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Searching for Radioactive Sources by Numerical Fitting Method

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Abstract:

In order to locate out-of-control orphan nuclear sources in a short period, we randomly search for out of control orphan source in barrier-free areas by mimicking ideas similar to human search radiation sources. An intelligent random search model with human thinking is established. Based on the complex situations that may occur in real-world search, the single search strategy was optimized, and a random search model with human thinking was established. It is theoretically proved that the time complexity of the algorithm of the search model and the complexity of the average storage space used in the search were linear. For the random search of multi-point radioactive sources, a random search model of two-point radioactive sources was established, and the search success probability of different random search strategies was discussed. We demonstrate the location of the radiation source through a random search algorithm in the simulation environment. The simulation results showed that the optimization algorithm has good efficiency and fault tolerance.

Keywords:*Nuclear radioactive source,Random search algorithm,Complexity*.

I. INTRODUCTION

The search of out of control radioactive source is mostly limited to the workers who are engaged in nuclear technology. With the help of ray detector, the position of radioactive source can be searched by experience. However, due to the lack of experience in the search of radioactive source or the low search efficiency in special environment. The long-term exposure of personnel in high radiation environment has become a bottleneck problem restricting the development of radioactive source search technology.

Scholars at home and abroad use the vehicle borne large crystal sodium iodide detector to searchthe suspected area in the conventional search of radioactive sources, and use the portable

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detectorcarried by people to search the large area on foot in the place where the traffic is inconvenient [1].When the radiation field is high, the long handle hand-held detector must be used to approach the radiation field to find the radiation source [2-3].

The research on search and location technology at home and abroad is mainly divided into two directions. One is the research on the method of locating radioactive source based on the change of counting rate with the change of detection position, the other is the design of direction detector [4-15].

In the later stage of source search, it is necessary to locate the source accurately, which can't meet the needs of the search. The linear measurement method is the easiest to realize, but the workload is very large. Either way is to operate in a high-level environment.

Some scholars also try to use mathematical methods to study the location of radioactive sources. From the mathematical point of view, the research on the location of radioactive source detectionchanges has also achieved certain results, jumping out of the restriction that only nuclear professionals can study the search of radioactive sources, and seeking new methods of searching for radioactive sources on the road of exploring new technologies.

The maximum likelihood estimation is used to obtain the parameters of the source and the multiple hypothesis test of the generalized maximum likelihood criterion to determine the number of sources [16] and realize the multiple source location. Ion filter algorithm for traveling measurement to locate radioactive source[17]. Using artificial neural network optimization method to locate radioactive source [18]. The problem of source location described by PDE in dynamical system [19]. In addition, the four point source potential method is used to measure the discrete radiation sources in three-dimensional space[20]. Locate radioactive sources based on G-M counting tube of multiple radioactive sources using maximum likelihood estimation[21]. Bayesian method is used to improve the source localization of MLM[22].However, there are also many scholars dedicated to the use of robots in radioactive search. In this way, experts in mechanical field also join in the research[23-26], but robot search costs are higher and the core technology of robot search is algorithm design, so continuous optimization algorithm is the key to improve robot search. The computer-aided implementation of artificial intelligence random search for radioactive sources meets the needs of safety assurance under the rapid development of nuclear technology, which is widely used nowadays for its low cost and research foundation. There are also many scholars who use algorithm design to search for radioactive sources on computers [27-33].

When developing and designing search algorithms, algorithm complexity is an important issue to be considered. If the actual problem is NP problem or super large scale problem, heuristic search algorithm is often considered[34-36]. Heuristic algorithm can usually find approximate solution or local optimal solution in a reasonable time.Because of the uncertainty of the search target, especially in large area, we consider the heuristic random search algorithm to realize the search for radioactive sources.

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II. SEARCH FOR ACCESSIBLE AREA RADIOACTIVE SOURCES

Assuming that the radiation source is located in a rectangle, the grid is divided in the region. Divided the rectangular area containing the radiation source into a grid and the corresponding grid node data is collected. Consider horizontal square area with point source $\Omega = \{(x, y)|0 \leq x \leq a, 0 \leq y \leq b\}$. In the X axis, insert $n-1$ points in range $[0, a]$, $x_1, x_2, \cdots, x_{n-1}$ and let $x_0 = 0, x_n = a$. In the Y axis, insert the $m-1$ points in range $[0, b]$, $y_1, y_2, \cdots y_{m-1}$ and let $y_0 = 0, y_m = b$, so (Fig1). Then $E_{n+1} \times E_{m+1} = \{(x_i, y_j)|i = 0,1,2, \cdots n, j = 0,1,2, \cdots m\}$ is the rectangular point set (see Figure1), the grid node dose(x_i, y_j) is $f_{i,j}, i = 0,1,2, \cdots, n, j = 0,1,2, \cdots m$.

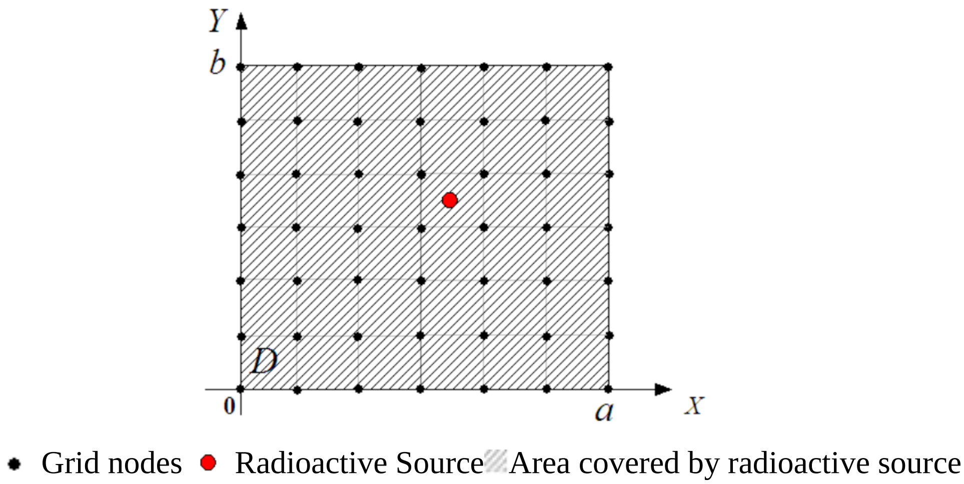

Fig 1:Meshing of the search area

2.1 Discrete Data Search Radioactive Source

Using discrete grid data to search for radioactive sources, we use line scan search and hierarchical line scan search algorithms, which have been discussed in the article[15].The radioactive source search problem in the barrier-free area mainly searches for the maximum dose of the radiation measurement of the radiation-metering field, and uses the idea of fitting to search for the radioactive source.

2.2 Continuous Data Search for Radioactive Sources

There are one or more radioactive points in the search area. The following two search strategies can be considered: (1) Maximum optimization search, first search for the point with the largest radiation measurement, clear the point after searching and adjust the radiation measurement dose. In the new radiation field, the source of the radiation source with the largest radiation dose is continuously searched, and then the point is removed, and then the radiation measurement dose is adjusted, and so on, until the radiation dose of the grid node in the search area is all 0, and the source search is ended. (2) Maximization optimization search strategy, that is, one-time search for all maximum points can be used, and then all the maximum points are called to call the source point discrimination algorithm to identify whether they are radioactive source points one by one, thereby searching to all sources.

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2.2.1Clear Max Dose Point Search

In the search, you can clear the maximum dose points (the point where the radiation source is located) one by one until the grid node data in the search area is all 0, that is, all the radioactive sources are searched.

The method of line scanning is used to search the maximum value point in the area. The main idea is to select a grid data parallel to the$X$-axis direction for cubic spline interpolation to restore the radiation measurement curve expression on the line when the grid node data in the radiation field is known. In order to search the maximum value point on the radiation measurement curve, the radiation measurement function is calculated as the stagnation point, that is, the guide a point with a number of zero. Compare the radiometric values of several stagnation points, select the grid data adjacent to the vertical direction where the coordinatex_0 of the largest stagnation point of radiometric is located to obtain the radiometric curve by cubic spline interpolation, and calculate the coordinate $y_0$of the maximum point of the curve, so as to obtain the coordinate (x_0,y_0) of the maximum point of radiometric value, which is the center of further accurate search to find the location of the radiation source.

If there are multiple radiation sources in the search area, you can find a radiation source with the maximum radiation measurement value, clear the radiation source, adjust the grid radiation measurement data in the search area, repeat the above search process, and so on until the node radiation amount in the search area is all 0, then all radiation sources can be searched(see Fig 2).

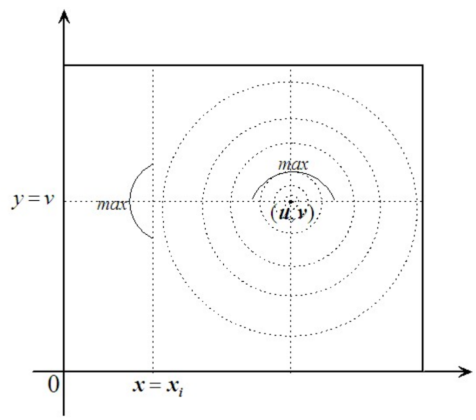

Fig 2: Schematic diagram of the maximum point search algorithm for single point source

Single-point radioactive source maximum dose search algorithm. The specific operation process in the search region D for the data$(x_1, y_j), (x_2, y_j), \dots, (x_n, y_j)$ on the$j(j = 1,2, \dots, m)$ parallel to the X-axis direction grid line, using the cubic spline interpolation to obtain the radiation measurement curve function $f(x, y_j)$, and the derivative of X is obtained.

$$\frac{df(x,y_j)}{dx} = 0 \tag{1}$$

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Find the maximum pointx_0 on the data line $j(j=1,2,\ldots,m)$. Then use the grid data line passing through the x_0 point and perpendicular to the x-axis direction or the cubic spline interpolation with the grid data line adjacent to $x=x_0$ to obtain the radiation measurement function curve$g(x_0,y)$, and obtain the derivative number for y.

$$\frac{df(x_0,y)}{dy}=0 \quad (2)$$

Find the coordinate of the $g(x_0,y)$ maximum point y_0, and obtain the coordinate (x_0,y_0) of the source, and then judge whether point (x_0,y_0) is the source or not by the source point discrimination algorithm. The clear maximum search algorithm 1 is given below.

Algorithm 1 Clear Maximum Search Algorithm

Step1 Input $n\times n$ field radiation metering matrices$[f_{ij}]_{n\times n}$.

Step2 Perform cubic spline interpolation on each mesh node data parallel to the X-axis direction in the search area to obtain the function $f(x_i,y), i=1,2,\ldots,n$ about y.

Step3 Find the stagnation point for $f(x_i,y)$,$\frac{df(x_i,y)}{dy}=0, i=0,1,2,\ldots,n$ find all stagnation points and compare the radiation measurement doses of each stagnation point, and obtain the maximum dose $y=v$.

Step4 When $min_{0\le j\le n}|y_j-v|$,then$y_j=y_u$.

Step5 Let $y=y_u$, use the data on the grid to perform the cubic spline interpolation to restore the radiation measurement function curve on the$n+1$ grid line, and obtain the cubic spline interpolation function related to$g(x,y_u)$ and x.

Step6 Find the stagnation point for $g(x,y_u)$,$\frac{dg(x,y_u)}{dx}=0$, get all stagnation points, compare the dose of stagnation point and select the maximum dose of points, let x = u, then the coordinate of the source is(u,v).

Step7 Correct the coordinate$(u,v)$of maximum dose. Select the field character from the center of (u,v), divide further fine meshing the field, and collect the grid data. Repeat step1-5. Search for the point (u_n,v_n) at which the radiation measurement dose is the largest until the source coordinates satisfy the error within a range of cells.

The following gives a few explanations for the clear maximum search algorithm:

(1) The maximum dose search algorithm for single-point radioactive sources is also applicable to the search of multiple point radioactive sources. Search for a maximum source, clear the source and update the search area radiation metering field, and then remove the second largest source of radiation according to the same strategy, and so on, until the radiometric grid of the search area is a radiometric value of 0.

(2) When there is one or more radioactive sources in the monitoring area, when the cubic spline interpolation method is used to restore the grid line radiation metering field function, the radiation field will have more peaks and the maximum points will increase. When searching for

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a radioactive source, it will waste the search time and affect the running speed, which will cause a large deviation of the search results. Therefore, in the design of the algorithm, it is necessary to take into account the multiple point radioactive sources, data fault tolerance and try not to add new extreme points. To solve the above problem, a search algorithm combining a maximum dose search and a local fine search is considered to accurately search for the position of the radiation source.

(3) When the radiation source in the search area is a radiation field formed by a plurality of radiation sources of a large or small size, the radiation field formed by the smaller radiation source may be covered by the radiation area formed by the stronger radiation source. If you search directly for all sources, it is possible to search for smaller sources. At this time, the clear maximum search strategy is adopted, firstly, the stronger radioactive source is cleared, and the radiation field formed by the smaller radioactive source is slowly presented. At this time, the search can find a smaller radioactive source.

2.2.2 Labeled Maximum Search

When there are many radioactive sources in the search area and the radiation dose of the radioactive source is equivalent, in addition to the scavenging random search radioactive source, a labeled random search strategy can also be used. First search all the maximum points in the area, and use the threshold function to judge whether the maximum point is the source point one by one. The labeled maximum dose search algorithm 2 is given below.

Algorithm 2 Labeled Maximum Search Algorithm

Step1 Input $n \times n$ field radiation metering matrices$[f_{ij}]_{n\times n}$.

Step2 Perform cubic spline interpolation on each mesh node data parallel to the X-axis direction in the search area to obtain the function $f(x_i, y), i = 1,2, \dots, n$ about y.

Step3 Find the stagnation point for $f(x_i, y), \frac{df(x_i,y)}{dy} = 0, i = 0,1,2, \dots, n$ find all stagnation points and obtain all the stagnation points$x_{p_1}, x_{p_2}, \dots, x_{p_s}$, where S is the number of maximum points.

Step4 Selecting the (or adjacent) grid data line passing through $x_{p_1}, x_{p_2}, \dots, x_{p_s}$and parallel to the y-axis, performing cubic spline interpolation to obtain a radiation metering function curve $g(x_{p_i}, y), i = 1,2, \dots, s$.

Step5 Find the stagnation point for $g(x_{p_i}, y), \frac{dg(x_{p_i},y)}{dx} = 0$, and find all the stagnation point $y_{q_1}, y_{q_2}, \dots, y_{q_t}$, where t is the maximum number.

Step6 Combine $x_{p_1}, x_{p_2}, \dots, x_{p_s}$ and $y_{q_1}, y_{q_2}, \dots, y_{q_t}$ to obtain the possible source point coordinates$\left(x_{p_i}, y_{q_j}\right), i = 1,2 \dots, s, j = 1,2, \dots, t$.

Step7 Call the threshold function for all possible source points$\left(x_{p_i}, y_{q_j}\right), i = 1,2 \dots, s, j = 1,2, \dots, t$, and output all source points.

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Give some explanations for the tagged maximum dose search algorithm:

(1) Due to the small data fluctuations in the low-radiation measurement area, there will be small fluctuation peaks and valleys, and there will be no radioactive sources in the fluctuation area of the low-radiation measurement data. Therefore, before searching for the maximum dose, it can be utilized first. The threshold dose is used to remove part of the data with lower radiation metering and to search for the maximum point in the higher radiation metering area. This can reduce unnecessary maximum dose search, reduce the maximum dose points to be judged, reduce data running time, and improve search efficiency.

(2) In step 7, the radioactive source can be judged by combining the level threshold.

(3) The mark search strategy does not repeatedly remove the radioactive source, and does not waste time and space generated by the clearing of the radioactive source, which is beneficial to improve the search speed and efficiency.

2.2.3 Quadratic Fitting Search

Since the time and space occupied by the cubic spline interpolation radiation metering curve are large, the radiation metering maximum point only appears in the peak section of the curve. In order to simplify the process of maximizing the dose, it is only possible to have a similar opening downward. The parabolic peak data is quadratically fitted to obtain the maximum point of the quadratic parabola, so as to simplify the search for the maximum point.

The main idea of the quadratic fitting search is to quad-rate the peak segment data with the second opening downward feature and then the quadratic fitting curve when searching for the extreme dose of the grid data of the search region. Great dose. If a further precise location of the source is required, a local optimized search algorithm can be reused for the source. The quadratic fitting search algorithm reduces unnecessary data interpolation operations and improves search efficiency.

In determining whether the continuous k data on the grid line has the feature of the opening down quadratic parabola, the following two methods can be adopted:

(1) The maximum dose method, considering finding the maximum dose point in the data first, and observing the whether the data on the left and right of the maximum point gradually decreases.

(2) The cursor moving method selects consecutive continuous k data from left to right on the grid line to observe whether there is a secondary opening the next feature. Both methods can be used. After finding the k data with the second opening down feature, perform a quadratic fitting and then find the maximum dose point.

2.2.3.1Maximum Dose Method Quadratic Fitting Search

When using the maximum point method to find the characteristic data with the second opening downward, it is first necessary to determine the position of the maximum dose point, so the definition of the maximum dose is given below and the judgment condition is given.

Definition 1 If the$i$-th data dose for the parallel X axis satisfies$f_{i,j-1} \leq f_{ij}\ and f_{ij} \geq f_{i,j+1}, j = 1,2 \ldots, m-1$, then $x_{ij}\,(i = 0,1, \ldots, n)$ is called the horizontal direction radiation

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measurement maximum point.

Definition 2 If the j-th data dose for the parallel Y axis satisfies$f_{i-1,} \leq f_{ij}$ $and f_{ij} \geq f_{i+1,j}, j = 1,2 \dots, n-1$, then $y_{ij}\,(j = 0,1, \dots, m)$ is called the horizontal direction radiation measurement maximum point.

The maximum dose quadratic fitting search algorithm 3 is given below.

Algorithm 3 Maximum Quadratic Fitting Search algorithm

Step1 Input $n \times n$ field radiation metering matrices$[f_{ij}]_{n\times n}$.

Step2 Quadratic function fitting $f_i = [f_{i,0}, \dots, f_{i,1}, f_{i,n}]$.

Step2.1 For the$i$-th row$(i = 0,1,2, \dots, n)$, perform quadratic function fitting, and get the curve function $S_i(x)$.

Step2.1.1 Let $y_j = y_i, i = 0,1,2, \dots, n,$ and get the maximum, get the maximum point in the data$f_i = [f_{i,0}, \dots, f_{i,1}, f_{i,n}]$, where S is the maximum number.

Step 2.1.2 Determine whether the K consecutive data including the maximum dose point has the characteristics of the secondary opening downward parabola, if the maximum dose point F satisfies the following conditions

When $k$is odd$\begin{cases} f_{i,p_r-\left[\frac{k}{2}\right]} \leq f_{i,p_r-\left[\frac{k}{2}\right]+1} \leq \cdots \leq f_{i,p_r} \\ f_{i,p_r+1} \geq f_{i,p_r+2} \geq \cdots \geq f_{i,p_r+\left[\frac{k}{2}\right]} \end{cases}$, $or$$\begin{cases} f_{i,p_r-\left[\frac{k}{2}\right]} \leq f_{i,p_r-\left[\frac{k}{2}\right]+1} \leq \cdots \leq f_{i,p_r} \\ f_{i,p_r+1} \geq f_{i,p_r+2} \geq \cdots \geq f_{i,p_r+\left[\frac{k}{2}\right]} \end{cases}$

When k is even$\begin{cases} f_{i,p_r-\left[\frac{k}{2}\right]} \leq f_{i,p_r-\left[\frac{k}{2}\right]+1} \leq \cdots \leq f_{i,p_r} \\ f_{i,p_r+1} \geq f_{i,p_r+2} \geq \cdots \geq f_{i,p_r+\left[\frac{k}{2}\right]-1} \end{cases}$, $or$$\begin{cases} f_{i,p_r-\left[\frac{k}{2}\right]+1} \leq f_{i,p_r-\left[\frac{k}{2}\right]+2} \leq \cdots \leq f_{i,p_r} \\ f_{i,p_r+1} \geq f_{i,p_r+2} \geq \cdots \geq f_{i,p_r+\left[\frac{k}{2}\right]} \end{cases}$,

then for any $x \in [f_{i,p_r-\left[\frac{k}{2}\right]}, f_{i,p_r+\left[\frac{k}{2}\right]}] \cup [f_{i,p_r-\left[\frac{k}{2}\right]}, f_{i,p_r+\left[\frac{k}{2}\right]-1}] \cup [f_{i,p_r-\left[\frac{k}{2}\right]+1}, f_{i,p_r+\left[\frac{k}{2}\right]}]$, let $S_{i,r}(x) = a_r x^2 + b_r x + c_r, (a<0)$, use the K observations in the interval to find the $S_{i,r}(x)$, when $min(\sum_{\substack{t\in\left[p_r-\left[\frac{k}{2}\right], p_r+\left[\frac{k}{2}\right]\right] \\ t\in N}} |f_{i,t} - (a_{i,r}t^2 + b_{i,r}t + c_{i,r})|)$, then find the current dose$a_{i,r}, b_{i,r}, c_{i,r}$.

Step2.2. For the j-th column$f_j = [f_{0j}, \dots, f_{1j}, f_{nj}]$, perform a quadratic function fitting curve function $g_j(y)$.

Step2.2.1 Let$x_j = x_i, j = 0,1,2, \dots, n,$find the maximum point$f_{p_1 j}, \dots, f_{p_2 j}, f_{p_l j}$, in the data $f_j = [f_{0j}, \dots, f_{1j}, f_{nj}]$, where l is the maximum number.

Step2.2.2 If the maximum dose point $f_{p_r j}, r = 1,2, \dots l$ satisfies the following conditions

When k is odd$\begin{cases} f_{p_r-\left[\frac{k}{2}\right],j} \leq f_{p_r-\left[\frac{k}{2}\right]+1,j} \leq \cdots \leq f_{p_r,j} \\ f_{p_r+1,j} \geq f_{p_r+2,j} \geq \cdots \geq f_{p_r+\left[\frac{k}{2}\right],j} \end{cases}$, or$\begin{cases} f_{p_r-\left[\frac{k}{2}\right],j} \leq f_{p_r-\left[\frac{k}{2}\right]+1,j} \leq \cdots \leq f_{p_{r-1},j} \\ f_{p_r,j} \geq f_{p_r+1,j} \geq \cdots \geq f_{p_r+\left[\frac{k}{2}\right],j} \end{cases}$

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When $k$is even$\begin{cases} f_{p_r-\left[\frac{k}{2}\right],j} \le f_{p_r-\left[\frac{k}{2}\right]+1,j} \le \cdots \le f_{p_{r,j}} \\ f_{p_r+1,j} \ge f_{p_r+2,j} \ge \cdots \ge f_{p_r+\left[\frac{k}{2}\right]-1,j} \end{cases}$, or$\begin{cases} f_{p_r-\left[\frac{k}{2}\right]+1,j} \le f_{p_r-\left[\frac{k}{2}\right]+2,j} \le \cdots \le f_{p_{r,j}} \\ f_{p_r+1,j} \ge f_{p_r+2,j} \ge \cdots \ge f_{p_r+\left[\frac{k}{2}\right],j} \end{cases}$

then for any $x \in [f_{p_r-\left[\frac{k}{2}\right],j}, f_{p_r+\left[\frac{k}{2}\right],j}] \cup [f_{p_r-\left[\frac{k}{2}\right],j}, f_{p_r+\left[\frac{k}{2}\right]-1,j}] \cup [f_{p_r-\left[\frac{k}{2}\right]+1,j}, f_{p_r+\left[\frac{k}{2}\right],j}]$, let $g_{r,j}(x) = a_r y^2 + b_r y + c_r$, $(a<0)$, use the K observations in the interval to find the function $g_{r,j}(y)$, when $min(\sum_{\substack{t\in\left[p_r-\left[\frac{k}{2}\right], p_r+\left[\frac{k}{2}\right]\right] \\ t\in N}} |f_{i,t} - (a_{i,r}t^2 + b_{i,r}t + c_{i,r})|)$ then find the current dose$a_{r,j}, b_{r,j}, c_{r,j}$.

Step3 Determination of the maximum point;

Step3.1 For the selected i-row$(i = 0,1,2,\ldots,n)$, perform a quadratic fitting curve$S_{i,r}(x)$, and then find the maximum dose point of $S_{i,r}(x), r = 1,2,\ldots,s$.

Step3.2 For the selected j-row$(j = 0,1,2,\ldots,m)$, perform a quadratic fitting curve$g_{r,j}(y)$, and then find the maximum dose point of $g_{r,j}(y), r = 1,2,\ldots,l$.

Step 4 The maximum dose point (x, y) of the global mesh node obtained by combining the abscissa of the maximum dose point searched in step 3.1 with the ordinate of the maximum dose point searched in step 3.2, using a local optimization search algorithm 2.5 obtain the local radiation measurement function dose maximum point $(x + \varepsilon, y + \varepsilon)$.

Step5 Determine if the maximum dose point $(x + \varepsilon, y + \varepsilon)$ is a source of radiation.

Here are a few points for the quadratic fitting of the maximum:

(1) The maximum dose quadratic fitting search takes the maximum dose point on the grid line first, and then judges whether the data points on the left and right sides of the maximum dose point have the feature of the secondary opening downward parabola. Secondary fit.

(2) The quadratic fitting only uses a small amount of data for fitting the data of the peak segment. Especially under the coarse grid, the error between the maximum dose point searched by the quadratic fitting and the maximum dose searched under the fine grid is small, so that the grid data collection amount can be greatly reduced, the search cost can be reduced, and the search can be improved. Speed, thereby reducing the exposure risk of the ecological environment in the radiation zone.

(3) When the data is quadratic with the opening downward on the line where the source point is located, data overflow may occur, which may cause the fitting to fail. At this time, the fitting data is known according to the characteristics of the radiation measurement. There must be a radioactive source in the segment, and the maximum dose point in the data point is directly output, and then the local fine search of the point can find an accurate radioactive source position.

(4) Maximum dose quadratic fitting When searching for the maximum dose point, if the maximum dose is found strictly according to the maximum dose definition, it is possible that

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many neighboring point data of many small fluctuations are judged to be in accordance with the quadratic fitting. The characteristics are quadratic fitted according to the algorithm. In fact, the source points do not appear in the small fluctuations of the data segment, so the second fit of this part of the data will waste time and space. When judging the characteristics of the data, the dose should not be too small, and the dose is generally suitable when the dose is 5-7 data points.

(5) When judging whether the grid data has an open-down feature, if the maximum dose point is taken as the center, and the data on the left side of the maximum dose point and the data on the right side are judged, the essence is to find the odd number. The points determine whether the left and right points of the intermediate point are gradually decreasing data features, so the quadratic fitting search is actually performed, and the cursor-like quadratic fitting search algorithm is employed.

2.2.3.2 Cursor-type Quadratic Fitting Search

When performing the quadratic fitting, when judging whether the continuous K mesh node data has the feature of the secondary opening downward, the continuous K data may be selected from left to right to determine whether the feature has the feature, and then move one cell. Select whether the next K point data has the feature, then move a cell judgment, and so on, and judge the data segment of the secondary opening downward on the line one by one, and perform quadratic fitting on the data satisfying the feature. Determine the location of the source point. See the cursor-type quadratic fitting search algorithm 4 for details.

Algorithm 4 Cursor Quadratic Fitting Search Algorithm

Step1 Input $n \times n$field radiation metering matrices$[f_{ij}]_{n \times n}$.

Step2 Quadratic function fitting$f_i = [f_{i,0}, \dots, f_{i,1}, f_{i,n}]$.

Step2.1 For the i-th row(i = 0,1,2, …, n), perform quadratic function fitting, and get the curve function$S_i(x)$.

Step2.1.1 Let $y_j = y_i, i = 0,1,2, \dots, n$, and get the maximum, get the maximum point$f_{i,p1}, \dots, f_{i,p_2}, f_{i,p_s}$ in the data$f_i = [f_{i,0}, \dots, f_{i,1}, f_{i,n}]$, where S is the maximum number.

Step 2.1.2 If the maximum point $f_{i,p_r}, r = 1,2, \dots, s$ meets the following conditions

When k is odd$\begin{cases} f_{i,p_r-[\frac{k}{2}]} \le f_{i,p_r-[\frac{k}{2}]+1} \le \cdots \le f_{i,p_r} \\ f_{i,p_r+1} \ge f_{i,p_r+2} \ge \cdots \ge f_{i,p_r+[\frac{k}{2}]} \end{cases}$, $or\begin{cases} f_{i,p_r-[\frac{k}{2}]} \le f_{i,p_r-[\frac{k}{2}]+1} \le \cdots \le f_{i,p_r} \\ f_{i,p_r+1} \ge f_{i,p_r+2} \ge \cdots \ge f_{i,p_r+[\frac{k}{2}]} \end{cases}$

When k is even

$$\begin{cases} f_{i,p_r-[\frac{k}{2}]} \le f_{i,p_r-[\frac{k}{2}]+1} \le \cdots \le f_{i,p_r} \\ f_{i,p_r+1} \ge f_{i,p_r+2} \ge \cdots \ge f_{i,p_r+[\frac{k}{2}]-1} \end{cases} or \begin{cases} f_{i,p_r-[\frac{k}{2}]+1} \le f_{i,p_r-[\frac{k}{2}]+2} \le \cdots \le f_{i,p_r} \\ f_{i,p_r+1} \ge f_{i,p_r+2} \ge \cdots \ge f_{i,p_r+[\frac{k}{2}]} \end{cases},$$

then for any $x \in [f_{i,p_r-[\frac{k}{2}]}, f_{i,p_r+[\frac{k}{2}]}] \cup [f_{i,p_r-[\frac{k}{2}]}, f_{i,p_r+[\frac{k}{2}]-1}] \cup [f_{i,p_r-[\frac{k}{2}]+1}, f_{i,p_r+[\frac{k}{2}]}]$, let $S_{i,r}(x) = a_r x^2 + b_r x + c_r$, ($a<0$), use the K observations in the interval to get the

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$S_{i,r}(x)$,when $min(\sum_{\substack{t\in\left[p_r-\left[\frac{k}{2}\right],p_r+\left[\frac{k}{2}\right]\right]\\ t\in N}}|f_{i,t}-(a_{i,r}t^2+b_{i,r}t+c_{i,r})|)$, then find thedose$a_{i,r},b_{i,r},c_{i,r}$.

Step2.2. For the i-th column$f_j=[f_{i0},\dots,f_{i1},f_{in}]$, perform a quadratic function fitting curve function$S_i(x)$.

Step2.2.1 Let $y=y_j, j=0,1,2,\dots,n$, find the maximum point$f_{p_1 j},\dots,f_{p_2 j},f_{p_k j}$, in the data $f_j=[f_{i0},\dots,f_{i1},f_{in}]$, where k is the maximum number.

Step2.2.2 If $(x_i,y_j),(x_{i+1},y_j),\dots,(x_{i+k-1},y_j)$ $,i=1,2,\dots n-k+1$ satisfies thefollowing conditions

When k is odd

$$\begin{cases} f_{i,j}\le f_{i+1,j}\le\cdots\le f_{i+\left[\frac{k}{2}\right],j} \\ f_{i+\left[\frac{k}{2}\right]+1,j}\ge f_{i+\left[\frac{k-1}{2}\right]+2,j}\ge\cdots\ge f_{i+k-1,j}\end{cases}, or \begin{cases} f_{i,j}\le f_{i+1,j}\le\cdots\le f_{i+\left[\frac{k}{2}\right]-1,j} \\ f_{i+\left[\frac{k}{2}\right]j}\ge f_{i+\left[\frac{k-1}{2}\right]+1,j}\ge\cdots\ge f_{i+k-1,j}\end{cases}$$

When$k$ is even

$$\begin{cases} f_{i,j}\le f_{i+1,j}\le\cdots\le f_{i+\left[\frac{k}{2}\right]-1,j} \\ f_{i+\left[\frac{k}{2}\right],j}\ge f_{i+\left[\frac{k-1}{2}\right]+1,j}\ge\cdots\ge f_{i+k-1,j}\end{cases},$$

then for any $x\in[f_{i,j},f_{i+k-1,j}]$let $g_{i,j}(x)=a_iy^2+b_iy+c_i$, *(a<0)*, use the k observations in the interval to find the function $g_{,j}(y)$, when $min(\sum_{\substack{t\in[x_i,x_{i+k-1}]\\ t\in N}}|f_{t,j}-(a_it^2+b_it+c_i)|)$,

then find the current dose$a_{i,j},b_{i,j},c_{i,j}$. Determine the quadratic fit of column *j (j=0,1,⋯,n)* in the same way;

Step3 Determination of the maximum point;

Step3.1 For the selected$i$-row($i=0,1,2,\dots,n$), perform a quadratic fitting curve$S_{i,r}(x)$, *r=1,2,* ⋯s and then find the maximum dose point of x.

Step3.2 For the selected j-row($j=0,1,2,\dots,m$), perform a quadratic fitting curve$g_{r,j}(y), r=1,2,\dots,l.$, and then find the maximum dose point of y.

Step 4 The maximum dose point *(x, y)* of the global mesh node obtained by combining the abscissa of the maximum dose point searched in step 3.1 with the ordinate of the maximum dose point searched in step 3.2, using a local optimization search algorithm 2.5 obtain the local radiation measurement function dose maximum point $(x+\varepsilon_i,y+\varepsilon_j)$.

Step5 Determine if the maximum dose point $(x+\varepsilon_i,y+\varepsilon_j)$ is a source of radiation.

Here are some explanations of the cursor-type quadratic fitting search algorithm:

(1) Cursor-type quadratic fitting search is a carpet-type search of continuous grid data to reduce the possibility of missing secondary characteristic data.

(2) The radiometric maximum point generated in step 4 may contain false radioactive sources. At this time, the radioactive source point judgment algorithm can be called to remove the false points in the maximum dose points, and then the remaining radioactive source points

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are further searched. Identify locations to reduce unnecessary search time.

(3) If multiple radioactive sources are densely located in the search area, and the distance between the radioactive sources and the radioactive sources is relatively short, the selection of the K dose at this time will cause the situation where the two radioactive sources are combined into one radioactive source. The maximum point obtained by the fitting may deviate from the position of the true radioactive source. Especially when searching under a coarse grid, in order to reduce such occurrences, it is generally appropriate to choose a dose of 3-5 for k.

Theorem The running time complexity of the maximal second-fit search algorithm is $o(n+m+(\frac{|D'|}{l^*})^2 \cdot q)$.

Proof: Assume that the fine grid of the search area is divided into $\mathrm{n} \times \mathrm{m}$, where n is the number of grid data rows, m is the number of grid data columns, and *T (n)* is the complexity of algorithm 4.5.

In step 2, the complexity of searching for the maximum point for each horizontal grid data line is $o(m)$, and the complexity of performing a second fitting on a limited number of maximum doses on the line is $o(c)$.

Under the premise of ensuring that the range of effective detection by the instrument can be appropriately divided into coarse grids, there are k (k is far less than m) horizontal grid data, so the complexity of the horizontal search is$o(k \times m)$.

Determine the number of data lines to be searched in the vertical direction according to the maximum points of the horizontal data. Assume that the number of lines to be fitted in the vertical is l, and l is the number of online maximums and is far less than *n*.

The complexity of the maximum point is $o(m)$, and the complexity of performing the second-order fitting is $o(c)$, so the horizontal search complexity is $o(l \times m)$, so the complexity in step 2 is $o(n+m)$.

The complexity in step 3 is $o(c)$.

In step 4, further local search is performed for each extreme point to determine the location of the radioactive source. The number of iterations is less than or equal to $o(\left(\frac{|D'|}{l^*}\right)^2 \cdot q)$, where $|D'|$ is the maximum dose of the length and width of the square area with the maximum dose at the center, and l^* is the grid step size. q is the number of extreme points, generally a small constant.

In the step 5, it is used to determine whether a limited number of extreme points are radioactive sources. A threshold function is required to determine the number of iterations as $o(c)$, so the complexity of the algorithm is $o(n+m+\left(\frac{|D'|}{l^*}\right)^2 \cdot q)$.

Explanation, If $n = max\{m, n\}$, the complexity of the maximum quadratic fitting algorithm is $o(n+\left(\frac{|D'|}{l^*}\right)^2 \cdot q)$. If$\frac{|D'|}{l^*}$ is a constant, the complexity of the extreme quadratic fitting algorithm is $o(n+m)$. When performing longitudinal quadratic fitting on these maximum

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points, it is not necessary to perform quadratic fitting on each vertical grid line, only a few longitudinal data lines where the lateral maximum are located need to be selected for quadratic After fitting, the maximum points obtained by the second-order vertical fitting are determined, and finally the maximum doses obtained by the horizontal and column fitting are combined to obtain possible radiation source position coordinates. Therefore, it is $o(n)$ for both the number of horizontal fittings and the number of vertical fittings.

2.2.3.3 Local Optimization Search for Maximum Point

The location of the radioactive source searched by the quadratic fitting search algorithm is not necessarily the exact location of the radioactive source, but may be a location closer to the source. In order to further determine the precise location of the radioactive source, a further precise search is required. The maximal point local optimization search algorithm is based on the field grid with the line scan method to search for the position of the radioactive source. The field grid is finely divided to become a fine grid of $n \times n$ (see Fig 3).

Compare the radiation measurement dose of the central position point with the radiation measurement dose of the four vertices in the fine grid where the point is located, and determine the maximum point of the adjacent radiation measurement as the new radiation source position. Repeat this process until the four vertices are no longer greater than the central point radiation. Up to the source radiometric dose, when the algorithm terminates, the local radiometric maximum point may be the location of the radioactive source.

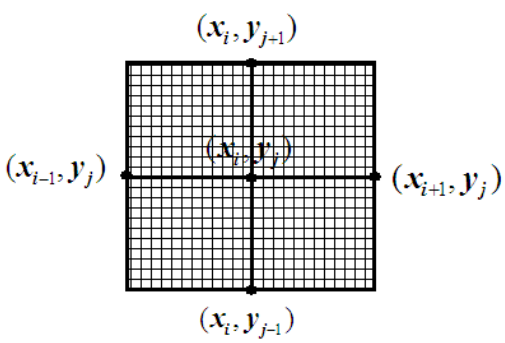

Fig3: Schematic diagram of local maximum search

The local optimal search algorithm 5 is given below.

Algorithm 5 Local Optimization Search Algorithm for Maximal Points

Step1 Enter the maximum point(x_i, y_j).

Step2 Select the square areaD' with (x_i, y_j) as the center.

Step3 Divide area D' as $n \times n$ grid (interchangeable step size is l).

Step4 Determine the four vertices(x_{i-1}, y_j),(x_{i+1}, y_j),(x_i, y_{j-1}), (x_i, y_{j+1}) *of* (x_i, y_j).

Step5 Calculate the radiation measurement of the four vertices of the top, bottom, left and right, and let the maximum radiation measurement function

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$M = f(x_s, x_t) = max\{f(x_{i-1}, y_j), f(x_{i+1}, y_j),\ f(x_i, y_{j-1}), f(x_i, y_{j+1})\}$.

Step6 Replace point (x_i, x_j) with point $(x_s, x_t)$and return to step 2, If the dose is not more than its own dose, get $(x_i + \varepsilon_i,\ y_j + \varepsilon_j)$.

Step7 Output the radiation source position coordinates $(x_i + \varepsilon_i,\ y_j + \varepsilon_j)$.

Here are some explanations of the local optimization search algorithm for maximum points:

(1) The line scan method avoids excessive maximum points caused by three spline interpolations, increases the search for the precise location of the radioactive source, and determines whether the extreme point is a radioactive source, which effectively avoids the extreme Cases where the dose search algorithm may not find a radioactive source.

(2) The quadratic fitting algorithm searches for radioactive sources rather than discrete data. Although the secondary fitting process takes more time and space, the quadratic fitting is more accurate than the discrete search radioactive source search for the location of the radioactive source.

(3) When designing the step size in step 3, generally the step size can be taken as L (which can be a unit grid length), and four adjacent points are obtained as $(x_i - l, y_j)$, $(x_i +$ *l,yj,xi,yj−l,xi,yj+l*. This can save storage space in the instance search. To increase the speed of operation.

In the second-fit search, human error and machine error may occur during data collection and processing, especially in the case of relatively small grid data, due to steps 2.1.2 and 2.2.2 in the z algorithm 4.6, it is relatively harsh to meet the quadratic fitting conditions for the arrays A_i and B_i. There may be large deviations during the search, and even the radio source cannot be searched, so the quadratic fitting fails. Therefore, we designed a cubic fitting method. Not only can the fitting at the extreme points be strengthened, but also the radiometric field function can be roughly restored, which has a greater effect on improving search accuracy and correcting data deviations.

2.2.4 Line Scan Search of Cubic Fitting

When collecting radiation field grid node data, data misreading sometimes occurs. When a data dose near the radiation source point is misread and becomes larger, the live ratio becomes smaller, which may destroy the left and right data of the radiation source point. Structural characteristics. If the algorithm for searching the radioactive source using the second-order fitting is used, this data will be discarded. Therefore, the second-fitting algorithm will fail, and there will be cases where the radioactive source cannot be searched. Insufficient, designed to resist the trouble caused by data fluctuations, we designed a three-dimensional fit search algorithm for radioactive sources.

Principle of Cubic Function Fitting In order to fit S-shaped data, in each data line, the midpoint of the previous minimum point and the adjacent maximum point and the next set of minimum points are taken. A cubic function fitting is performed with the interval near the midpoint of the maximum point to improve the accuracy of fitting the radiometric curve peaks.

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The definitions of the maximum and minimum points are given below.

Definition 3 If there is$f_{i,j-1} \geq f_{i,j}$ and $f_{i,j} \geq f_{i,j+1}$,$j = 1,2, \dots, m-1$ on the data line of the*i*-th row of the parallel *X* axis, the ordinate $\mathrm{x}_{\mathrm{i,j}}$ of the point corresponding to the radiation measurement dose of$f_{i,j}$ is called a maximum point on the data line of the *i*-th row ($i = 0,1,2, \dots, n$).

Definition 4 If there is$f_{i,j-1} \geq f_{i,j}$ and $f_{i,j} \geq f_{i,j+1}$,$j = 1,2, \dots, m-1$ on the data line of the i-th row of the parallel *X* axis, the ordinate $x_{i,j}$ of the point corresponding to the radiation measurement dose of$f_{i,j}$ is called a minimum point on the data line of the *i*-th row ($i = 0,1,2, \dots, n$).

Definition 5 If there is$f_{i-1,j} \leq f_{i,j}$ and $f_{i,j} \geq f_{i+1,j}$,$i = 1,2, \dots, n-1$ on the data line of the j-th column of the parallel *Y* axis, the ordinate$y_{i,j}$ of the point corresponding to the radiation measurement dose of $f_{i,j}$ is called a maximum point on the data line of the *j*-th column ($j = 0,1,2, \dots, m$).

Definition 6 If there is$f_{i-1,j} \geq f_{i,j}$ and $f_{i,j} \leq f_{i+1,j}$,$i = 1,2, \dots, n-1$ on the data line of the j-th column of the parallel *Y* axis, the ordinate $y_{i,j}$ of the point corresponding to the radiation measurement dose of$f_{i,j}$ is called a minimum point on the data line of the *j*-th column ($j = 0,1,2, \dots, m$).

In order to fit the radiometric curve three times effectively, it is noted that the midpoint of the previous set of maximum and minimum doses and the midpoint of the next set of maximum and adjacent minimum doses are selected on the radiometric curve. The radiometric curve has exactly the structure. The entire line of data is divided into several sections, and each piece of data is fitted three times. Therefore, when fitting a data line of the grid three times, when the maximum number of extreme points and the minimum points on the grid line are different, the way of intercepting the data segment is different, and the maximum point appears first. Whether the minimum dose appears first will affect the way of the three-dimensional fitting, so it needs to be discussed on a case-by-case basis.

Assume that the maximum point on the *i*-th grid data line parallel to the *X*-axis in the search area is found on the line. Let $x_1, x_2, \dots, x_p$ be the maximum point on the*i*-th grid data line and $y_1, y_2, \dots, y_q$ be the *j*-th line. The minimum dose points ($j = 0,1,2, \dots, m$) on the grid data line, and the subscripts p, q are the maximum and minimum number of points on the grid data line, respectively.

(1) When $p = q$, there are two cases of minimum dose or maximum dose (see Fig 4).

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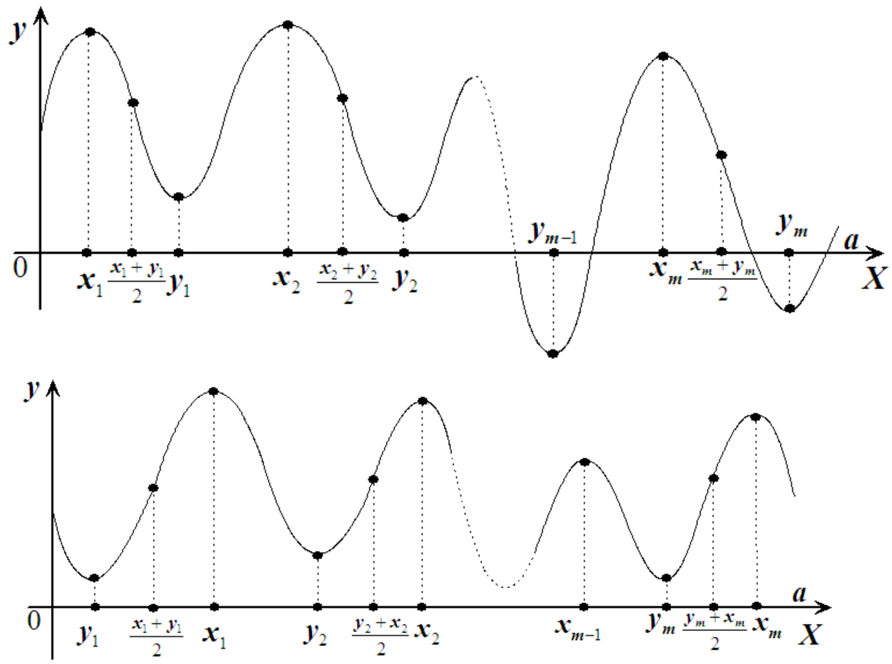

Fig 4: Data segmentation when the maximum and minimum doses are equal

When the number of maximum points and minimum points on the grid line are equal, whether the minimum point appears first and ends with a maximum point; or the maximum point appears first, with an extreme point Small dose ends, the entire data line will be divided into m + 1 interval segments $\left[0,\frac{x_1+y_1}{2}\right],\left[\frac{x_1+y_1}{2},\frac{x_2+y_2}{2}\right],\ldots,\left[\frac{x_{p-1}+y_{p-1}}{2},\frac{x_p+y_p}{2}\right],\left[\frac{x_p+y_p}{2},a\right]$. Perform quadratic fitting on the intervals at both ends of $\left[0,\frac{x_1+y_1}{2}\right]$ and $\left[\frac{x_p+y_p}{2},a\right]$, and perform cubic fitting on the remaining intervals.

(2) When $q = p + 1$, only the minimum dose appeared first (as shown in Fig 5).

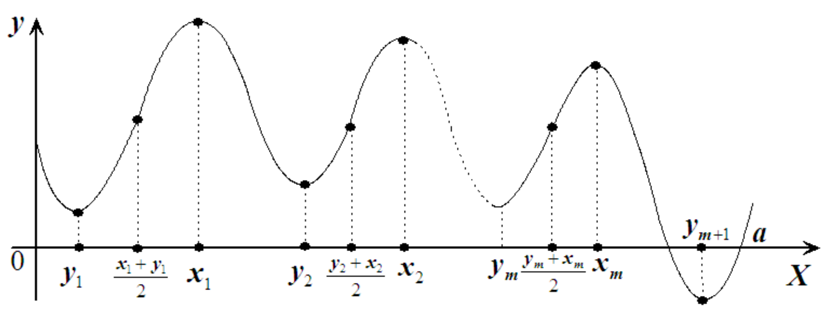

Fig 5: Data segmentation when the minimum dose is greater than the maximum dose

When the number of maximum points on the grid line is one less than the number of minimum points, the entire data line needs to be divided into p + 1interval segments $\left[0,\frac{x_1+y_1}{2}\right],\left[\frac{x_1+y_1}{2},\frac{x_2+y_2}{2}\right],\ldots,\left[\frac{x_{p-1}+y_{p-1}}{2},\frac{x_p+y_p}{2}\right],\left[\frac{x_p+y_p}{2},a\right]$. Perform quadratic fitting on the

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intervals $\left[0,\frac{x_1+y_1}{2}\right]$ and perform cubic fitting on the remaining intervals.

(3) When $q = p - 1$, only the maximum dose appears first (as shown in Fig 6).

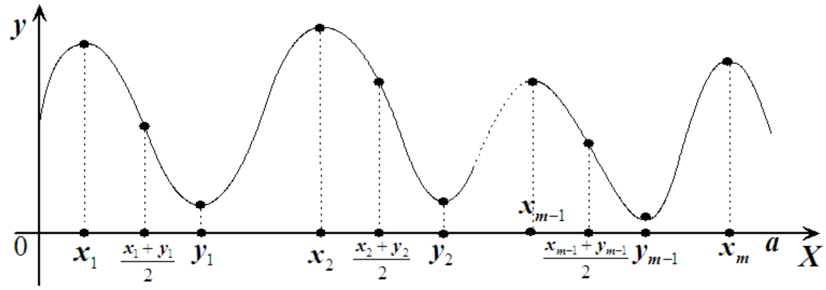

Fig 6: Data segmentation when the maximum dose exceeds the minimum dose

When the number of maximum points on the grid line is one more than the number of minimum points, the entire data line needs to be divided into p interval segments$\left[0,\frac{x_1+y_1}{2}\right]$, $\left[\frac{x_1+y_1}{2},\frac{x_2+y_2}{2}\right]$, … , $\left[\frac{x_{p-2}+y_{p-2}}{2},\frac{x_{p-1}+y_{p-1}}{2}\right]$, $\left[\frac{x_{p-1}+y_{p-1}}{2},a\right]$. Perform quadratic fitting on the intervals$\left[0,\frac{x_1+y_1}{2}\right]$ and perform cubic fitting on the remaining intervals.

Similar to interval segmentation of parallel Y-axis grid data.After discussing the segmentation of the data in the search area, a cubic function fitting search algorithm 6 is given below.

Algorithm 6 Cubic Function Fitting Search Algorithm

Step1 Enter the radiation measurement dose$f_{i,j}, i = 0,1,2,\dots n, j = 0,1,2,\dots,m$ in the search area.

Step2 Find the maximum and minimum points parallel to the first data of the axis as $\mathrm{x}_1, \mathrm{x}_2, \dots, \mathrm{x}_\mathrm{p}$ and $y_1, y_2, \dots, y_q, i = 0,1,2,\dots n(q = p\ or\ (p-1)\ or\ (p+1))$, respectively.

Step3 segment the grid data line i.

Step3.1 If $q = p\ \ or\ q = p + 1$, the data is divided into p+1 intervals, that is$\left[0,\frac{x_1+y_1}{2}\right]$, $\left[\frac{x_1+y_1}{2},\frac{x_2+y_2}{2}\right]$, … , $\left[\frac{x_{p-1}+y_{p-1}}{2},\frac{x_p+y_p}{2}\right]$, $\left[\frac{x_p+y_p}{2},a\right]$.

Step3.2 If $\mathrm{q} = \mathrm{p} - 1$, the data is divided into p+1 intervals, that is$\left[0,\frac{x_1+y_1}{2}\right]$, $\left[\frac{x_1+y_1}{2},\frac{x_2+y_2}{2}\right]$, … , $\left[\frac{x_{p-2}+y_{p-2}}{2},\frac{x_{p-1}+y_{p-1}}{2}\right]$, $\left[\frac{x_{p-1}+y_{p-1}}{2},a\right]$.

Step4 Perform a quadratic function fitting on the first interval segment in the i-th data segment.For any point$Z_i \in \left[0,\frac{x_1+y_1}{2}\right], i = 0,1,2,\dots n,$ let$S_1(z_i) = a_{i,1}{z_i}^2 + b_{i,1}z_i + c_{i,1}$,, if $f_{i,j}$ is the radiometric observation of the i-th row, so that $min(\sum_{\substack{j\in\left[0,\frac{x_1+y_1}{2}\right]\\ j\in N}} |S_1(z_i) - f_{i,j}|)$, find the dose of$a_{i,1}, b_{i,1}, c_{i,1}$.

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Step5 Perform a quadratic function fitting on the last interval within the *i*-th data segment.

Step5.1 If $q = p$ or $q = p + 1$, the data is divided into p+*l*intervals,$Z_i \in \left[\frac{x_p + y_p}{2}, a\right], i = 0,1,2, \dots n$, $let S_{p+1}(z_i) = a_{i,p+1}{z_i}^2 + b_{i,p+1}z_i + c_{i,p+1}$,if $min(\sum_{\substack{j \in [\frac{x_p + y_p}{2}, a] \\ j \in N}} |S_1(z_i) - f_{i,j}|)$, find the dose of$a_{i,p+1}, b_{i,p+1}, c_{i,p+1}$.

Step5.2 If $\mathrm{q} = \mathrm{p} - 1$, the data is divided into p intervals,$Z_i \in \left[\frac{x_{p-1} + y_{p-1}}{2}, a\right], i = 0,1,2, \dots n$, let $\mathrm{S_p(z_i)} = \mathrm{a_{i,p}{z_i}^2} + \mathrm{b_{i,p}z_i} + \mathrm{c_{i,p}}$, , if $min(\sum_{\substack{j \in [\frac{x_{p-1} + y_{p-1}}{2}, a] \\ j \in N}} |S_p(z_i) - f_{i,j}|)$, find the dose of$a_{i,p}, b_{i,p}, c_{i,p}$.

Step6 Perform a cubic function fitting on the middle section interval section in the i-th data section.

Step6.1 If$q = p$ or $q = p + 1$, the data is divided into p intervals,$Z_i \in \left[\frac{x_{k-1} + y_{k-1}}{2}, \frac{x_k + y_k}{2}\right]$, $k = 2$,let $S_k(z_i) = a_{i,k}{z_i}^3 + b_{i,k}{z_i}^2 + c_{i,k}z_i + d_{i,k}$, if $min(\sum_{\substack{j \in [\frac{x_{k-1} + y_{k-1}}{2}, \frac{x_k + y_k}{2}] \\ j \in N}} |S_k(z_i) - f_{i,j}|)$, find the dose of$a_{i,k}, b_{i,k}, c_{i,k}$.

Step6.2 If $q = p - 1$, the data is divided into p intervals,$Z_i \in \left[\frac{x_{k-1} + y_{k-1}}{2}, \frac{x_k + y_k}{2}\right], k = 2, \dots p - 1$, let$S_k(z_i) = a_{i,k}{z_i}^3 + b_{i,k}{z_i}^2 + c_{i,k}z_i + d_{i,k}$, if $min(\sum_{\substack{j \in [\frac{x_{k-1} + y_{k-1}}{2}, \frac{x_k + y_k}{2}] \\ j \in N}} |S_k(z_i) - f_{i,j}|)$,find the dose of$a_{i,k}, b_{i,k}, c_{i,k}$.

Step7 Determination of the maximum point.

Step7.1 Perform a quadratic fitting curve $S_{i,r}(x), r = 1,2 \dots p$ on the selected *i*-th ($i = 0,1,2, \dots n$) row and find the maximum point *x*.

Step7.2 Perform a quadratic fitting curve $g_{r,j}(y), r = 1,2 \dots p$ on the selected *j*-th ($j = 0,1,2, \dots m$) column and find the maximum point y.

Step8 The maximum point(*x*, *y*) of the global grid node obtained by combining the abscissa of the maximum point searched in step 7.1 and the ordinate of the maximum point searched in step 7.2.

Step9 For all maximum points (*x*, *y*), call the threshold function to determine when the point is a radioactive source.

Here are some explanations of the three-fit search algorithm:

(1) When there is an error or deviation in the data of the peak section of the radiometric curve (as shown in Fig7), if the quadratic function is fitted, the data section with the error will not meet the judgment criteria, resulting in failure to search for radioactive sources. However, a cubic function fitting is used. Since the cubic function fitting can better fit the data of the "S" type of peaks and valleys, all the maximum points will be fitted, so that the radioactive source

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will not be missed, which improves Search success rate.

(2) When there is an error or deviation in the peak data of the radiometric curve, the cubic spline interpolation will not miss the radio source, but due to the limitations of the cubic spline interpolation itself, some unnecessary small peaks and Valleys, which increase the difficulty of searching, so it is not ideal. Cubic fitting improves the fault tolerance of the data and avoids fluctuations in the radiometric curve caused by errors.

(3) The three-dimensional fitting algorithm strengthens the search for maximum points, making up for the possibility of missing large doses from the second fitting, and improving the fault tolerance of the algorithm, but it requires more running time.

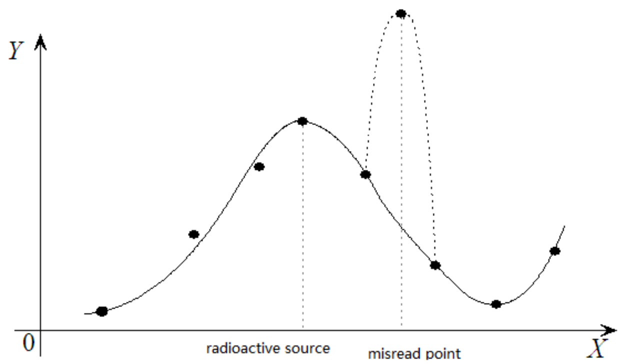

Fig 7: The abnormally large dose near the radioactive source caused by misreading

(5) The three-dimensional fitting is more suitable for the search of multipoint radioactive sources. When two or more radioactive sources are close to each other, these radioactive sources can be combined into one radioactive source for three times. For fitting, when you need to find the maximum point, the radioactive source is near the maximum point. As long as you perform a local fine search, you can find two radioactive source points. If quadratic fitting is used, the data will be discarded according to the conditions of the data characteristics, resulting in missing radioactive sources (as shown in Fig 8).

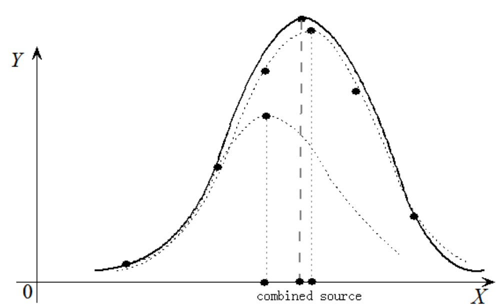

Fig 8: The abnormally large dose near the radioactive source caused by misreading

III. CONCLUSION

This paper imitates the human search experience and establishes a random search model, and optimizes the model to make it more suitable for the actual search. It has strong operability

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and implements simulation on the computer to realize search. The random search model has a smaller storage space than the traditional search algorithm and runs faster than the traditional search algorithm.

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