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Skyline Extraction using a Multistage Edge Filtering

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***Abstract*—**Skyline extraction in mountainous images can be used for navigation of vehicles or UAV(unmanned air vehicles), but it is very hard to extract skyline shape because of clutters like clouds, sea lines and field borders in images. We developed the edge-based skyline extraction algorithm using a proposed multistage edge filtering (MEF) technique. In this method, characteristics of clutters in the image are first defined and then the lines classified as clutters are eliminated by stages using the proposed MEF technique. After this processing, we select the last line using skyline measures among the remained lines. This proposed algorithm is robust under severe environments with clutters and has even good performance for infrared sensor images with a low resolution. We tested this proposed algorithm for images obtained in the field by an infrared camera and confirmed that the proposed algorithm produced a better performance and faster processing time than conventional algorithms.

***Keywords*—**MEF, mountainous image, navigation, skyline

I. Introduction

The Skyline can be defined as a boundary between sky regions and mountainous areas. This skyline can is used for navigation of vehicles or UAV because of the characteristic which has hardly changed for a long period[1][2]. But the skyline extraction in the image is not easy because of the diversity of skyline shapes and clutters like clouds, the horizon, sea lines, field borders and so on.

Skyline extraction algorithms can be generally classified into two groups, which are the region-based method and the edge-based method. In the region-based method[3], sky and mountainous regions are classified by image segmentation algorithms[8]. But this method causes the prior extraction performance to lower in case that mountainous areas have lack of homogenous parts. In the edge-based method[4][5][6], unique characteristic of skylines is first defined and then the skyline is selected among edge candidates in an edge-domain image. But this method has a poor performance in images where there are clutters such as clouds and the horizon which are similar to skylines, because skyline has a variety of shapes and it is very hard to define the unique characteristic of skyline compared to similar clutters. We think that ‘unexpectable shapes of skyline’ is the reason that the extraction performances are poor in the recent papers for images with clutters even if many researchers try to define the unique characteristic of a skyline.

We proposed a new idea reversing a way of thinking in this paper unlike conventional methods.

We first defined *the characteristics of clutters*, not thoue of skylines, because shapes of clutters are more expectable than those of skylines. After that, we minimize the number of candidates of skyline using the multistage edge filtering (MEF) technique proposed in this paper. This MEF technique can delete clutters like a skyline by stages in an edge-domain image and this makes the probability of skyline extraction increase.

We tested our proposed algorithm with images obtained in the field using an infrared camera and confirmed that this algorithm produced a better performance and faster processing time than conventional algorithms.

II. Conventional Algorithms

Mr. Yang proposed the upgraded algorithm[6] as follows compared to that of Mr. Woo’s paper[5].

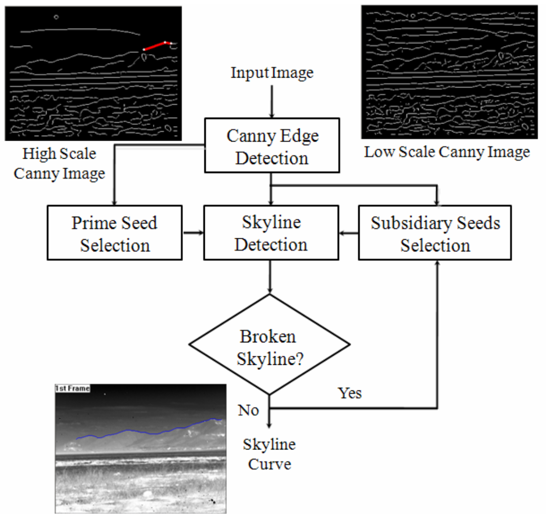

Fig. 1 Yang’s proposed algorithm

We analyzed that the important idea of the Mr. Yang and Mr. Woo’s methods was *the prime seed selection*. They defined the skyline’s characteristic as the conical hat shape. But this kind of shapes can usually exist on the cloud shape and other clutters, and this is the primary reason accounting for the poor performance. Moreover, Mr. Yang made two different canny edge images for the processing and this can be also a drawback because canny edge filtering is one of the most time-consuming steps in the system. So we propose a new idea which can overcome these kinds of drawbacks in the conventional methods.

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III. Proposed Algorithm

In the conventional methods, the skyline characteristics for the last selection among candidates in the edge image usually are defined as follows;

- *Edge with a long length.*
- *High contrast between sky and mountain regions.*
- *Homogeneity in the mountainous region.*

But we cannot tell that these characteristics are unique for a skyline because a skyline has a variety of shapes as mentioned before. For examples, the edge length of the sea line or field border is also long and has a high contrast near lines vertically. In addition, cloud regions are also homogeneous.

So we proposed new idea reversing a way of thinking by defining clutters instead of skylines as follows;

- *Many pixels with 0° angle on clutter lines.*
- *Asymmetric ratio between rising and falling pixel angles.*
- *Edge with a short vertical length.*

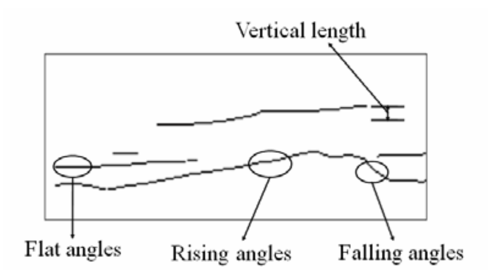

Fig. 2 New definitions

Fig. 3 shows our proposed skyline detection algorithm. As a first step, mountainous input images are transformed in the domain of the canny edge. Candidate lines are selected by eliminating lines with a short horizontal length and then, clutters like skyline are deleted by the proposed MEF algorithm. As the last step, skyline is finally selected using the defined measures among candidate lines. We explain our algorithm specifically in stages as follows.

A. Canny Edge Detection

Mr. Yang made two different canny edge[7] images with a low scale and a high scale. We need only one canny edge image with a low scale. Processing time is surly shorter than that of the conventional method.

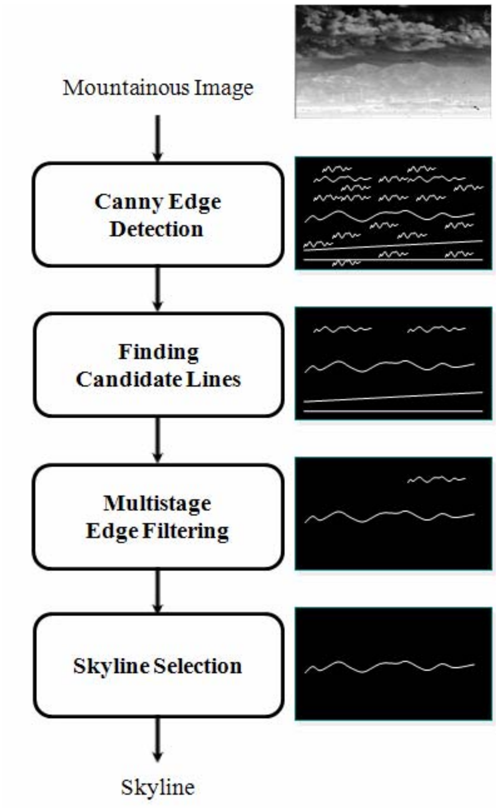

Fig. 3 Proposed algorithm.

B. Finding Candidate Lines

Candidate lines for the skyline are selected in this step in order to shorten the process time. The first thing we have to do is to create a vertical seed line. The skyline is generally extended in the horizontal direction. With this trend, we pick the lines that cross with the vertical seed line and finally select the candidate lines by deleting lines that have shorter horizontal length than the threshold among these picked lines. In this paper, two vertical seed lines are used against the case that the skyline is short. Two vertical lines in Fig. 4(a) are vertical seed ones and candidate lines selected are shown in Fig. 4(b).

The skyline candidates can have separate lines with a small space like a circle area in Fig. 4 because of IR sensor characteristics. We developed the grouping algorithm that can connect these separate lines as shown in Fig. 5. We introduce the term, *Horixel* from the paper[5], which means a pixel on the skyline. L_T means the horizontal tolerance range. We can effectively group these broken lines with this process as far as the length of these lines is shorter than the L_T.

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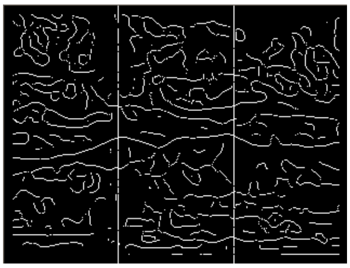
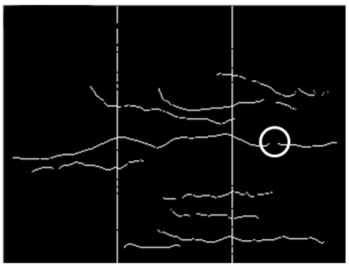


(a)



(b)

Fig. 4 (a) All edge lines and (b) candidate lines.

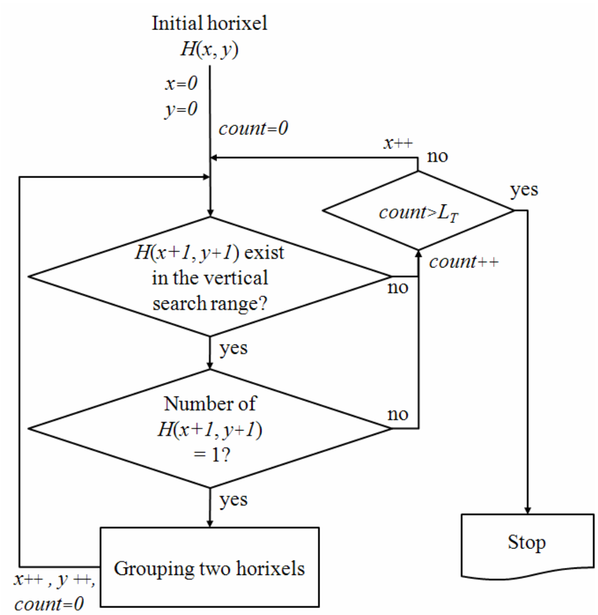


Fig. 5 Flow chart of the grouping process

C. Multistage Edge Filtering

We can delete clutter lines among skyline candidates by a *multistage edge filtering technique* proposed in this paper. We here define three measures of clutter characteristics and then, select and delete those clutter lines by stages. We define three filtering measures of clutter lines as follows.

1) *Measure for the number of 0° angles*

All horixels on a skyline candidate are filtered by the 3×3 sobel operator in order to extract the angle of the horixel.

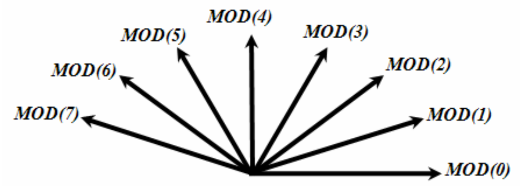


Fig. 6 Angle categories for a horixel.

After processing one horixel, an approximate value among eight directional categories is determined as depicted in Fig. 6. We use definition of *MOD(k)* accounting for those angles, for example, *MOD(0)* is for 0°, *MOD(2)* is for 45°, *MOD(7)* is for 157.5°.

MOD(k) is calculated for all the horixels on a skyline candidate. If *MOD(0)* is dominant than other categories, we can definitely regard this candidate line as a clutter like horizon, sea line, or fields border .

The measure P_a for the number of 0° angles is

$$P_a = \frac{\sum_{k=1}^{7} MOD(k)}{\sum_{k=0}^{7} MOD(k)} \tag{1}$$

And that candidate line is deleted if

$$P_a < TH_a \tag{2}$$

TH_a is the threshold value of the measure for the number of 0° angles.

2) *Measure for the symmetric ratio*

Generally, skyline has rising and falling angles. If this ratio of a candidate line is extremely large or small, it is surely a clutter like horizon, sea line, or fields border with a roll angle.

The measure P_s for the symmetric ratio is

$$P_s = \frac{\min\left[\sum_{k=1,2,3} MOD(k), \sum_{k=4,5,6} MOD(k)\right]}{\max\left[\sum_{k=1,2,3} MOD(k), \sum_{k=4,5,6} MOD(k)\right]} \tag{3}$$

And that candidate line is deleted if

$$P_s < TH_s \quad (4)$$

TH_s is the threshold value of the measure for the symmetric ratio.

3) *Measure for the vertical length*

If the candidate line has a short vertical length, it can be a clutter like clouds or fields with ripple shape, even if the candidate line satisfies 2) and 3) conditions.

The measure P_v for the vertical length is

$$P_v = \max[y] - \min[y] \quad (5)$$

y is the vertical position of the $H(x, y)$ horixels and that candidate line is deleted if

$$P_v < TH_v \quad (6)$$

TH_v is the threshold value of the measure for the vertical length. After filtering edges by stages, candidate lines similar to a skyline remains in the image.

D. True Skyline Selection

At last, the skyline selection measure is applied for the remaining candidates in the image. In this case, the performance of the skyline extraction can be good even if the skyline measure is not perfect, because clutters are deleted through the MEF algorithm in advance.

Three characteristics of the skyline are as follows.

- Measure for the horizontal length M_L is

$$M_L = \frac{Horizontal\ \ length\ \ of\ \ the\ line}{Horizontal\ \ length\ \ of\ \ the\ image} \quad (7)$$

- Measure for the contrast M_C is

$$M_C = \sum_{x=1}^{L-1} \left| H(x, y+1) - H(x, y-1) \right| \quad (8)$$

L is the horizontal length of the horixels $H(x, y)$.

- Measure for the homogeneity M_H is

$$M_H = \sum_{x=1}^{L-1} \left| H(x, y+1) - H(x-1, y+1) \right| + \sum_{x=1}^{L-1} \left| H(x, y-1) - H(x-1, y-1) \right| \quad (9)$$

At last, the skyline selection measure M is

$$M = \frac{M_L \times M_C}{M_H} \quad (8)$$

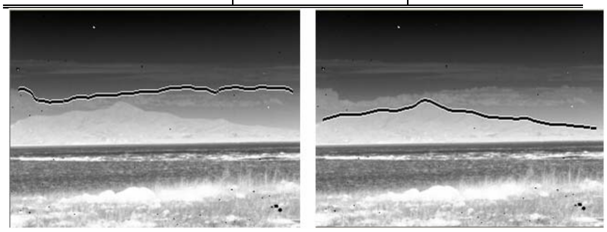
Only one line that has the largest M is finally selected as the true skyline among candidate lines.

IV. Experimental Results

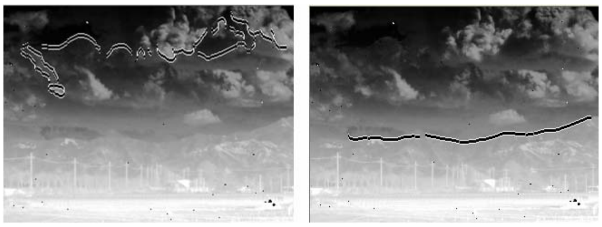
We present experimental results in this section using the algorithm above. We obtained test images with an infrared camera in the field. Total 38 images are used for the experimental results and the result of the proposed algorithm is compared with one of the Yang's algorithm. TABLE I shows the experimental results and some sample images of the results are as shown in Fig. 7.

TABLE I
EXPERIMENTAL RESULTS

Total 38 images	Success / Fail	Success Ratio
Yang's algorithm	13 / 25	34.2 %
Proposed algorithm	32 / 6	84.2 %



(a)



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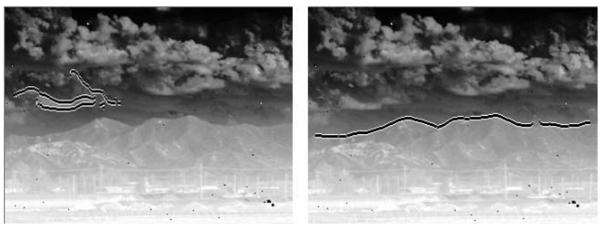
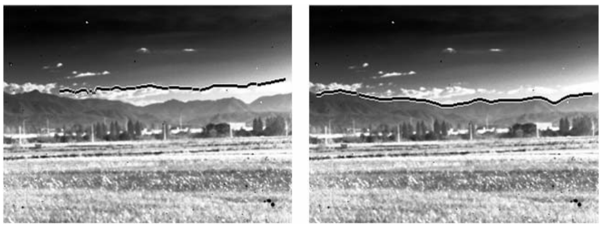
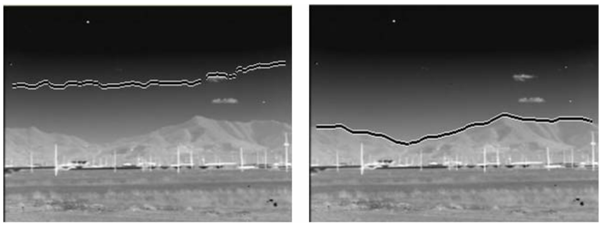


(c)

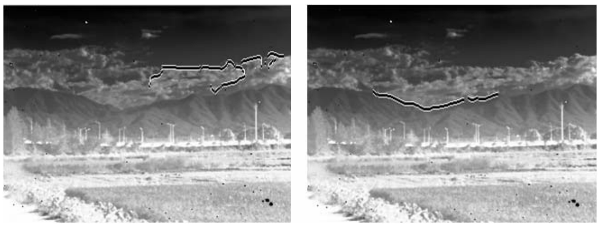
(d)



(e)



(f)



(g)

Fig. 7 Skyline extraction results;
Yang's one (left), Proposed one (right)

V. Conclusion

We have proposed a new algorithm to extract the skyline using a multistage edge filtering technique.

We showed the usefulness of the proposed algorithm compared with the conventional one through simulation with real infrared test images.

This proposed algorithm will be useful for the navigation of vehicles or UAV.

There are some parts which should be enhanced in this algorithm even if it is very useful one. As shown in (g) Fig. 7, the skyline lengths for some images are short due to break parts between lines, which are caused of the characteristics of the infrared sensor. If we use the large horizontal tolerance range L the extracted skyline can be long, but in this case, the extraction performance is a little poor because the length of clutters can be also long and this makes uniqueness of the skyline deteriorate.

For all that this situation, we don't think that this is critical part because we anyway found the seed line of the true skyline.

Moreover, we used some threshold values as like L_T, TH_a, TH_s, TH_v. They need a theoretical basis to be determined even if we determined these values by training for test images in this paper.

These two parts mentioned above can be future works.

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