A NEW INTERACTIVE METHOD OF VELOCITY DEALIASING

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1. INTRODUCTION

Doppler radar has the ability to detect the atmosphere with high spatial and temporal resolutions, but the velocity ambiguity disturbs the data application. Many studies have been made to resolve this problem [Liang,2002; Joe,2003; Iwan,2003; Katja,2004; Gu¨,2004].

Except for the hardware dealiasing methods, the software dealiasing methods are usually divided into two types: the automatic unfolding and the manual unfolding. Automatic methods mainly depend on various hypothesis and algorithms. When the data still remain a lot of error velocity areas after dealiasing with the automatic way, the manual way have to be used to correct them. Traditional manual unfolding methods are very complicated, which chooses every error radial line to rectify data, is neither convenient nor practicable. If an image has many alias areas, people have to do much more work and spend a lot of time to put right. For example, an automatic method (called "point by point recovery") is usually supposed as the first point to be right, every behind point be judged depends on the former one, and then to be corrected point by point. This method is sensitive to the start point, noise and echo-free points. Similarly, other methods are also sensitive to the first radial line. This work tries to study a new interactive method to unfold the velocity ambiguity areas with computer graphic function.

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2. BASIC FORMULA

As the theory of Doppler radar measuring velocity, the relationship among the maximum measurable velocity ($V_{r\max}$), wavelength(λ) and pulse repetition frequency (PRF) is:

$$V_{r\max} = \pm\frac{1}{4}\lambda PRF \qquad (1)$$

when the actual velocity is faster than the maximum measurable velocity, it will occur a measuring error. If V_r means measuring velocity, V_{rT} means actual velocity, then the relationship between them are as follows. For the first velocity ambiguity:

$$V_{rT} = \begin{cases} V_r + 2*V_{r\max}(when V_{rT} > V_{r\max}) \\ V_r - 2*V_{r\max}(when V_{rT} < -V_{r\max}) \end{cases} \qquad (2)$$

For the second velocity ambiguity:

$$V_{rT} = \begin{cases} V_r + 2*V_{r\max}(when V_{rT} > 2*V_{r\max}) \\ V_r - 2*V_{r\max}(when V_{rT} < -2*V_{r\max}) \end{cases} \qquad (3)$$

3. NEW METHOD OF DEALIASING

The traditional velocity dealiasing method is similar with the extrapolation which is used in the weather forecast. The extrapolation uses computer to identify the data which contain some inaccurate information，while this method, the first step must be made by the human. We distinguish the positive and negative areas by zero velocity line in the radial velocity field. This step is easy to do with human's experience. Then we input the correct information to the computer and let computer to process the data which is located in the selected area. If an image only contains the first ambiguity, the problem will be easy. For instance, we select an area (RGN1) and sign it with “positive (or “negative”), then use a certain arithmetic to process RGN1, (the complicated way is to process from the first radial line and /or first gate, even for an array of 360 line x460 gate, have to judge 360x460 times). When an area feature is “negative” (or “positive”), we add it with doubled maximum velocity (subtract doubled maximum velocity), this step is corresponding with formula (2). If an area feature is the same with the region or if there is an echo-free area, we do not make any change. In this method, we do not need any extrapolation and hypothesis, so that to ensure most information is correct. If the user selects carelessly an area which does not have aliased velocity, its feature is the same with RGN1, it will not be changed. After this step, we will get a satisfying result. In fact, we always select the big domain including velocity ambiguity, need not draw the border exactly.

For the second ambiguity, based on the method introduced above, we have two realizable ways. The first one is to judge the second ambiguity by human beings, sign the area with “1” (or “-1”), which means the positive velocity (or negative velocity) is very high, reading data process is similar with the first ambiguity, but the judging condition is:

$$V_{rT} = \begin{cases} V_r + 2*V_{r\max}(when V_r < V_{r\max} * mStretch) \\ V_r - 2*V_{r\max}(when V_r > -V_{r\max} * mStretch) \end{cases} \quad (4)$$

$mStretch$ is a parameter, which means when a velocity absolute value is small enough, we can rectify it with the second velocity dealiasing. In fact, we do not need this parameter, just give an area as color information called color suffix (cr), the color represents the fastest velocity’s absolute value in the second ambiguity. In any point, if the velocity absolute value is less than the fastest one, we will rectify it.

The formula is:

$$V_{rT} = \begin{cases} V_r + 2*V_{r\max}(whenflag = 1, and VeloN(V_r) >= RgbN(cr)) \\ V_r - 2*V_{r\max}(whenflag = -1, and VeloN(V_r) <= RgbN(cr)) \end{cases} \quad (5)$$

$VeloN(V_r)$ means original velocity’s corresponding color suffix, $RgbN(cr)$ means the color which we used to fill the image. This way needs human to judge which area is the second ambiguity.

Another way is automatic discrimination method, it is similar with “point by point recovery”, but ideas of two methods are quite different. The former one’s data information is inaccurate, and the latter method is based on the first velocity dealiasing, the data accuracy is ensured. When extrapolating, we work in the RGN1 where have been rectified in the first velocity dealiasing. Positive velocity are always positive, it is unlikely to appear the situation that the first point’s information is false. For the noise points, because data have already been filtered after the first velocity dealiasing, they will do not impact the result. The second velocity dealiasing arithmetic can be described with the sketch map below.

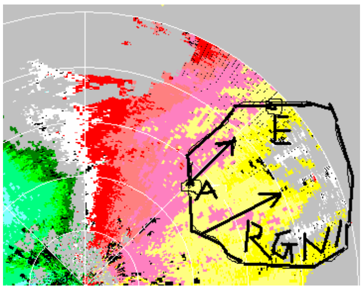


Fig.1 Image of the second velocity dealiasing arithmetic

We start from the RGN1’s nearest the centre’s boundary, reading data point by point along the radial. For example, a radial range is AE as shown in Fig.1, we consider A is correct, search point by point, always depend on the former point is correct. If we meet the echo-free point, fill it with the former point. If the difference between former and latter is bigger than a certain value, we consider the latter one is the second ambiguity. As the first dealiasing is almost 100% correct, this search always does not have any error. From this “hypothesis”, for the first ambiguity, we could select a relative large area, let RGN1 contains the second ambiguity. This way reduces amount of work by human, and is much easier than selecting an actual ambiguity area.

In order to explain this idea, a data list is following:

1.1 2.1 3 5 B 8 11.2 -11.4
-9.1 –7.8 –5.4 –2.1 2.1 3

The measurable maximum velocity is 11.7m/s, B means echo-free. When we dealias the first ambiguity, as the division of the image, suppose the information which is given by the user is “negative”, after one time unfolding, the data should be:

1.1 2.1 3 5 B 8 11.2 12 14.3
15.6 18 21.3 2.1 3

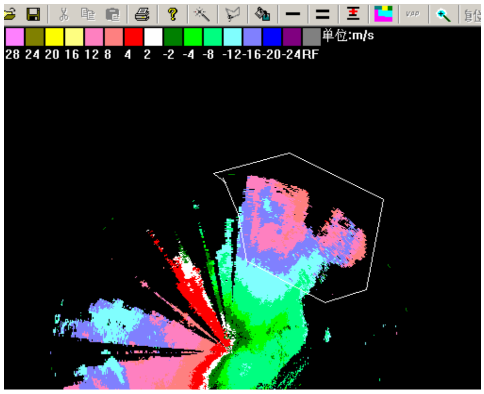
Unfolding the second ambiguity start from 1.1, we can see from 21.3 to 2.1 is the second ambiguity. So 2.1 and 3 are changed to 2.1+2*11.7 and 3+2*11.7. The question is: if the first data is negative, for example the first data is -1.1, should we unfold the second ambiguity from the second data? In fact, it is easy, because we use human’s judgment at first, could insure the correct division being 100%. We divide the image in positive velocity area between 1.1 to -11.4. In the image there has a large space to draw lines.

4. SOFTWARE OPERATION AND ARITHMETIC REALIZATION

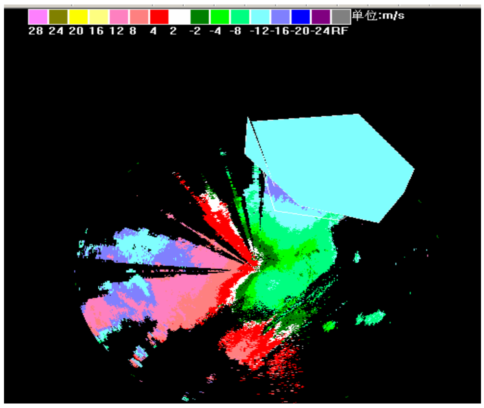
To search a certain area, we use MFC’s powerful function to design the magic stick and the polygon selection, which are similar with the corresponding parts in PhotoShop. When using the magic stick, we select it and left click the mouse in a connected area at first, then right click the mouse to choose color to fill it. The connected area with the same color will be filled by another color. The magic stick does not need the user to draw a polygon of ambiguous area. Another tool is the polygon selecting, we use it to draw any shape of polygon (see Fig.2). The way of filling color is the same as with the magic stick. In fact an ambiguous area is not always connected with other one, the polygon selection is used much more than magic stick.

With the help of these two tools, dealiasing steps become so easy: selecting and filling. If an image has two ambiguous areas, we just need to fill twice. For most of the image, it is enough.

After the filling, we use this function to unfold velocity. We design the software like this: once an area is filled with new color, the software will check it and refresh.



a



b

Fig. 2 The interactive dealiasing display
a: selecting b: filling

5. EXAMPLE VERIFICATION

In order to explain the effect of this method, example verification has been done. Compare with the method [Liang, 2002], they used one dimension, two dimensions and human-computer method to unfold velocity, correction is more than 87%. Cost more than 24 seconds. With this method, the time consumption is consist of these parts: the time to make a judgment by human, filling color’s time and the time which is used to unfolding one time and two time ambiguity. We calculate the time which dealias the first and the second ambiguity and find: even filling the whole circle, this way only needs 4 seconds, which is better than two-dimension method. Total time of judging and filling are no more than 20 seconds. The correction is based on the judgment. If the judgment is correct, because dealiasing the first ambiguity does not use extrapolation, the false data do not affect the correct one. The correction is higher than 99%, even 100%. Fig. 3 is the dealiasing result of “point by point recovery”, left is the primary alias echo, and right dealiased echo still has the error information.

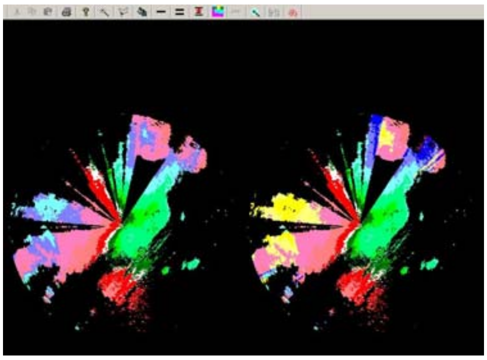


Fig.3 The dealiasing result of “point by point recovery”,left: primary echo, right: dealiased echo

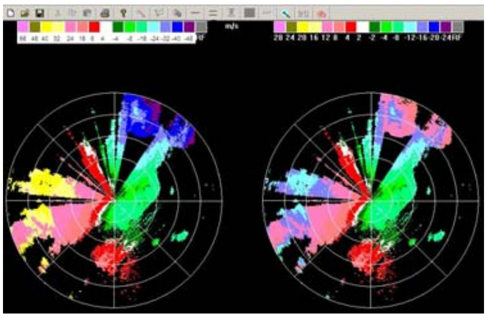


Fig.4 The dealiasing result with new human-computer interactive method, right: primary echo, left：dealiased echo.

Fig.4 shows that this new human-computer interactive dealiasing method has the good result. Right is primary echo, left is new method dealiased echo.

6. CONCLUSION

6.1 This dealiasing method is based on the correct judgment of human and the computer graphic function, it does not extrapolate linearly but distinguish by zero velocity line.

6.2 We use MFC to design the human-computer interface and provide two kinds of tools, one is “magic stick” and another is “area selection”.

6.3 The dealiasing results indicate this method need much less time, the velocity validity is more than 99%.

6.4 This method is a great improvement than the traditional complicated human-computer method, and could be used in operational work easily. More over, it provides convenience in scientific research for getting the correct velocity information.

Acknowledgement. This research was supported by National Natural Science Foundation of China through Grant 60674074, 40333027 ， Jiangsu key Laboratory of Meteorological Disaster Grant KLME 05011 and Nanjing University of Information Science and Technology Research Foundation QD62.

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