Two Optimization Algorithms for Inversing Atmosphere Refractivity Profile from Radar Sea Clutter

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Abstract

Application of Genetic algorithm and artificial immunization algorithm on getting atmosphere refractivity profile form radar sea clutter (RFC) is introduced. GA can satisfy the nonlinearity, complexity and other special requirements of RFC. Artificial Immune algorithm can avoid the problems of getting into local optimization, population variety decreasing, and other problems caused by using GA, and the convergence can be improved. The two algorithms are analyzed using the data of radar sea clutter, air sounding, and so on which are acquired in the south sea field, and the quality of two algorithms is gotten, which can be the reference of solving the problem of RFC.

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Keyword: optimization algorithm; radar sea clutter; atmosphere refractivity profile

1. Introduce

Sea duct is caused by the quickly decreasing of atmosphere humidity, which is caused by the water evaporation on the sea. When the sea duct appears, microwave radar system can utilize the effect of evaporation duct to implement over-the-horizon detection on the sea. The environment information of the sea duct on the propagation path is taken by the radar sea clutter. The atmosphere refractivity profile of

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the sea duct is inversed by the radar sea clutter power using the real-time gathered data, and the accuracy of the predicted sea duct is also improved. In order to get the nonlinear relation between the radar sea clutter power and the atmosphere refractivity profile, GA and artificial Immune algorithm are used to search for the optimization parameters, which construct the atmosphere refractivity profile.

Among traditional algorithms to realize RFC, GA is the used usually. In this paper, artificial Immune algorithm is introduced. Artificial Immune algorithm can avoid the problems of getting into local optimization, population variety decreasing, and other problems caused by using GA, and the convergence can be improved at the same time.

2. Fundamental of RFC technology

The flow chart of RFC technology is listed as follows [1,2] and shown as Fig 1.

(1) Discretize the radar sea clutter signal, and the power chart of radar sea clutter $P_{\text{obs}}$ is gotten on the discrete distance $r_1, r_2, \ldots, r_n$, which is the input of RFC.

(2) The model of atmosphere refractivity profile is parameterized, the parameter vector $x = (x_1, x_2, \ldots, x_m)$ is the solution vector, which is one-to-one correspondence with atmosphere refractivity profile.

(3) Radar sea clutter strength simulates. The model of superimposed electromagnetic wave transmission and the model of backward dissipation coefficient of radar sea clutter are established to calculate the simulated discrete radar sea clutter power chart, whose inputs are atmosphere refractivity profile parameter vector $x = (x_1, x_2, \ldots, x_m)$.

(4) Establish the object function $f(x)$ to evaluate the matching level of radar sea clutter power chart between the simulated value $P_c(x)$ and the measured value $P_{\text{obs}}$. If $f(x)$ satisfied the terminal condition turn to (6), else turn to step (5).

(5) Change the parameters of solution vector using optimization algorithm, and different atmosphere refractivity profile is acquired. Use the changed solution vector as the inputs and turn to step (3).

(6) Output the value of $x$, use $x$ to construct atmosphere refractivity profile, and this refractivity profile is optimal result.
3. Fundamental to Realize RFC technology using GA

Genetic Algorithm (GA) is an artificial technology develops according to the process and principle of biology evolution, which has some good characteristics such as parallelism, self-organization, and adaptive searching [3]. The particular steps of GA are described as below and shown as Fig 2.

1. Define main parameters of GA, such as population quantity, probability of duplication, crossover, mutation and the least Eulerian distance. Then initialize the population, which can be considered as uniform distribution in the feasible solution space.

2. Input the radar sea clutter data, which is preprocessed receiving by radar, and calculate the fitness value;

3. Check the terminal condition. Two terminal criterions are proposed: the max generation condition \((Gen < 50)\) and min fitness in the population \((fitness < 50)\). If the terminal condition is satisfied, turn to step 7, else turn to step 4.

4. Implement genetic operator to generate new individuals.

5. Check whether the distances between the individuals of new population are big enough [4]. If the distances are too small, the fitness value will be compute through and through to degrade the search efficiency. And the local optimization solution may be gotten. If the distance condition can’t be satisfied, turn to step 4, or turn to step 6.

6. Add one to Evolution generation, turn to step 2

![Flow chart of RFC using genetic algorithms](image)

Fig. 2. Flow chart of RFC using genetic algorithms

4. Fundamental to Realize RFC using Artificial Immune Algorithm

Artificial immune algorithm develops from the biologic natural science, which has excellent local and global optimization ability. Artificial immune algorithm consists of four parts, which are generation of
initial population, clone selection operation, immune net restraining and feedback control [5]. The
detailed steps are listed as follows and show as Fig 3.

Fig. 3. Flow chart of RFC using artificial immune algorithms

(1) Generation of initial population
Some individuals (real vector) are introduced in the definition domain of objective function, and the
artificial immune net is constructed. The initial individuals are generated using random numbers method,
but this method isn’t stable, which can’t make full use of the advantages of artificial immune algorithm.
The use of prior knowledge will improve the performance of

(2) Clone selection operation
Clone can generate population continuously. In the algorithm, some individual is cloned using
reproduction duplication operator firstly. Then mutation operation is implanted to every cloned individual
using mutation operator. The cloned individual with high fitness is selected at last. The highly frequent
mutation causes the congenial mature and antibody diversity in immunology theory. The mutation
operator with inverse ratio relationship with congenial degree is utilized during the process of clone
selection, so that the high fitness and quick convergence of the population can be realized. The detailed
relationship equations are:

\[ c' = c + \alpha N(0,1) \]  
\[ \alpha = \left(1 / \beta \right) \exp(-f^*) \]  

Where \( c' \) is the new mutated individual from \( c \), \( N(0,1) \) is a Gauss random variable whose mean value is
0, and the standard deviation is 1. \( \beta \) is a variable to control the decaying of exponential function. \( f^* \) is
the individual fitness value after normative approach, whose value belong to [0,1]. If the mutated individuals exceed the range of feasible zone, those individuals can be ignored.

3) Immune net restraining
Evolution of the individuals’ average fitness will stop after the net becomes stable, then the new individuals need to be introduced in order to search for the optimal solution. But the new individuals have to satisfy the condition of appetency. The individuals whose appetencies are lower than the preinstall threshold, are restrained by negative selection. The rest individuals are remained as the memory. Repeat the previous process, until satisfy the terminal condition.

4) Feedback control
Feedback control is contained in the process of step (2) and step (3), the clone selection is implemented continuously by the variation degree of the average fitness value, until the fitness value stop changing. In the process of immune net restraining, the addition of individuals and the restraining of off-grade individuals are also be adjusted by the feedback of the number of net individuals.

5. RFC Results Analyse using the two algorithms

RFC is implemented using the gathered radar sea clutter data of a given rata during the testing process of detection effectiveness, which was carried out in some field of South China Sea. At the same time, the atmosphere refractivity calculated by the synchronism weather data, which are gathered by the automatic weather facility and tied sounding acquisition system on the testing ship, are used as the true measured profile to certify the RFC results using the two algorithms.

Two groups of data are selected as the computing samples of RFC. The RFC results using different data are shown as Fig 4. The refractivity profiles using GA and artificial algorithm are compared in the figures, and both of the calculated results are compared with the true measured profiles. The results of can prove the feasibility of RFC and the performance of the two optimization algorithms. The parameters of GA and artificial immune algorithm are set as Table 1 and Table 2. In order to save the calculation time, the convergency conditions are set loosely.

According to the results shown in Fig 4, the trends of RFC using the two optimization algorithms accord with the true measured profile. The inversion errors of sea duct high are in the range of 2m. Especially, the results of artificial immune algorithm are in the range of 1m, so the performance of artificial immune algorithm is better than GA. At the same convergency conditions, the calculation precision is improved 10% or so, and the velocity is improved 15% or so. There are some random, but according to the large numbers of RFC simulation results, artificial immune algorithm is better than GA.

Table 1. the parameters of GA

<table>
<thead>
<tr>
<th>Parameter name</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population number</td>
<td>30</td>
</tr>
<tr>
<td>Cross probability Pc</td>
<td>0.8</td>
</tr>
<tr>
<td>Mutation probability Pm</td>
<td>0.1</td>
</tr>
<tr>
<td>Gen</td>
<td>50</td>
</tr>
<tr>
<td>Max objective</td>
<td>20</td>
</tr>
</tbody>
</table>

Table 2. the parameters of artificial immune algorithm

...
Parameter name | Value
--- | ---
No | 20
Nc | 20
δ | 0.2
β | 10
d% | 40
Gen | 50
Max objective | 20

Fig. 4. Results of RFC (a) using first group data; (b) using second group data

6. Conclusions

Application of Genetic algorithm and artificial immunization algorithm on getting atmosphere refractivity form radar sea clutter (RFC) is analyzed, and it is proved that both algorithms can be used to realize the calculation of RFC. Because some disadvantages of GA, such as mature early, losing diversity, and so on, artificial immune algorithm is introduce to the field of RFC. True measured radar data, air sounding data and automatic weather facility data on ship are used to analyze the performance of inversion calculation. The results show that artificial algorithm is more fit for the problem of RFC than traditional GA.

References


