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Differential Filtration for Mechatronic Tracking System

Karol Dobrovodský and Pavel Andris

Institute of Informatics, Slovak Academy of Sciences, Slovakia
E-mail: {utrrdobr, utrrandr}@savba.sk
URL: www.ui.sav.sk

Abstract. Mechatronic tracking system recognizes potential objects for tracking. At this stage, the system is working in a search mode and recognizes the greatest number of objects that may be subject to tracking. A simple differential filtration is used in this mode. An operator makes the choice from the offered objects and the system starts the track mode. From this moment the tracked object is the only one to be recognized by the visual subsystem. To increase the reliability of the tracking process, online differential filtration with measuring the size and the brightness of the object is introduced.

Keywords. Mechatronics, Tracking, Vision, Image Processing, Differential Filtration

1. Introduction

Recognition of moving objects while recording the moving camera picture in real-time is an extremely complex problem. The camera movement makes impossible to eliminate the background as the existing monitoring systems with static cameras do. It must be noted that multi-level image segmentation of objects flying on the cloudy background accentuates the edges of the clouds, (Ping-Sung Liao et al., 2001), (Arora et al., 2006). Many spurious objects are produced by the subsequent image processing analyzer from these edges. For this reason it is not possible to identify the movements using a simple comparison of the sequence of consecutive images, (Dobrovodský and Andris, 2007). Potential objects of tracking must first be recognized without specifying the identity and then estimate their identity in the context of the previous positions of the detected objects, (Dobrovodský and Andris, 2008). An extensive approach to the recognition of potential objects to be tracked is first necessary because the initial guiding of the camera optical axis in order to track the object is, especially for flying targets, difficult to achieve, (Dobrovodský and Andris, 2009). Moreover, critical is also the transition from extensive to intensive recognition at the start of the tracking process. During tracking the object, the only one object becomes the subject of the recognition coupled with automatic search of the position that is expected in the near future.

2. Goals

The first aim of the paper is to concentrate efforts on pre-processing image information for the purpose of actively tracking the recognized objects.
The benefits will mainly address the following tasks:

- Symmetric differential filtration aimed at detecting critical jumps of brightness level between adjacent pixels of the image
- An efficient algorithm for finding of local extremes of brightness level in the rows and columns based on simple differential filtration
- The identity estimation of the detected moving objects using continuously measured parameters of movement, shape and surface texture of objects
- Continuous monitoring of the object near its expected location without the possibility of eliminating the background changing in a wide range

3. Principle of Operation

The discussed mechatronic monitoring and tracking system for automatic detection, observation and tracking of the moving objects is composed of several relatively independent subsystems. These subsystems operate in real-time with a sample period of 100 milliseconds. Some modules operate independently of the results of other modules, others work together to achieve a common goal to identify potential objects of automatic tracking.

The system works with day and night cameras, which are oriented in space with two degrees of freedom. In the mode of searching operator manually guides the optical axis of camera using the joystick. In this mode the extensive recognition of all potential objects of monitoring is performed. All detected objects are tentatively attributed by default distance. After the transformation of the position coordinates, objects are placed in a common 3D model of the outside world without specifying their identity. For new objects pairing is performed with objects that already exist in the model from previous observations. The pairing is allocating a new object identity, i.e. identification of objects in new positions. During the extensive phase of searching of potential object of tracking, system recognizes the scene in the order of tens of objects. Priority is given to objects around the optical axis of the camera.

The system offers the operator to select from the objects around the optical axis. The track mode starts after an object is selected. At the start of the track mode, extended filtration or intensive phase of pattern recognition begins. The number of objects to be recognized in the scene is reduced to only one.

3.1. Simple Differential Filtration

The search mode of the image processing is devoted primarily to elimination of changing background. This ensures the stability of the recognition process of the moving scene. It should be distinguished between background and objects according to the dark and light alternation without direct comparison of the image with previous images. The images are in fact shifted in time, but also in space, because the cameras are not static. In many cases highlighting the potential object of tracking by simple differential filtration may work successfully. Simple differential filtration of subcritical jumps of background luminance level in particular creates sufficient conditions for a successful recognition of flying objects, especially in clouds. The output of the filtration is further processed by the algorithm of connectivity analysis, which is the product of the previous work.

3.2. Extended Differential Filtration

In some cases in the search mode, but namely in the track mode, the image information processing is focused on further suppress of spurious objects that remain after simple differential filtration. These are the cases of substantially different background alteration between the sky and the earth's surface on the horizon. In such cases, searching local extremes of brightness levels appears to be effective. In comparison with the simple differential filtration, couple of opposite critical jumps of brightness level is searched. Moreover, there is limited distance requirement of these jumps and coincidence of local extremes in rows and columns. Extremal differential filtration (EDF) generally leads to the suppression of clouds.

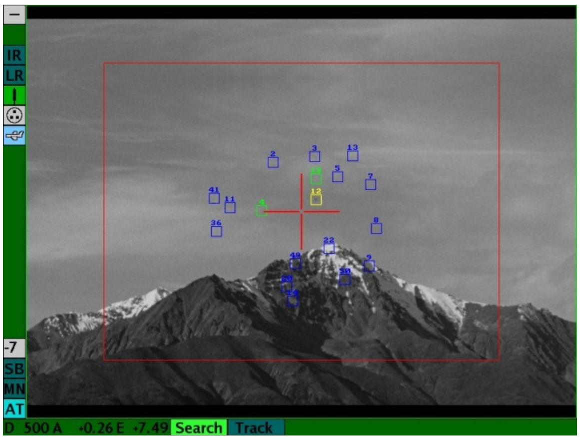

Fig. 1. Unfiltered image in differential mode

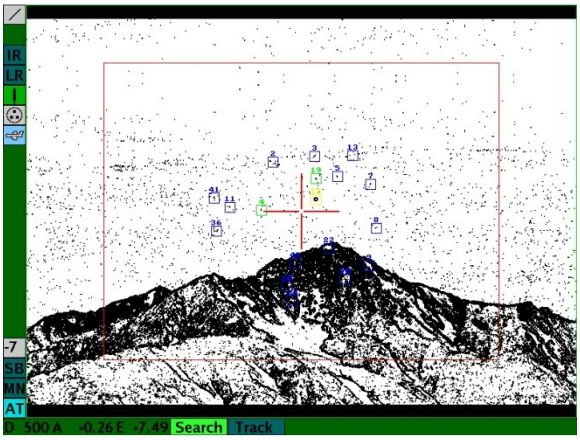

Fig. 2. Filtered image in differential mode

3.3. Intensive Recognition

In some cases in the track mode, namely in complex surroundings, the advanced image processing is needed. The intensive recognition with the single object search is performed. Underlying approach is the search of location of the tracked moving object using continuously measured parameters of movement, shape and surface texture. The object is continuously searched near its expected location without the possibility of elimination of the changing background on a large scale.

4. Extremal Differential Filtration

The simple differential filtration is based on finding critical jumps of brightness level between the adjacent pixels of the processed image. We define critical jump simply as the jump exceeding the selected value. A set of added conditions may extend the definition. We are speaking about an extended differential filtration in such case. Moreover, looking for special combinations of critical jumps may take place. In the case of filtration through a search of local extremes we search for two consecutive critical jumps opposite to each other.

4.1. EDF algorithm

Let us introduce the following terms.

Critical jump	CJ
Critical jump down	CJD
Critical jump up	CJU
Record the Type and Position	RTP
Write To Output	WTO

The principle is that we localize two consecutive CJ opposite each other in rows as well as in columns. We write the section between them into the output as black or white strip of minimum length 1 pixel. This is the case when opposite CJ are closest to each other. The maximum length of the section in pixels may be limited by the maximum size of the object. For example, in rows 40 points and 30 points in columns. Basic background of the output will be medium gray, that is to say 128 from the interval <0,255>.
At the start of line reset of RTP is performed, that is to say is empty. The next RTP overwrites the previous one thus RTP is only one or none.
Overrun the maximum lengths of the section is checked after each move of 1 pixel. The RTP reset is done after reaching a maximum without having appeared opposite CJ. The algorithm is continued as if starting a new line in such case. Once the opposite type of CJ appears before reaching the maximum, WTO is performed according to the order of types: CJD-CJU black strip, CJU-CJD white strip. At the same time, CJ is overwritten by the opposite type of CJ and the algorithm is continued. In case of no opposite CJ, the row or column remain without WTO. Conversely, if they occur alternately CJU and CJD, alternation of black and white sections will occur. In case of the same type of CJ repetition, medium gray appears.

4.2. Row and Column Oriented Output

In order to achieve symmetry in the sense that it will not matter whether you start the row or column, we do separately output from rows and columns. The resulting output will do as a logical product of the two outputs. Finally, we will use information from the operator on whether the object of interest is darker or paler than its immediate surroundings. According to information from the operator, grey background turns white or black by whether the object is dark or pale, respectively.

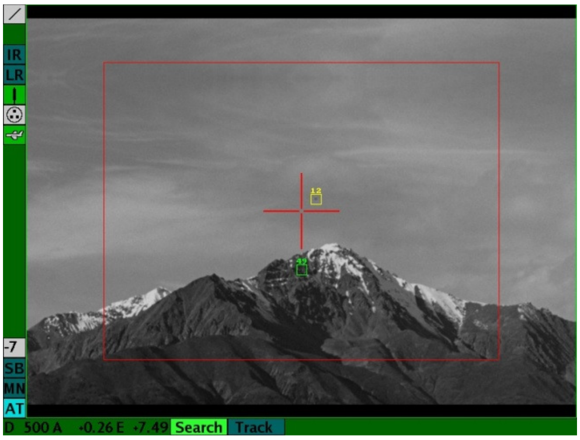

Fig. 3. Unfiltered image in extended differential mode

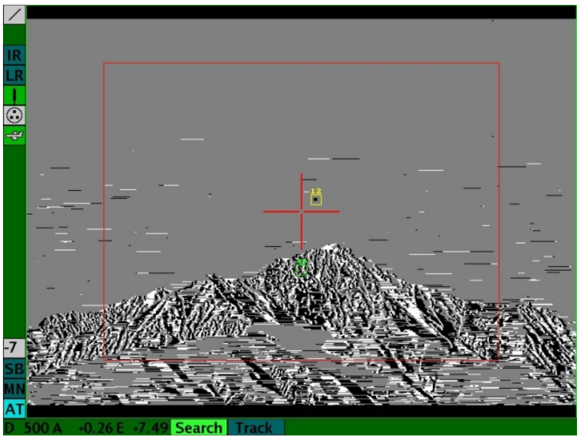

Fig. 4. Row oriented output of EDF

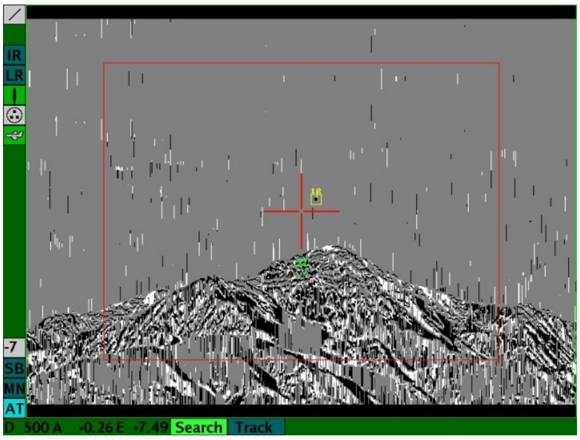

Fig. 5. Column oriented output of EDF

5. Experimental Results

The combination of simple or extended filtration with

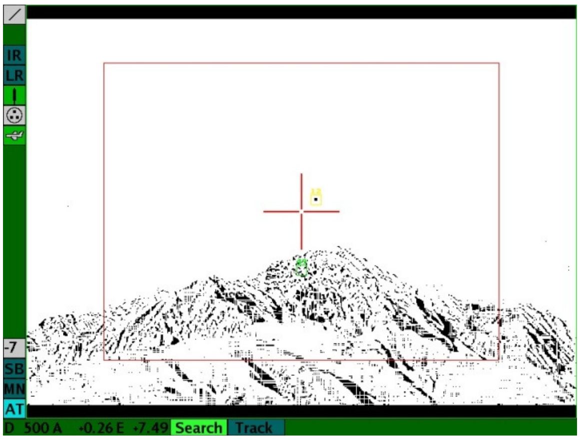

Fig. 6. Filtered image in extended differential mode

extensive or intensive approach to automatic recognition is motivated by the authors' experience gained during the implementation of the automatic fire control system for an anti-aircraft gun, Dobrovodský and Andris, 2009.
In the search mode system works extensively, i.e. recognizes the many objects that could happen in the next phase to become objects of tracking. The operator is selecting the object of tracking from the offer of the extensive working visual subsystem. Object-oriented extremal filtration is applied in order to suppress spurious objects at the beginning of the track mode. In this mode, extremal filtration extended by measuring the size and brightness of the tracked object takes place. The proposed extremal differential filtration offers much more reliable results in comparison with the simple one. Especially in complex situations with a lot of spurious objects.
It should be pointed out, that more sophisticated approach to image processing based on rough unfiltered image is needed in the most difficult circumstances. An intensive approach to recognition process may be introduced when extended filtration does not fulfill stability requirements of the tracking process. In this case a part of the unfiltered image at the selected object along with its immediate surroundings becomes a sample object.
The visual system may operate under the intense recognition when the object of interest is the only one reference object in the scene. In this mode search algorithm for a new position of the tracked object in the relative vicinity of the predicted position is repeatedly performed. It should be noted that a portion of the object pattern is actually the changing environment acting as a disturbing factor of the recognition process.

6. Conclusion

A general concept of the combination of extensive and intensive approach to the recognition process for mechatronic tracking system has been presented. In respect of the previous work activities related with various modes and the detailed geometric analysis of the tracked object, online measuring of the size and the brightness has been proposed.
The realization output is oriented both toward civil and military sector and is based on the real time kit, (Dobrovodský et al., 2006). The system is developed in cooperation with the Slovak producer of the servo systems for control of the camera head orientation in space.

7. Acknowledgments

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