MATCHING TECHNIQUE OF OBJECTS IN RADARS WITH STEREOSCOPIC VISION

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ABSTRACT

We present in this paper a new method of matching by the adaptive correlation, dedicated to Radar applications with stereoscopic vision. This work is related to the detection and calculation of the object depth in the Radar images. This system has the advantage to be invisible and it allows the measurement of the radial distance or the depth of each object separately even at low-altitude.

The most classical area-based Methods used in this domain are the cross correlation with a fixed window-size. However, objects presented herein have some variable forms (planes with different sizes and depths). These methods cannot provide a depth directly and separately for every object. The aim of this paper is to present a new algorithm in matching, based on the correlation with chains, that holds account of the object form. The using of the improved chaining method allows the following:

Working on a linear description under form of a chained contour list.

Possibility of an extended storage for various type of information (level of gray, coordinates of pixels, amplitude of the gradient...).

Possibility to work with storages reduced of images.

Easy processing to find the depth of each object.

Simulations are carried on the synthetic Radar images, presenting four planes with different radial distances and sizes.

Keywords: Radar (RVS), stereovision, the range, disparity, radial distance, chains.

I. INTRODUCTION

The range of a radar or the domain inside of which it is capable of discerning the presence of an object is limited by two phenomena:

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- The very strong attenuation of the collected signal power by radar due to the wave propagation;
- The presence of a noise in the receptor that can come to conceal, or at the very least distort this very weak signal.

Besides, the fluctuating character of the noise renders this signal detection uncertain and subject to mistake, which promotes the idea of participating in the conceiving of a Radar with Stereoscopic Vision or RVS, which is recognized by its big range. On the other hand, this type of radar doesn't intervene emission power, it is therefore important to use the stereoscopic sensors or two stereoscopic cameras calibrated that "observe" the same scene where objects are mobile.

This RVS has the particularity to be invisible and to allow measurement of the radial distance or the depth of each object separately, even though it is in low-altitude and the particular treatments of the stereoscopic image sequences.

Stereovision processes in a binocular system estimate 3D surface depths using a pair of images taken from different points of view. For that, depths of 3D surface characteristics are estimated by matching 2D images areas or features corresponding to the projections of same 3D points.

Classical methods use the correlation based on the fixed blocks. These methods don't give depth for each separated mobile object of 3D scene. Other methods take into account the movement and the disparity of regions with Quad tree segmentation previously computed to code views or to compute objects depths [1]. In this paper, we present our current approach of matching in RADAR images.

The correlation function support will be therefore adapted according to the detected mobile object and that takes account of its form. So a disparity of each gravity center will be assigned to the scene object (Plane).

In simulations, we introduced the synthetic RADAR stereovision images, with horizontal and parallel epipolar lines, that contain 4 objects (4 planes). Five phases of stereoscopic images meadow-treatment have been introduced (figure 1) to match these objects:

1. detection of mobile objects between instants t and $t+\Delta t$ of the left and right views;
2. contours extraction of mobile objects;
3. chaining objects contours;
4. filtering and merging of chains;
5. adaptive windows determination and gravity centers for each mobile object;
6. matching of object images.

These phases will be discussed in the following of this article.

II. DETERMINATION OF THE ADAPTIVE SUPPORT

The determination of the adaptive support of the correlation measure is decomposed as indicated below in five stages:

a) Mobile object detection

That is the difference and threshold between reference stereoscopic images at the instant t and the stereoscopic images at the instant $t+\Delta t$ that containing the mobile objects in two views.

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b) Contours extraction of mobile objects

After extracting the image couple of stereoscopic mobile objects, the extraction of its contours has been proceeded; many operators [4,6,9] can be used, we have built our own operator that allows edge detection inside and along the boundaries. The width of these edges is reduced to one pixel in order to minimize the number of chains to construct and to compute easily the coordinates of the objects circumscribed rectangles which represent the adaptive support correlation function[8; 9].

c) Chaining objects contours

First of all, we identify chains contours that are defined by $\{C_i,\ i = 1,\ldots,n\}$, each contour chain is characterized here by two extremities $C_i = [H_i\ ,\ T_i]$ $(i = 1,\ldots,n)$ where H_i and T_i represent respectively Head and Tail of C_i.

Chaining consists in linking together all related pixels to built an edge chain list [5, 8, 11]. Note that it is at this level where the data structure is modified and matrix processing is left aside.

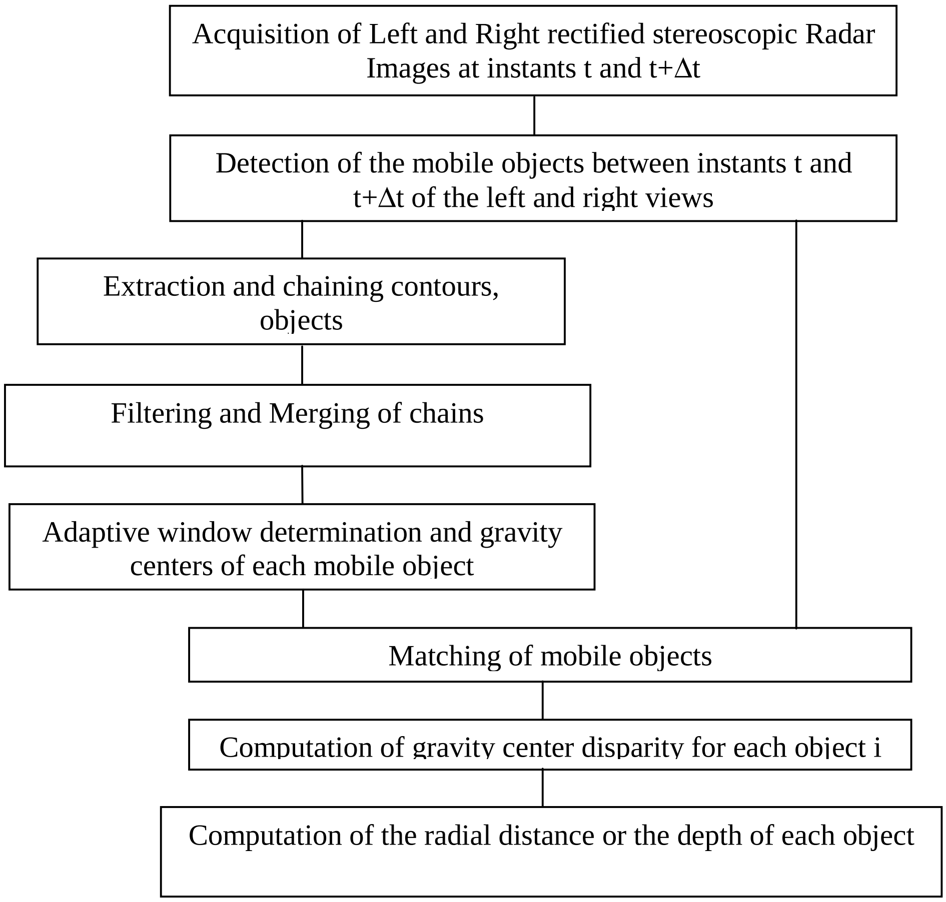

Figure1: Matching algorithm with adaptive correlation

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Chains building is performed even over the picture boundaries. Generally, the chain structure (figure 2) is characterized by the following variables:

- H_i or $Head_i$: a pointer to the first edge pixel (x_{Hi}, y_{Hi}) of the chain.
- L_i: a length which represents the number of edge pixels belonging to the chain
- G_{ci}: a pointer of gravity center coordinates (x_{Gci}, y_{Gci}) of region i delimited with contour i.
- GL_i : a gray level of region i delimited also with contour i.
- T_i or $Tail_i$: a pointer to the last pixel (x_{Ti}, y_{Ti}) of the chain.
- Next: a pointer to the next chain.

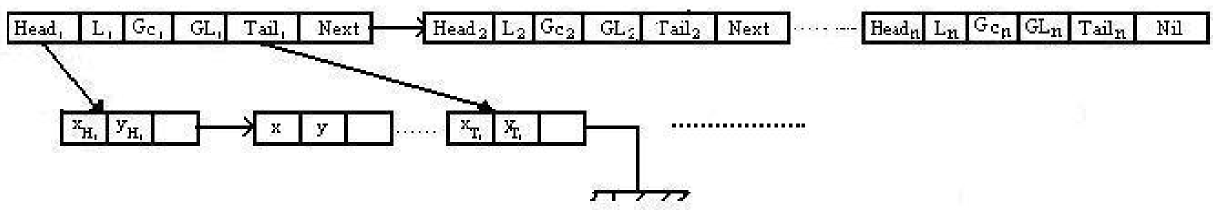

Figure 2: Chained list architecture

The chain construction, proposed here, can be also performed on edge pixels belonging **to rims of image**. Indeed, the processing is made by different paving blocks which are function of the position of the current edge pixel.

Let the edge boundaries image be a (M*N) binary image. The processing allowed to each edge pixel is function to its neighborhood information. So, the dimension of the paving blocks depends of the edge pixel position as it is mentioned in figure 3.

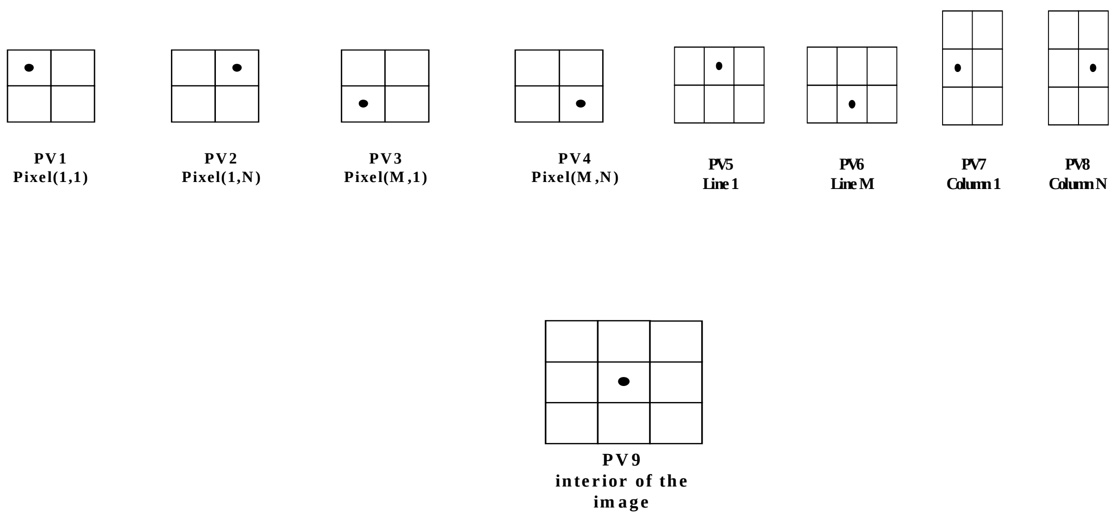

Figure 3: Paving blocks for the chain construction processing

By computing with these paving blocks except (PV_1, PV_2, PV_3 and PV_4), there are three types of edge pixel configuration:

- The isolated point: There is no other edge pixel in the considered paving block.

- The simple or double point: It possesses one or two edge pixels in its neighborhood included in the paving block.
- The multiple point: It possesses more than two edge pixels in its neighborhood included in the paving block.

When processing comes to the first edge pixel, the chain will be opened and will have this pixel as a head. The gray level of this pixel will then be put to zero. If the edge pixel is not isolated or multiple point, the processing is made in two steps:

- Chaining to right (or translation of the tail): While the current point is an edge pixel, it is associated to the chain. Then, the tail of this chain points at this new edge pixel. This process is iterated until coming to isolated or multiple point. This point is the real tail which closes the chain.
- Chaining to left (or translation of the head): In this phase, the paving window is moved to the head of the chain; if it is a simple point, it will be the definitive head. Otherwise, this point is double; So the head points on the other edge pixel existing in the considered paving block. This process is iterated until coming to an isolated or a multiple point which will be considered as the definitive head of the chain.

Chained Contours are then stored in a file for others possible operations.

d) Filtering and merging of chains

In order to compute windows and gravity centers for each mobile objects, it was primordial to reduce the number of chains which increase by noisy spurious chains or degraded edge boundaries image. This operation is done by eliminating any chain which length is smaller than an optimal number of pixels as introduced in [5,6]. The second operation consists in merging the chains within the same neighborhood [9]. This phase works only on the basis of the chains list. Each chain is processed as it is presented. Two chains will be merged if they are found in the same paving block with a given connexity and have the same gray level GL_i. This paving block can have variable dimensions according to its connexity. Chains can be merged according to the following possibilities (figure 4):

- Head of first chain H_i with Tail of second chain T_j ;
- Head of first chain H_i with Head of second chain H_j ;
- Tail of first chain T_i with Head of second chain H_j ;
- Tail of first chain T_i with Tail of second chain T_j ;
- Head H_i with Tail T_i of the same chain C_i ;

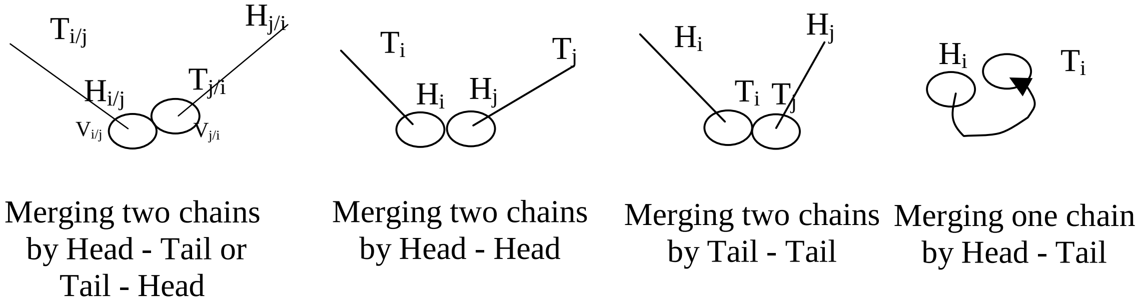

Figure 4: Merging of chains

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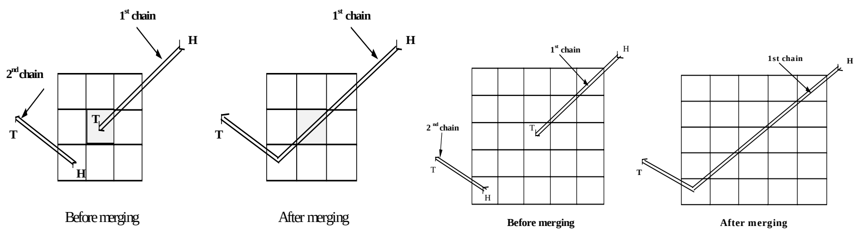
Figure 5 presents two examples of merging two chains (tail of 1st chain with head of 2nd chain) using different factors of connexity F_C; i.e. with 8-connexity (cf. figure 5.a, F_C=1), and with 24-connexity (cf. figure 5.b, F_C=2). Note that the head of the second chain can be found anywhere in the 8-neighborhood, respectively in the 24-neighborhood, of the current point.



a) F_C = 1 **b) F_C = 2**

Figure 5: Merging of two chains

The curvature of the restored contour depends on the curvature of the vicinity (V_1 and V_2) of each chain. If the curvature of V_1 is equal to that V_2, therefore the curvature of the contour to restore is identical to those of V_1 and V_2. Otherwise, this curvature will take an optimal path between the two chains by polynomial interpolation. As some contours can be degraded in the original edge boundaries image or with filtering process, an operation for closing down of contours is then processed to restore significant contours.

e) Determination mobile objects windows and its gravity centers

With these operations of chaining approach, each object of the scene is associated to an adaptive window whose size depends on its form. This form (width and height) is computed from chains: each chain is associated to an object of the scene. With this condition we determine easily the extremes x_{min}, y_{min}, x_{max}, y_{max}, for each chain . So the coordinates of circumscribed rectangles of our mobile objects are: (x_{min}, y_{min}), (x_{min}, y_{max}), (x_{max}, y_{min}), (x_{max}, y_{max}).

Also we determine for each chain C_i its gravity center G_{ci} with these coordinates:

$$x_{Gci}=\frac{\sum_{n=1}^{n=L_i}(x_n)_{Ci}}{L_i};\quad y_{Gci}=\frac{\sum_{n=1}^{n=L_i}(y_n)_{Ci}}{L_i} \tag{1}$$

$(x_n)_{Ci}$, $(y_n)_{Ci}$: coordinates of each pixel contour of the object I (n=1 to L_i);

L_i: number of pixels circling the object i or contour perimeter.

III. MATCHING WITH CORRELATION FUNCTION

The objects matching in the two views is performed by associating one object i (of the left view) to another object j (of the right view) verifying the maximum of similarity [10]. For this, our work has been based on the similarity of windows circumscribing the objects i and j in two views figure 6.

The fact of the big depth of objects in Radars, disparities will be supposed small. To this effect, the research window in the right image of the object j will have the size 2Mx2N where $M=(x_{max}-x_{min})$ and $N=(y_{max}-y_{min})$.

The central point P of the window i, having as coordinates (u, v) is associated to its object i of the left image, with $u=(x_{max}+x_{min})/2$ and $v=(y_{max}+y_{min})/2$. We look for point P', that is the window center j, with coordinates $(u+\Delta u, v+\Delta v)$ where Δu and Δv are components in x and y of disparity vector.

The similarity function (correlation) that we adopted, is defined by the following formula:

$$c(P,P')=\sum_{x=-M/2}^{x=M/2}\sum_{y=-N/2}^{y=N/2}\left[I(u+x,v+y)-I'(u+x+\Delta u,v+\Delta v+y)\right] \tag{2}$$

I(u, v) is the value of gray level to the pixel of coordinates u and v. The correlation is inexistent for a perfect resemblance between windows associated to the objects i and j.

Values of Δu and Δv that make the similarity function (Interco relation) minimal, represent respectively the horizontal and vertical of disparity values.

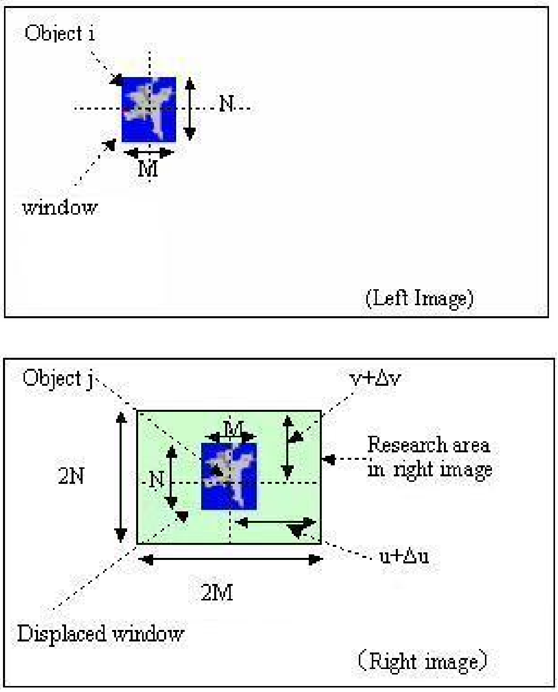


Figure 6: Windows of circumscription and research area

In following, we compute the disparity of gravity centers (calculated by the formula 1) of the objects i and j. Since epipolar lines of left and right images are horizontal, the

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computation of 3D components at the instant t of the point P (X_p, Y_p, Z_p), that is the gravity center of an object, is made of the following manner [2]:

$$X_p=\frac{x_{Gci}\times d}{disp}; \qquad Y_p=\frac{y_{Gci}\times d}{disp}; \qquad Z_p=\frac{f\times d}{disp}$$

disp is the disparity of the projected point P of coordinates (x_{Gci} ,y_{Gci}) in the left view and (x_{Gcj} , y_{Gcj}) in the right view. disp is equal to $x_{Gcj} - x_{Gci}$. f is the common focal length of two cameras, d is the baseline length: distance between the optic centers of two cameras. Z_p is the radial distance of the object.

This geometric constraint considerably reduces the complexity of the stereovision process for our RVS.

V. RESULTS AND DISCUSSIONS

Figure 7 is one example of stereoscopic images sequence, that contains several objects (4 planes). From these stereoscopic sequences at the instants t and t+Δt, the image couple of the scene mobile objects was taken (figures 8e and 8f). To eliminate the impulse noisy from the left image (figure 8g) and to make easily the contours segmentation, the median filter was applied (figure 8h).

The extraction of the contour from this filtered image and the chains construction have been using tanks to the chaining approach (figure 8i) which gave 77 chains (table.1). Then the filtering process according to length criteria of chains (Length=3), has been introduced to reduce this great number due to spurious noisy chains or degraded edge boundaries images (figure 8j) from 77 to 33 chains. Also the number of chains pixels is decreased from 528 to 476.These chains are then reduced after five iterations from 33 to 4 by merging process according to the connexity factor or maximum distance (figure 5), but the number of chains pixels are increased from 476 to 499, this difference of added pixels was for closing down of contour chains and making the significant chains.

The processing, whose progress is illustrated by table 1, leads to image mentioned in figure 8k in order to have the number of chains (4) is equal to the number of mobile objects.

At the end of these chains, the associated windows to the left image objects (figure 8*l*) was determined in table.2 and considered as the correlation function support.

Also in this table, the coordinates of these computed windows or rectangles circumscribing objects, as well as coordinates of gravity centers of objects with disparities vectors calculated between left image figure 7c and right image figure 7d that give back the minimal intercorrelation function, are indicated.

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(a)


(b)


(c)


(d)

Figure 7: Stereoscopic image sequence examples (a) Left Image at the instant t ; (b) Right Image at the instant t ; (c) Left Image at the instant t+Δt ; (d) Right Image at the instant t+Δt

Table.1: Filtering and merging of contours chains of figure 8i.
LEIM : Left Extracted Image; (4) is a number of objects figure 8g.

Iterations	Merging: Connexity Factor (F_c)	Filtering: Length (L)	pixels Number of LEIM*	chains Number of LEIM*
			528	77
1		01	490	39
2		02	482	35
3		03	476	33
4	01		476	16
5	02		484	6
6	03		492	4 (without closed chains)
7	04		495	4 (3 closed chains)
8	05		499	4 (closed)

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Table 2: Object matching results computed by our method

Chain s order	Circumscription Windows for 4 planes of the figure 8*l*				Gravity Centers of the figure 8*l*		Disparity figure 7e and f		Size of the object circumscription Windows	Size of the research area
Plane	x_{min}	y_{min}	x_{max}	y_{max}	x_g	y_g	H.Disp	V.Disp	MxN	2Mx2N
1	**9**	**5**	**37**	**38**	23	21	**10**	**9**	28x33	56x66
2	**55**	**13**	**82**	**48**	68	29	**10**	**7**	27x35	54x70
3	**19**	**47**	**48**	**78**	33	62	**3**	**14**	29x31	58x62
4	**62**	**67**	**95**	**96**	78	80	**17**	**7**	33x29	66x58

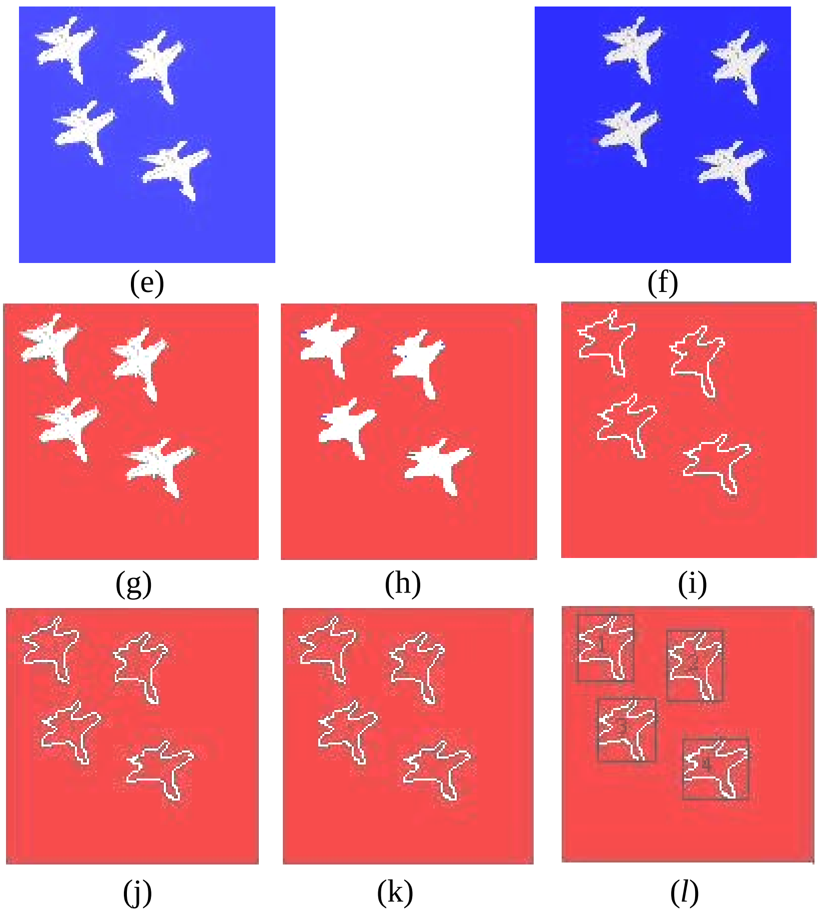

Figure.8: Detection and extraction of stereoscopic images (e) Left Image at the instant t + Δt after detection; (f) Right Image at the instant t + Δt after detection; (g) Choice of image (e) for treatment; (h) Eliminating of impulse noisy of (g) by median filtering; (i) Extraction and chained contours: number of pixels is 528, number of chains is 77; (j) Eliminating 38 chains (38pixels) which length are smaller than one pixel; (k) Merging and closing down of chains; (*l*) Recalling of the adaptive windows deduced from the contour map (k).

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VI. CONCLUSION

We present in this paper a new method of matching gravity centers not only for one object, as classically done, but for several objects as in real scene. This method is based on chaining approach. The chained contours contain only contours pixels coordinates of two views. This avoids matrix processing of images and problems related to memory saturation.

Indeed this method can be easily implemented and fast processed. The precision reached is one pixel and allows for each object an adequate adaptive window which cooperates with correlation function. It reduces considerably the localization of objects and increases the precision of the disparity vector computation. This cooperation allows also to minimize problems of bad matching and localization that hinder intercorrelation methods using fixed size windows.

Finally with this method, we can also calculate the depth for each mobiles objects of stereoscopic view. This work provides a framework for robotics, the stereoscopic vision, applications in automatic manufacturing, and so on.

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