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STUDY OF LOCAL IMAGE FEATURES DETECTORS

Abstract. The article is devoted to the optimization of local image feature detectors. They can be used in mobile augmented reality video information systems. A study was conducted of the effectiveness of using a brightness preliminary detector in conjunction with a Harris angle detector. The simulation results showed a reduction in the duration of detection of local features of the test image (on average 220 times), a reduction in the number of identified image features and a slight change in the threshold value of the angle response.

Keywords: video information system of augmented reality, brightness preliminary detector of special points, local feature of the image, special point of the image.

Introduction

Video information systems supplemented reality (VIS DR) are classified according to the method of obtaining information about the real world. There are marker, markerless systems, as well as systems based on spatial tracking.

Markerless augmented reality systems, as well as systems based on spatial tracking, use two main approaches to determining the position of the observing camera in space. This is method for identifying local features of an image and texture comparison method.

Main part

In augmented reality video information systems using the principle of spatial tracking, the main task is to continuously determine the change in the position of the observing camera in space [1]. To solve this problem, the algorithm shown in Fig. 1 is used.

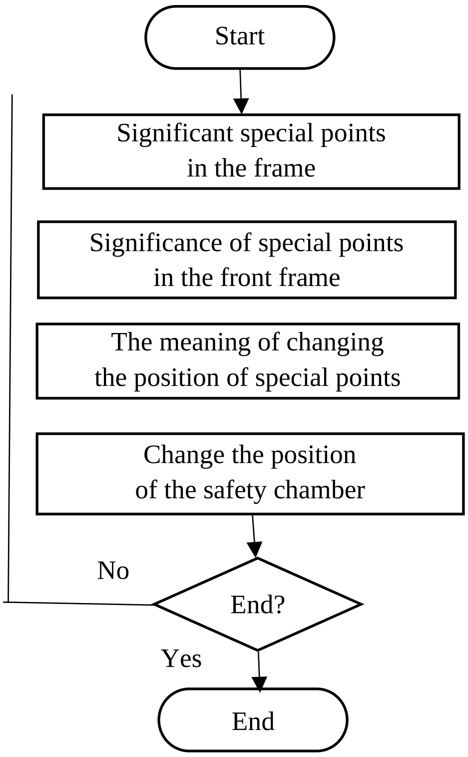

Fig. 1. Block diagram of the main algorithm of VIS DR using spatial tracking technology

In each new frame, local features of the image are determined, which are compared with the features found in the previous frame. Next, the change in the position of the associated special points is determined and, based on this information, the change in the position of the observing camera in space is calculated. To identify special points from the video stream coming from the camera, special algorithms are used - local image feature detectors, which are usually classified according to the type of special points identified. The two most common types of singular points are corners and circles (blobs).

An angle is a special point that is formed from two or more edges; the edges usually define the boundary between different objects or parts of the same object [2]. The main property of angles is that in the vicinity of an angle, two directions dominate the image gradient, which makes them distinguishable. Gradient is a vector quantity showing the direction of the fastest increase in the image intensity function $I(x,y)$. Depending on the number of intersecting faces, there are different types of angles, shown in Fig. 2: L, Y (or T), and X-connected (some also distinguish arrow-shaped connected angles) [2, 3].

Fig. 2. Different types of angles

In mobile video information systems of augmented reality, the most widely used are corner detectors, which have higher efficiency in contrast to blob detectors. Along with efficiency, an important characteristic of a detector is speed. Since augmented reality video information systems are real-time systems, for acceptable quality of the output video stream it is necessary that the frame rate does not fall below a threshold of 25 frames per second, which determines the upper limit of the processing time of one frame of the video stream, namely 40 ms [3]. To increase the speed of corner detectors, it is proposed to use a brightness preliminary detector of special points.

The principle of its operation is to select potential special points from the image and transfer them to the detector for further analysis. Thus, to highlight features, not the entire frame will be analyzed, but only those areas where they can be found. The block diagram of the preliminary detector operation algorithm is shown in Fig. 3.

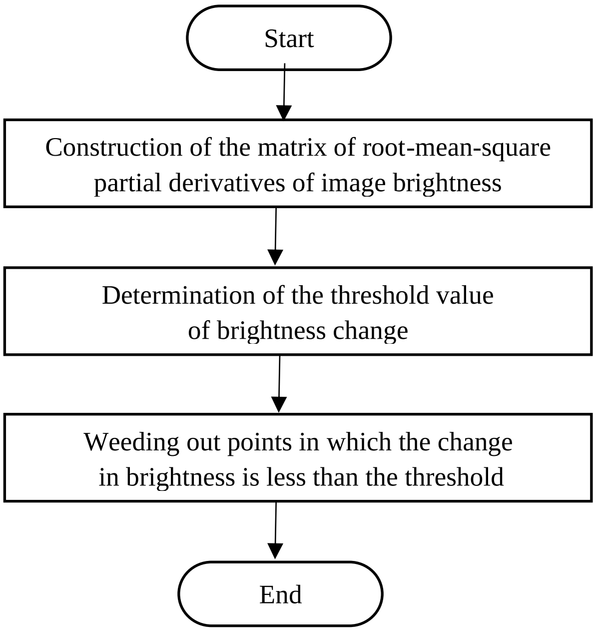

Fig. 3. Block diagram of the main algorithm of the brightness preliminary detector of special points

To determine brightness differences, a matrix of the root-mean-square sum of partial derivatives of brightness in a pixel is constructed

$$S_{x,y} = \sqrt{\left(\frac{dI}{dx}\right)^2 + \left(\frac{dI}{dy}\right)^2}, \qquad (1)$$

where S is the matrix of root-mean-square sums of partial derivatives of image brightness.

After constructing the matrix, the maximum and minimum values of its elements are determined and, on their basis, the threshold value for brightness changes is calculated

$$d = S_{min} + \left(\frac{S_{max} - S_{min}}{k}\right), \qquad (2)$$

where k is an empirical constant, the value of which is usually chosen in the range [1.4 ... 2]; S_{min}, S_{max} are the minimum and maximum values of the matrix element S, respectively.

Potential singular point $I\,(x,y)$ such a point of the image I with coordinates x,y) is considered for which the following condition is satisfied:

$$S\;x\;,\;y \geq d. \qquad (3)$$

Selected potential singular points are transferred for analysis to an image feature detector [4]. Quite a lot of different angle detectors are described in the literature: Moravec detectors, Sh-Tomasi detectors, Harris detector, etc. One of the main disadvantages of many algorithms is their high computational complexity with not the highest accuracy. The most accurate results of detecting singular points are shown by the Harris detector; it is also the most commonly used detector of local image features in real-time systems, so a study was conducted on the use of a preliminary detector in conjunction with the Harris detector. To highlight local features in an image, the Harris detector analyzes each pixel in the image, as well as the pixels in its vicinity. Thus, to identify local features of an image with a size of N pixels in height and M pixels in width (with a neighborhood size of P × Q pixels) using the Harris detector, M × N × P × Q iterations of the algorithm will be required. In the proposed luminance pre-detector, each pixel is analyzed once, so pre-extracting feature points requires M×N iterations of the algorithm. Thus, the use of a brightness preliminary detector makes it possible, with insignificant computational costs, to determine potential special points of the image, which will subsequently be processed by corner detectors that require significant computational costs.

The following metrics are proposed to evaluate the effectiveness of using a pre-detector.

1. Changing the duration of frame processing when using a preliminary detector.

2. Changing the number of found special points in the image.

3. Changing the threshold value of the angle response for a set of points found by the Harris detector both without using a preliminary detector of singular points, and with its use.

The angle response measure is a dimensionless quantity that evaluates the degree of similarity of the neighborhood of a point to an angle [5]. The emulation computing experiment described below was carried out on a computer with a dual-core AMD Athlon II P360 processor with a clock frequency of 2.3 GHz. To determine changes in the duration of frame processing using a preliminary detector, a test application was implemented that measured the duration of frame processing. For each of the presented resolutions of the test image shown in Fig. 4, 1000 measurements of the processing duration were carried out, after which, based on the obtained data, the mathematical expectation of the duration of frame processing was calculated, presented in Table 1 [4, 6].

Fig. 4. Test image

Based on the data from Table 1, a graph was constructed of the dependence of the duration of image processing on the number of image points, shown in Figure 5. The resulting dependence of the duration of highlighting special points on the number of pixels for the selected computer is linear and is approximately described by the formula $t\,(N) = 9 \times 10^{-5}\,N$, where N is the number of pixels.

Table 1 – **Test image processing time**

Test image resolution, pixels	**320x240**	**640x480**	**768x576**	**800x600**	**1024x768**
Mathematical expectation of processing duration without a preliminary detector, ms	1386	5681	7839	8439	14006
Dispersion of processing duration without preliminary detector, ms	102	418	520	589	827
Mathematical expectation of processing duration with preliminary detector, ms	6	24	35	36	70
Dispersion of processing duration with preliminary detector, ms	3	4	5	6	13

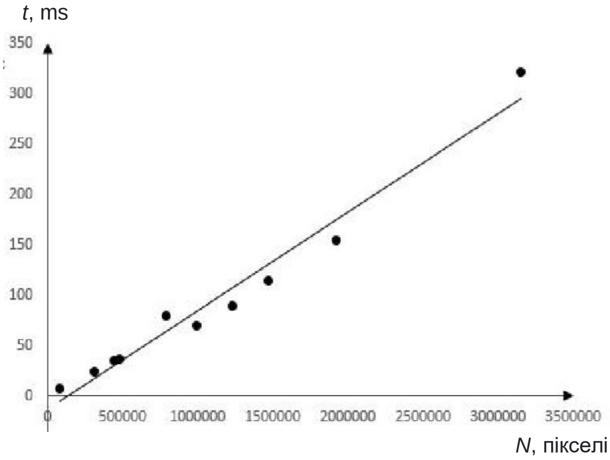

Fig. 5. Dependence of the duration of image processing on the number of points

As follows from Table 1, when detecting local features of a test image with a Harris detector, the use of a brightness preliminary detector made it possible to reduce the detection duration by approximately 220 times. The use of a preliminary detector significantly affects the number of found special points. The Harris detector identifies special points based on the angle response values. The pre-detector uses changes in image brightness.

They are characteristic not only of corners, but also of straight lines, as well as prominent points [7].

Conclusions

During the modeling process, data were obtained indicating that the use of a brightness preliminary detector of local image features significantly reduces the time for identifying local image features. This allows the use of angle detectors in augmented reality video information systems operating in real time. At the same time, when using a preliminary detector, the number of identified local features is significantly reduced. To increase the number of distinguished features, it is possible to use various noise filters at the preliminary detection stage, as well as reduce the threshold brightness value in the preliminary detector using numerical methods. The decrease in the angle response measure in the selected local features is explained by the fact that some local features do not fall into the set of points identified by the preliminary detector, which leads to a change in the threshold value of the angle response.

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Дослідження детекторів локальних особливостей зображення

Д. С. Жовтоніжко, В. П. Зубенко, О.О. Можаєв, А. С. Гук

Анотація. Стаття присвячена оптимізації детекторів локальних особливостей зображення. Вони можуть застосовуватись у мобільних відеоінформаційних системах доповненої реальності. Проведено дослідження ефективності застосування попереднього яскравого детектора спільно з детектором кутів Харріса. Результати моделювання показували скорочення тривалості детектування локальних особливостей тестового зображення (в середньому – у 220 разів), скорочення кількості особливостей зображення, що виділяються, і незначна зміна порогового значення відгуку кута

Ключові слова: відеоінформаційна система доповненої реальності, попередній яскравий детектор особливих точок, локальна особливість зображення, особлива точка зображення.