrightarrow{X_p}(t+1) = \overrightarrow{X_p}(t) - \vec{M}\vec{Z} \tag{3}$$

here t designates existing iteration, $\vec{M}$ and $\vec{N}$ are features vectors $\overrightarrow{X_p}(t)$ is situation vector of quarry, moreover $\overrightarrow{X_p}$ depicts situation vector of grey devour.

The vectors, $\vec{M}$ along with $\vec{N}$ are computed:

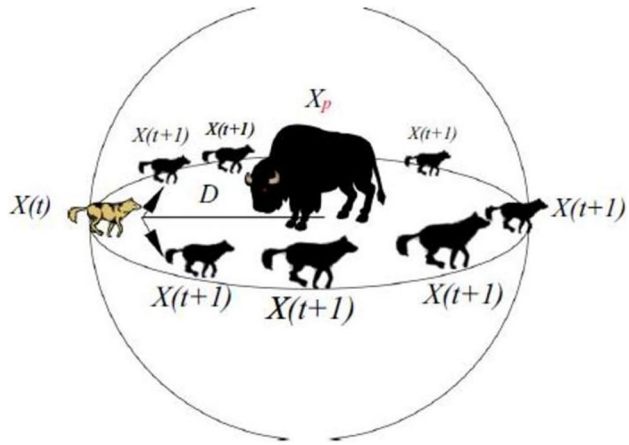


Fig. 4 How to position vary of Gray wolf in 3D

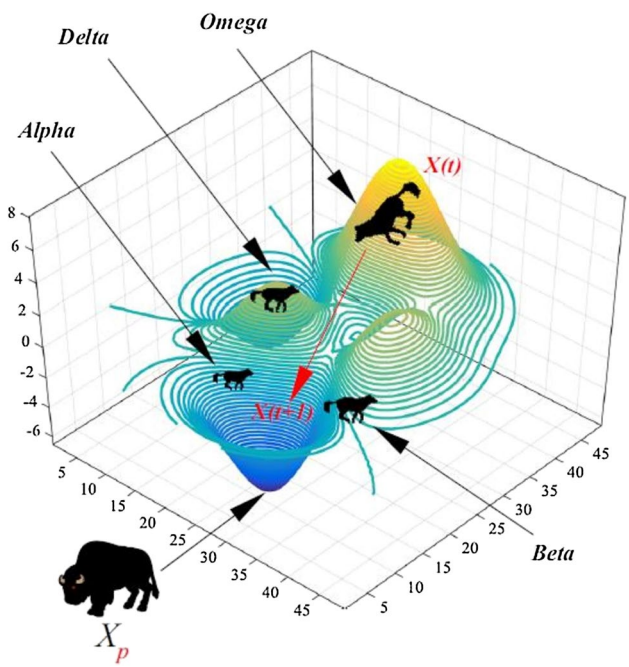


Fig. 5 How α, β, δ and ω are expressed in GWO

$$\vec{M} = 2\vec{b} \cdot \vec{l_1} - \vec{b} \tag{4}$$

$$\vec{N} = 2 \cdot \vec{l_2} \tag{5}$$

where components of $\vec{b}$ are linearly decreased from 2 to 0 over the course of iterations $\vec{l_1}$ and $\vec{l_2}$ are random vectors in [0,1].

Stride 6: End criteria terminate the procedure in the wake of acquiring the best arrangement.

The presented work states the GWO calculation be utilized to figure the ideal loads fore ANC channel that limit's mean square error (MSE). Figure 2 demonstrates stream diagram depicts executing GWO progression. Regarding functional casing, total information sign isn't corresponds to ANC channel at solitary period for example ideal credence vector modification during every emphasis. At the end of the day, a window or tests of the info sign are gotten in each cycle. In this strategy, the goal work (cost work) speaks to a gauge of MSE over the info tests utilized in that emphasis. The wellness capacity to assess wellness of arrangement is planned as:

$$\text{Fi} = \frac{1}{1 + J_i(n)} \tag{6}$$

The EMG information utilized in presented practise is drived via MIT informational collection in [31]. Fllowed information obtained via twice sound themes moreover hexa dissufferers determined to have essential cervical dystonia. Transcripted surface EMGs pro dystonic patients, utilizing dispensable glue Ag/AgCl anodes (H27P, Kendall-LTP, MA, USA) set respectively above symptomatic trapezius moreover sternocleidomastoid muscles. A solitary strait lead-II ECG be at the same time recorded as a kind of perspective sign for versatile sifting. Sign were all the while transcripted since reciprocal trapezius muscles throughout rest moreover head-rotational development. These sign be intensified utilizing secluded CED 1902 enhancers (1000×), separated at 0–1000 Hz and digitized utilizing CED 1401 imprint II at an examining pace of 2500 Hz. Throughout head-rotation ECG artefacts from the left trapezius muscle are combined with ECG free surface EMGs from right trapezius to produce contaminated EMG signals. This procedure allowed simulation of contaminated EMG signals with varying SNRs by ECG.

5 Result analysis

ANC filter performance designed with various evolutionary algorithms such as QPSO, PSO, CS, MCS, ABC, ABC-MR and GWO algorithms is evaluated with with 10 dB noise corrupted EMG signal in [31]. A random noise generated using Matlab with length of 1000 is the reference noise taken in this study. The parameters of fidelity such as output signal-to-noise ratio (SNR), MSE, maximum error (ME) and correlation factor (r) are determined by different SNR input. The following formulas are used to measure these fidelity parameters [15]:

At input, the SNR is calculated as:

$$SNR_{dB} = 10\log_{10}\frac{\left(S_{EMG_{pure}}\right)^2}{\left(S_{EMG_{noisy}} - S_{EMG_{pure}}\right)^2} \tag{7}$$

At output, the SNR is calculated as:

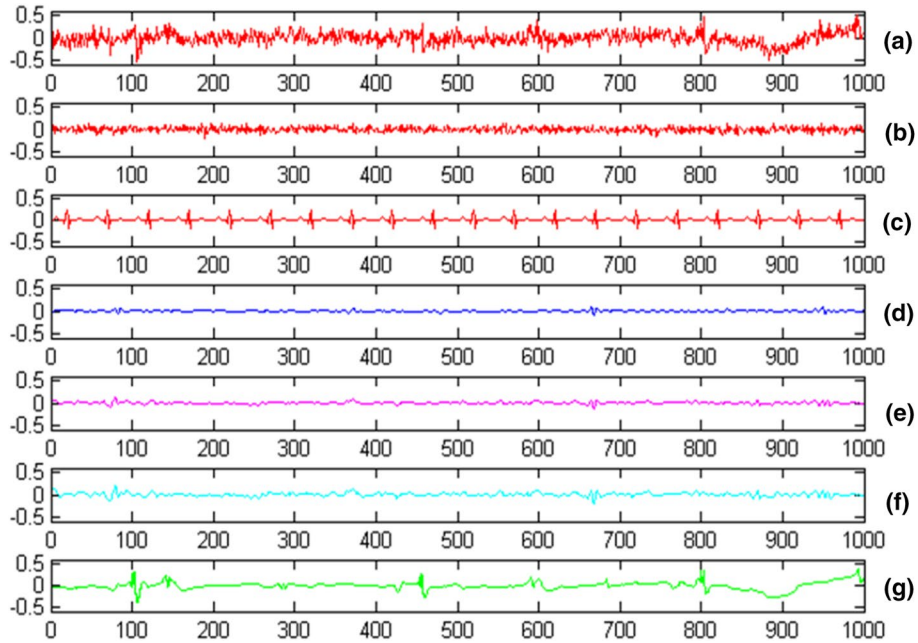


Fig. 6 Improvement of EMG sign utilizing proposed ANC channel dependent on various methods: **a** noisy EMG signal, **b** reference noise at high frequency, **c** reference noise at low frequency, **d** yield EMG sign utilizing PSO, **e** yield EMG sign utilizing MCS, **f** yield EMG sign utilizing ABC-MR, **g** yield EMG sign utilizing GWO strategy

$$SNR_{dB} = 10\log_{10}\frac{\left(S_{EMG_{pure}}\right)^2}{\left(S_{EMG_{filter}} - S_{EMG_{pure}}\right)^2} \tag{8}$$

$$S_{MSE} = \frac{1}{N}\sum_{i=1}^{N}\left(S_{EMG_{noisy}} - S_{EMG_{pure}}\right)^2 \tag{9}$$

$$S_{ME} = abs\left(S_{EMG_{filter}} - S_{EMG_{pure}}\right)^2 \tag{10}$$

$$S_r = \frac{N\sum S_{xy} - \sum S_x \sum S_y}{\sqrt{N\left[\sum S_x{}^2 - \left(\sum S_x\right)^2\right]}\sqrt{N\left[\sum S_x{}^2 - \left(\sum S_y\right)^2\right]}} \tag{11}$$

Where S_x and S_y are the unadulterated and sifted yield EMG signals, individually. In light of the debased EMG signal, the adequacy of ANC channel yield utilizing PSO, MCS, ABC-MR and GWO techniques is appeared in Fig. 6. The signal soutces of Fig. 6a–c be MIT-BIH EMG record [31] moreover matlab, separately. Figure 6d–g demonstrate the remade EMG sign utilizing ANC channel dependent on PSO, MCS ABC-MR and GWO, individually. It is plainly observed that the ANC filter with GWO calculation gives higher amplitude of EMG signal.Therefore, GWO method permits increasingly precise identification of EMG data. Reproduced yield SNR amid variety via information SNR pro various calculations is recorded here Table 1. An examination of yield SNR pro various calculations likewise sketched depicted via Fig. 7. As seen along yield SNR

Table 1 Estimate of output SNR for various input SNR in filtering EMG signal

Input SNR (dB)	Output SNR (dB)				
	SNR_{RLS} [14]	SNR_{-PSO} [16]	SNR_{-MCS}	SNR_{ABC-MR}	SNR_{-GWO}
−5.0	0.89	2.49	4.59	6.86	9.67
−2.5	3.04	5.63	5.36	7.26	13.45
0.5	4.78	9.68	7.68	12.47	20.36
1.5	6.24	9.76	10.57	17.34	25.47
3.0	7.04	8.69	16.45	23.64	34.57
4.5	13.27	19.57	28.65	31.65	38.12
6.0	17.43	22.34	39.24	42.41	48.96
7.5	18.68	33.35	45.72	53.32	56.84
9.5	19.32	34.31	48.68	59.78	65.87
10	21.65	35.43	54.49	65.23	80.43

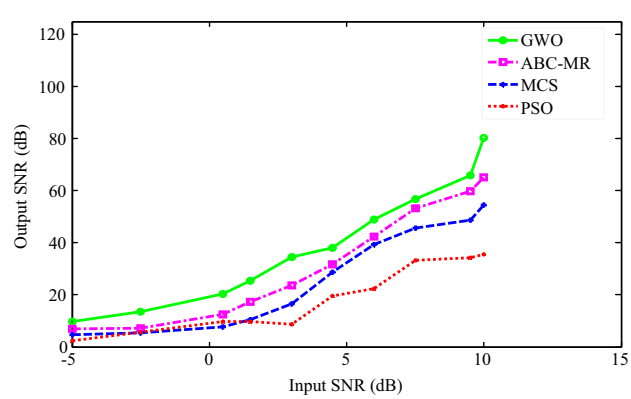


Fig. 7 Output SNR ploting for various input SNR

Table 2 MSE estimate of filtering EMG signal for various input SNR (dB)

Input SNR (dB)	MSE ($\times 10^{-6}$)				
	MSE_{-RLS} [14]	MSE_{-PSO} [16]	MSE_{-MCS}	MSE_{ABC-MR}	MSE_{GWO}
−5.0	11.65	8.87	7.6856	6.457	3.76
−2.5	10.69	8.23	7.0764	4.897	2.9
0.5	9.35	8.09	6.5774	5.901	2.4
1.5	8.58	7.067	6.2494	7.547	2.03
3.0	7.89	6.76	5.615	4.201	1.49
4.5	7.05	6.26	4.5287	3.214	1.08
6.0	6.89	6.06	4.3309	2.345	0.96
7.5	6.98	6.04	3.3188	1.654	0.84
9.5	5.68	3.803	2.107	1.547	0.203
10	4.98	3.503	2.021	1.002	0.0367

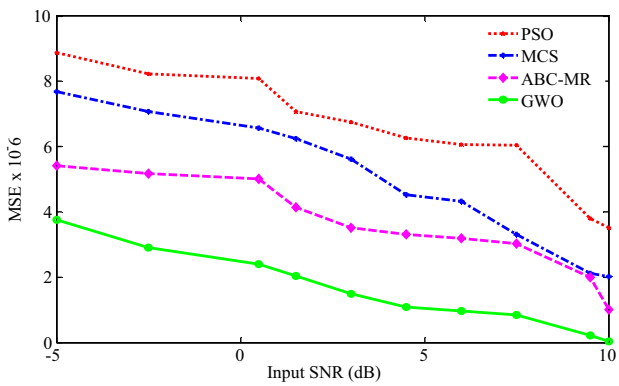


Fig. 8 MSE ploting for various input SNR

Table 3 ME estimate of filtering EMG signal for various SNR(dB)

Input SNR (dB)	ME ($\times 10^{-5}$)				
	ME_{-RLS} [14]	ME_{-PSO} [16]	ME_{-MCS}	$ME_{-ABC-MR}$	ME_{-GWO}
−5.0	34.657	25.2685	19.0453	16.1685	8.85
−2.5	28.578	21.2106	16.0237	15.1106	8.09
0.5	24.687	20.0996	15.0227	13.0796	4.842
1.5	21.245	19.0942	14.0212	12.0742	3.6
3.0	18.657	16.0889	13.0202	11.0689	1.78
4.5	16.657	15.0873	12.0180	10.0673	1.26
6.0	15.657	13.0751	11.0147	9.0551	1.61
7.5	13.357	12.0686	10.0145	8.0486	0.45
9.5	9.547	8.0494	7.0057	5.0294	0.12
10	8.657	7.0322	6.0044	4.0122	0.02

execution of ANC channel through GWO calculation be superior to upper bounded PSO, MCS moreover AMC-MR calculations. ANC filter based on GWO techniques provides 7 dB, 13 dB, 21 dB and 28 dB improvement in output SNR as compared to recently reported ANC filter based on ABC-MR, MCS, PSO and RLS algorithms. The different variety of MSE bean element of information SNR depicted via Table 2 that's sketched in Fig. 8 for ANC channel utilizing various strategies. As observed, the MSE execution of GWO calculation is vastly improved than different strategies. The ANC filter based on GWO technique provides 59.5%, 68.3%, 75.7% and 81% reduction in MSE as compared to recently reported ANC filter based on ABC-MR, MCS, PSO and RLS algorithms. The variety of ME with information SNR is given in Table 3. Figure 9 demonstrates sketch belonging ME of yield EMG pro various degrees of information SNR. ANC channel along GWO calculation accomplishes critical decrease in ME when contrasted with the MCS andABC-MR calculations surpassing estimation of info SNR. ANC filter based on GWO technique provides 69.2%, 75%, 77.7% and 84% reduction in ME as compared to recently reported

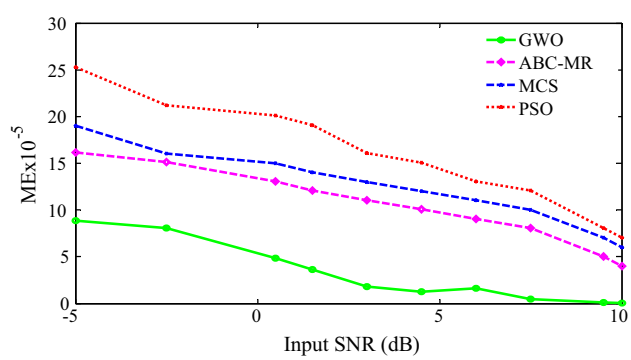


Fig. 9 ME Ploting with different input SNR (dB)

ANC filter based on ABC-MR, MCS, PSO and RLS algorithms. The performance fidelity parameters of proposed ANC filter using GWO algorithm are better as compared with other reported ABC-MR, MCS, PSO, and RLS techniques applied on EMG signal. Figure 10 demonstrates the corelation between unadulterated EMG and reproduced EMG

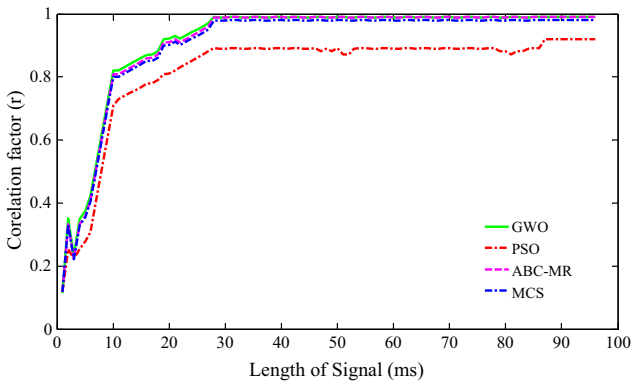


Fig. 10 Corelation factor (r) ploting for various shemes

sign utilizing ANC channel with GWO and ABC-MR systems. Figure 11 demonstrate the pace of transformation for GWO calculations. As observed, the GWO calculation displays higher correlation factor when contrasted with the ABC-MR system. For the investigation of adjustment time, the square blunder of versatile channels is dissected with mean and standard deviation.Table 4 records the $S_{\text{-mean}}$ and standard deviation ($S_{\text{-SD}}$) of diffent calculations alongwith computational time ($S_{\text{-computational time}}$). The GWO based versatile clamor canceller is having most minimal statical parameters. The values of statical parameters generated for proposed ANC filter using GWO algorithm shows better performance as compared with other reported ABC-MR, MCS, PSO, and RLS techniques applied on EMG signal.

6 Conclusion

In order to de-noise the EMG signal,the ANC filter design using GWO optimization method was presented. A performance comparison of the ANC filter was performed using designed techniques. The SNR, MSE, ME, and correlation factor improvement illustrates the superiority of the proposed ANC filter with GWO compared to other algorithms. This work shows that important improvement can be achieved with ANC filter based on GWO algorithm in all fidelity parameters on EMG signal. The suggested method is therefore, very desirable to denoising the EMG signal.

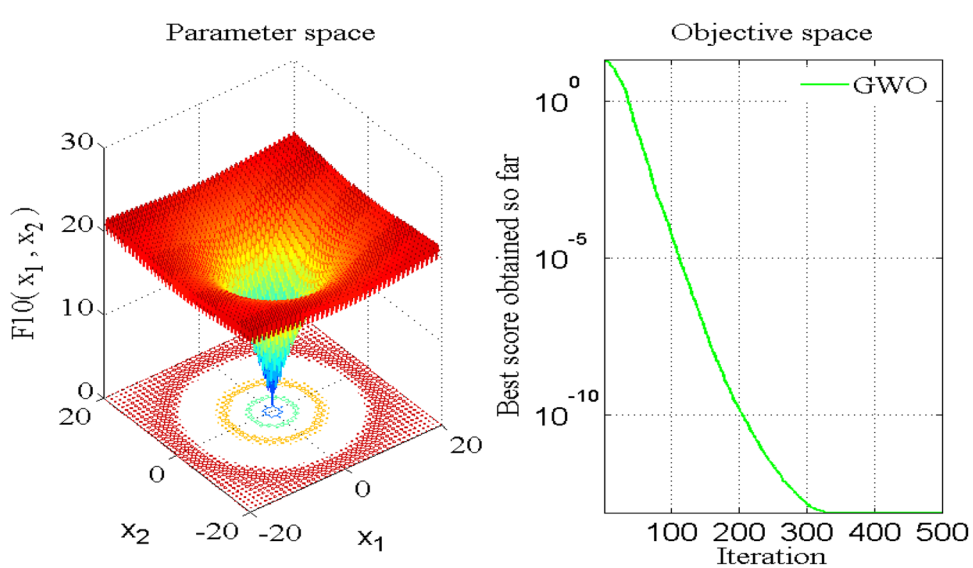
7 Future scope

As observed the the proposed ANC-GWO filter generates best results for de clamor EMG that other stated earlier algorithm. Further GWO can be modified or some other latest algorithm can used to develop a novel filter that give much better and improved results than ANC-GWO.

Table 4 Statical parameters calculated for different schemes

Parameter	$S_{\text{-RLS}}$ [14]	$S_{\text{-PSO}}$ [16]	$S_{\text{-MCS}}$	$S_{\text{-ABC-MR}}$	$S_{\text{-GWO}}$
$S_{\text{-Mean}}$	1.8056	1.635	1.421	1.0609	1.002
$S_{\text{-SD}}$	28.998	19.231	1.786	1.7407	1.002
$S_{\text{-Computational time (s)}}$	0.278	0.126	0.0821	0.0487	0.0058

Fig. 11 Optimization rate of conversion for GWO scheme



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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Human and animal rights Authors used the data available in [31] for their study and did not collect data from any human participant or animal.

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