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COMPARISON OF BRIEF AND ORB BINARY DESCRIPTORS

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***Abstract*—*A great deal of features detectors and descriptors are proposed nowadays for various computer vision applications. The task of image processing which is invariant to all weather conditions (such as rain, fog, smoke, unfavorable lights, camera rotation) is presented. The influence of weather conditions on the number of determined key points in the image is analyzed, and how certain unfavorable conditions influence the tracking of these points from frame to frame. Two binary descriptors are considered for finding special points of the image; BRIEF (Binary robust independent elementary features) and ORB (Oriented FAST and rotated BRIEF) descriptors, as well as their modifications, to explore the most efficient descriptor which can be used in applications that run in real time. The result of the study shows that the descriptors have high stability characteristics, working with different types of images and rotation angles, using the recommendations for the use of their modifications.*

Index Terms—Object recognition; binary descriptors, interest points, key points; descriptors, detectors.

I. INTRODUCTION

Image matching and recognition is of great interest nowadays since the areas of its applications vary from simultaneous localization and mapping to visual correlation extreme navigation, used for unmanned aerial vehicles (UAV). Other problems can be listed as follows: creating panoramas, creating a stereo pair and reconstructing a three-dimensional model of an object, recognition of the objects and searching on a sample from some base, tracking the movement of an object through several images, reconstructing affine transformations of images, etc.

Image matching can be done in several ways, and one of them is matching of keypoints (feature points) which are described in definite form, called *descriptors*. This has driven several recent works which present binary feature detectors and descriptors, promising both increased performance as well as compact representation. Such advantages are specifically important for usage in real-time mode aboard UAV. Therefore, comparison of binary descriptors is required. The efficiency is tested within the frame of the project on real-time with the aim of object detection

II. REVIEW OF EXISTING METHODS

First of all, it is necessary to mention that descriptor is the method to encode information about an image patch around a detected key point. Several popular descriptors, such as SIFT and SURF [1], [2], Binary Robust Independent Elementary Features (BRIEF) [3], and Oriented FAST and Rotated BRIEF (ORB) [4] have been devised for different purposes. So, it is possible to obtain meaningful comparison results using the performance criteria defined.

Binary pattern based descriptors have become popular thanks to their computational complexity. That is why they are suited for the real-time application or to smartphone usage. Currently, most of all binary descriptors rely on hand-crafted, heuristic structures. The search for key points is reduced to the task of sequential comparing all video frames of the original sequence.

Searching methods for determining frames differ in the mechanisms of video stream segmentation and in the similarity calculation metrics between video frames. The search for key points and their matching from frame to frame, in turn, is based on the formalization of the description of a video frame: finding image descriptors and comparing them among themselves in a given metric.

The purpose of this work is to compare two descriptors and to identify the better descriptor of key points for segmentation of different video and photo data, for which an analysis of frequently used algorithms was performed.

III. PROBLEM STATEMENT

General for all binary descriptors, they describe images patches using only a string of bits. The principle of binary descriptors is to compare 2 pixels leading to a Boolean response. All comparisons are made (locally) around the key point.

One of the binary descriptors advantages is ability to use Hamming distance (bitwise XOR followed by a bit count) it can replace the usual Euclidean distance. The descriptor vector is obtained by comparing the intensity of 512 pixel pairs after applying a Gaussian smoothing (with the aim to reduce the noise sensitivity). The positions of the pixels are pre-selected randomly according to a Gaussian distribution around the patch center.

Oriented Fast and Rotated Brief is an efficient replacement to SIFT descriptor, cause they have almost similar matching abilities, is less affected by image noise, and is capable of being used for real-time performance [5]. It performs better than gradient-base descriptors, such as SURF and SIFT, being almost 2 orders magnitude faster. Also, binary descriptors have no licensing restrictions, and can be freely used for all range of tasks. Unlike, SIFT and SURF, they couldn't be used in OpenCV library for programs on python etc., they available only for researching tasks.

The ORB uses the FAST algorithm for point detection [9] (the radius of the circle can be different), 9 pixels turned to be the most efficient in terms of performance. After identifying potential key points, the Harris Corner Detector should be used to refine them. To get n key points, let us use a low threshold to get more n-points, then they are ordered using the Harris metric and the first n-points are selected. To construct the descriptor of the obtained key points, BRIEF is used.

The ORB method has the best speed in calculating the singular points and calculating their descriptors, which allows using it in tasks where real-time image processing is necessary. One of these tasks is tracking a moving object. But the high speed of work affects the accuracy of matching the descriptors is not for the better [7]. The presence of digital noise or blurring of images further impairs the result of their comparison [8].

ORB should be invariant to rotation and limited affine changes, is designed to be robust to noise by taking into account the orientation of the key point.

BRIEF is the fast heuristic descriptor is constructed from 256 binary comparisons between the pixel brightness in the blurred image [6].

The BRIEF algorithm relies on a relatively small number of intensity difference tests to represent an image patch as a binary string. More specifically, a binary descriptor for a patch of pixels of size S×S is built by concatenating the results of the following test

$$\tau = \begin{cases} 1, \text{ if } & I(P_j) > I(P_i), \\ 0, & \text{otherwise,} \end{cases}$$

where $I(P_i)$ denotes the (smoothed) pixel intensity value at p_i, and the selection of the location of all the p_i uniquely defines a set of binary tests. The sampling points are drawn from a zero-mean isotropic Gaussian distribution with variance equal to $(1/25)S^2$. For increasing the robustness of the descriptor, the patch of pixels is pre-smoothed with a Gaussian kernel with variance equal to 2 and size equal to 9×9 pixels. The BRIEF descriptor has two setting parameters: the number of binary pixel pairs and the binary threshold.

The problem statement is formulated as follows. It is necessary to evaluate performance of given descriptors (BRIEF and ORB) using standard accepted metrics: recall, repeatability, and precision:

$$\text{Recall} = \frac{\text{Correct Matches}}{\text{Correspondences}},$$

$$\text{Repeatability} = \frac{\text{Correct Matches}}{\text{Features}},$$

$$\text{Precision} = \frac{\text{Correct Matches}}{\text{Putative Matches}}.$$

IV. Experimental Results

Let us investigate the sensitivity of BRIEF, and ORB descriptors against each good and bad weather conditions, day and night time, rotation of the camera, object rotation, scaling (view from different altitudes), distortions, and noise such as rain and fog.

For the descriptors comparing, different videos taken from the UAV board are selected. Each video is split into the frames, so there will be a plenty of datasets. But only some of them are showen.

1st dataset – bird view taken under the good weather conditions (day), this dataset consist from frames, which were taken on the different altitudes, conditionally they are called: low, medium, high.

2nd dataset – video frames filmed at night with good weather conditions, also taken from two different altitudes: low, high.

3rd, 4th, 5th, 6th, datasets – frames which were taken under the rain, fog, smoke, unwanted lights; respectively. All the conditions are verified for day and night.

Let us test ORB and BRIEF algorithms using Python 3.0 package and the set of images with different regions from UAV (unmanned aerial vehicle).

So, having a video stream and taking several sequent frames, one of them will be assumed the sample, the other – the scene.

Research was done using Python 3.0 package using OpenCV on images with size 1024×540 and 1280×720 pixels.

For example in 1st dataset it is known that the right number of keypoint detected on image should be within the limits (280 to 300). ORB finds in every sequential frame 300 keypoints, but not all of them are right, the maximum number of matches for ORB is 175.

BRIEF results are worst, average value of keypoints equal 246 for all dataset, 297 is single results out. The min number of keypoints is 162. BRIEF also makes more mistakes in matching. Matching results for two different datasets are shown in Fig. 1 and Fig. 2 with the frames changes ORB makes more constant output, unlike the BRIEF, with each new image it receives fewer matches.

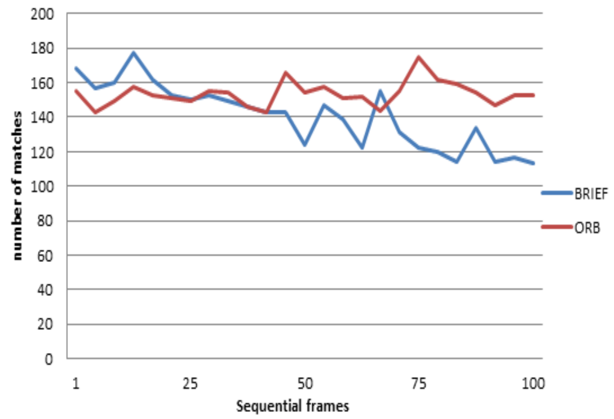

Fig. 1. Numbers of matches obtained by ORB and BRIEF for 1 dataset

A. Rotation.

It can be clearly seen that ORB descriptor needs information about the angle on rotation to keep their rotation invariant. Thus, when computing these descriptors, one must always provide orientation information to ensure a correct description. This brought one issue: how to estimate a good orientation angle (Table I).

TABLE I. MATCHING RATE VERSUS THE UAV CAMERA ROTATION

Conditions	ORB	BRIEF
Rain	36.5%	15.5%
Fog	45%	33.33%
Smoke	49%	24.79%
Lights	57.2%	33.33%
Night	49.4%	25.45%
Day	61%	21.12%

BRIEF is the worst invariant descriptor, allowing no correct match for angles between 50º and 300º. Detector ORB always present the best matching rate, while for other angles of rotations such as 45, 135, and 225, BRIEF presents the highest matching rate (Table II).

TABLE II. MATCHING RATE VERSUS THE ROTATION ANGLE

	0º	45º	90º	135º	180º	225º	270º
ORB	100	46	97	46	100	46	97
BRIEF	99	51	99	52	96	51	95

The concrete example of descriptors work is shown in Fig. 2, statistics for the BRIEF and ORB work is shown in Fig 3.

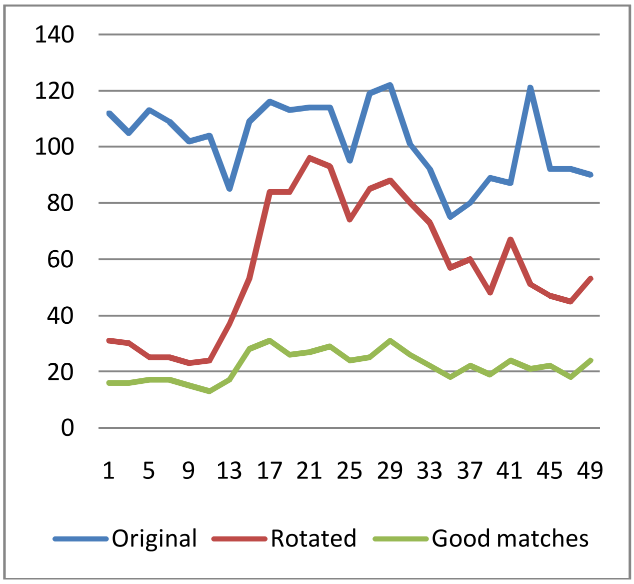

Fig. 2. BRIEF detector work with rotation for database

Blue line are keypoints in original image. Red line is number of detected keypoints on rotated image. Green line is number of matches.

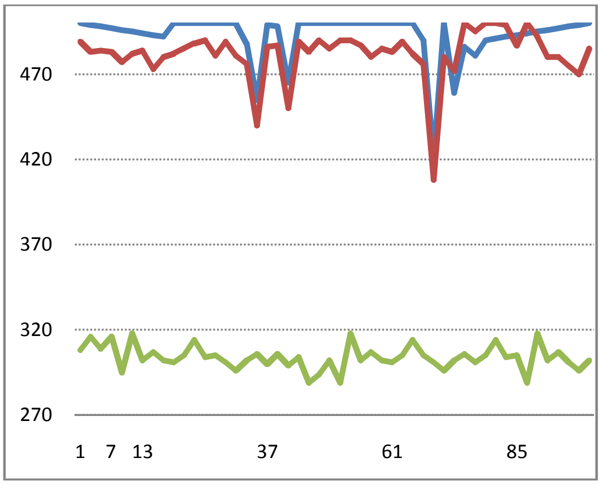

Fig. 3. ORB detector work with rotation for database

In the case of images with unwanted circumstances, noise is added to the original image to see the effect of noise on the matching rate.

To investigate BRIEF and ORB, let us get 4 videos taken from UAV, with such conditions.

Investigating different datasets, it is concluded that ORB is more stable for light changes on images. Concluding the results it is possible to say that fast changes in the scene worsen the work of algorithm. Such changes are present in light changeable dataset. Night photo critically react on light, especially if taking cars with headlight on, and condition when the UAV flies over the street lights.

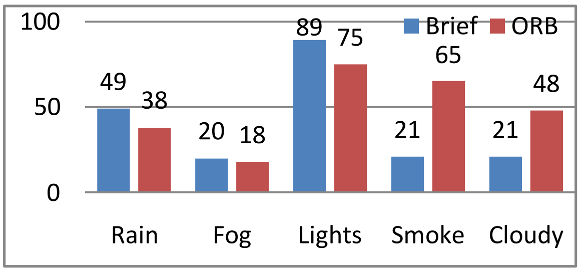

Fig. 4. Rates of good matches for each descriptor under the different circumstances

B. Time.

Let us compare the computational and storage time. Table III represents means values of all image processing stages. Time is measured using all images for different datasets. ORB relatively faster than BRIEF, theirs speeds are delicately optimized in the OpenCV3 and sky image implementation.

All of the images were obtained by comparing descriptors using the full brute force method. The distribution of common key points in the image varies slightly, and, consequently, the results differ to a small extent. Figures 5–7 show detected key points on our images, using above mentioned descriptors. It is necessary to mention, ORB descriptor can find any number of key points, it depends on the number that programmer will set, in the considered case; it was searching for 200 and 1000 and changed the number of key points till 8000 to check the resultativity (Table IV).

TABLE III MEAN VALUE FOR ALL IMAGE PAIRS

	FD&DT, 10^{-4}(s)		**FMT, 10^{-4} (s)**	**OR, 10^{-4} (s)**	**Total IMT, 10^{-4} (s)**
ORB	1119	1171	53813	92	**56400**
ORB200	385	427	10530	68	**11410**
ORB1000	129	133	113	51	**426**
BRIEF	1097	1253	9319	66	**11735**
BRIEF30	251	248	155	40	**694**
BRIEF60	200	206	149	54	**609**

FD&DT – feature detection & description time; **FMT –** feature matching time; **OR –** outlier rejection time; **Total IMT –** total image matching time.

TABLE IV. RECOMMENDATIONS OF DESCRIPTORS USAGE

Condition	**Recommended descriptor**				
	Low	***Medium***	***High***	***Camera rotation***	***Image rotation***
Day with good weather	BRIEF	BRIEF30	BRIEF60	BRIEF60	BRIEF60
Rainy day	ORB200	ORB	ORB	ORB	ORB
Morning with fog	BRIEF30	BRIEF60	BRIEF60	BRIEF60	BRIEF10
Day + smoke	ORB50	ORB50	ORB50	ORB	ORB200
Night + good weather	ORB1000	BRIEF10	BRIEF10	BRIEF10	ORB500
Rainy night	ORB	ORB200	ORB200	ORB50	ORB50
Night +fog	BRIEF60	BRIEF60	BRIEF60	BRIEF60	ORB200
Night + unwanted light	BRIEF30	BRIEF30	BRIEF60	BRIEF60	ORB
Night + smoke	BRIEF30	BRIEF5	BRIEF5	BRIEF5	ORB

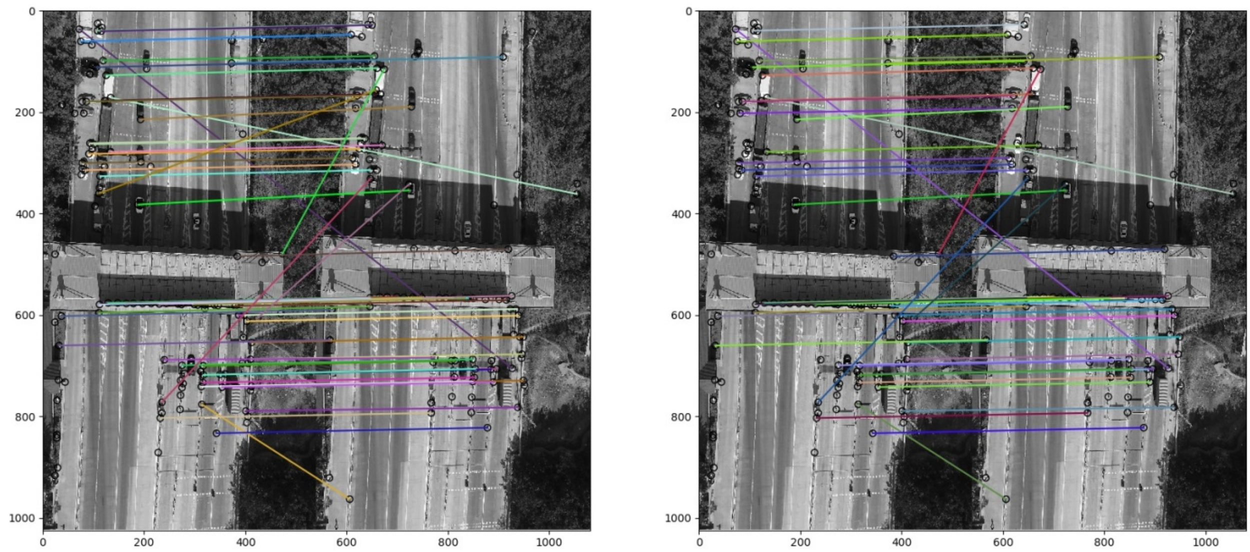

Fig. 5. Example of key point detectingand matching descriptors using ORB (dataset 1)

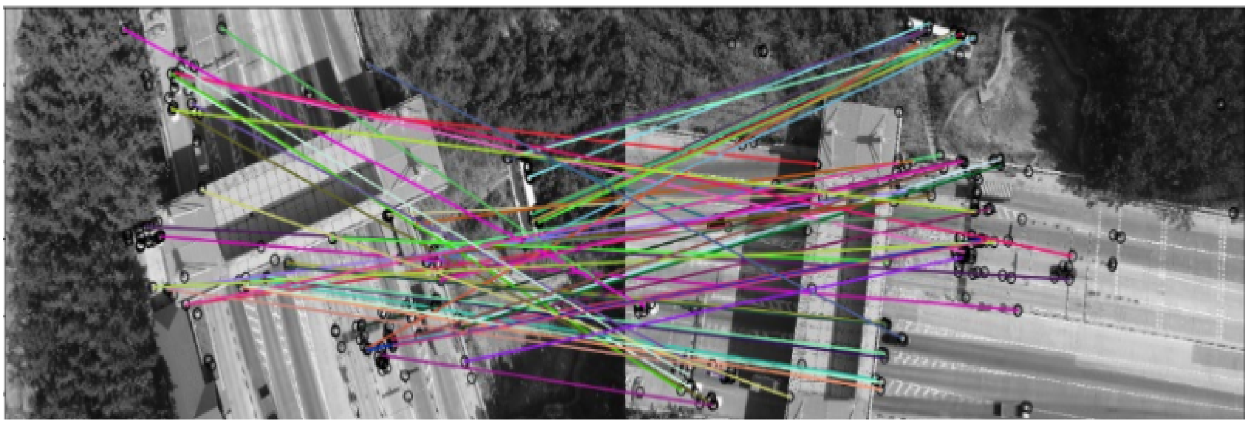

Fig. 6. Detected features using ORB(dataset 3)

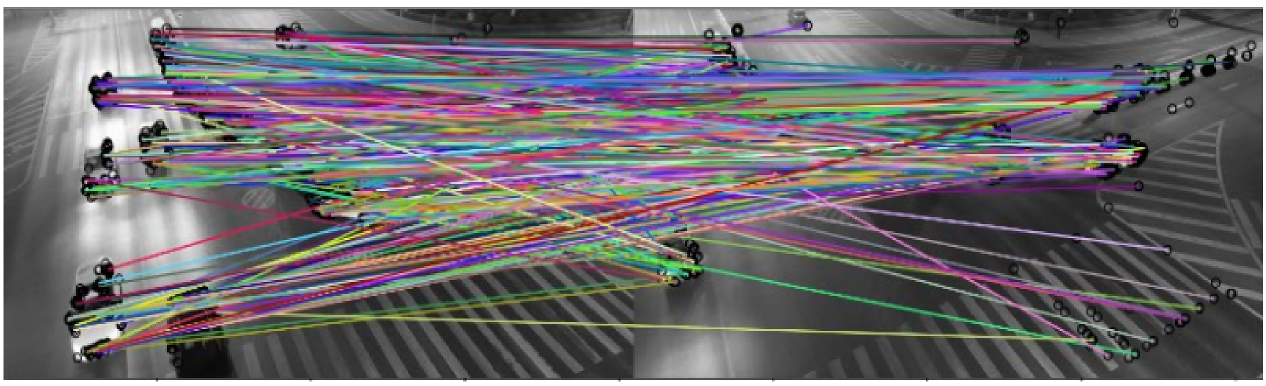

Fig. 7. Detected features using ORB(dataset 6)

V. CONCLUSIONS

The main existing methods for finding key points on the image and building their descriptors are considered in the classic Computer Vision problem of detecting, describing and detecting image keypoints for cases without a priori knowledge on the scene and camera poses. In contrast to well-known gradient-based SIFT and SURF descriptors with proven high performance the faster ones are considered, such as binary alternative BRIEF and ORB.

Nevertheless, each descriptor has a range of efficiency. The matching rate decreases outside the interval. Computation time responds as expected:

gradient based descriptors are slower than binary ones it is a fact. Also BRIEF detector is faster but ORB is more precise.

Difference between this two descriptors lies in ORB' invariance to the rotation, because of compensation mechanism. BRIEF uses randomly chosen sampling pairs, while ORB learn the optimal ones.

The unique properties of binary descriptors can be useful for a wide spectrum of applications, in particular for tasks with hard real-time constraints or limited computation power: they finally offer the quality of high-end features in such time-demanding applications.

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М. П. Мухіна, Ю. В. Трач, А. П. Примак. Порівняння градієнтних і бінарних дескрипторів у задачі виявлення ключових точок

В даний час пропонується безліч функцій детекторів і дескрипторів для різних додатків комп'ютерного зору. Представлене завдання обробки зображень, яка не залежить від погодних умов (таких як дощ, туман, дим, несприятливі джерела світла, обертання камери). Аналізується вплив погодних умов на кількість певних ключових точок на зображенні і з'ясовується, як певні несприятливі умови впливають на відстеження цих точок від кадру до кадру. Два бінарних дескриптора розглядаються для знаходження особливих точок зображення; дескриптори BRIEF (бінарні робастні незалежні елементарні функції) і ORB (Oriented FAST і повернені BRIEF), а також їх модифікації, щоб вивчити найбільш ефективний дескриптор, який можна використовувати в додатках, що працюють в режимі реального часу. Результат дослідження показує, що дескриптори мають високі характеристики стабільності, працюють з різними типами зображень і кутами повороту, використовуючи рекомендації щодо застосування їх модифікацій.

Ключові слова: розпізнавання об'єктів; двійкові дескриптори; відсоткові точки; ключові точки; відстеження.

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М. П. Мухина, Ю. В. Трач. А. П. Примак. Сравнение градиентных и бинарных дескрипторов для задачи обнаружения ключевых точек

В настоящее время предлагается множество функций детекторов и дескрипторов для различных приложений компьютерного зрения. Представлена задача обработки изображений, которая не зависит от погодных условий (таких как дождь, туман, дым, неблагоприятные источники света, вращение камеры). Анализируется влияние погодных условий на количество определенных ключевых точек на изображении и выясняется, как определенные неблагоприятные условия влияют на отслеживание этих точек от кадра к кадру. Два бинарных дескриптора рассматриваются для нахождения особых точек изображения; дескрипторы BRIEF (бинарные робастные независимые элементарные функции) и ORB (Oriented FAST и повернутые BRIEF), а также их модификации, чтобы изучить наиболее эффективный дескриптор, который можно использовать в приложениях, работающих в режиме реального времени. Результат исследования показывает, что дескрипторы обладают высокими характеристиками стабильности, работают с разными типами изображений и углами поворота, используя рекомендации по применению их модификаций.

Ключевые слова: распознавание объектов; двоичные дескрипторы; процентные точки; ключевые точки; отслеживание.

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