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USE OF THE SIFT ALGORITHM FOR AUTOMATIC TATTOO RECOGNITION

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ABSTRACT

This work presents a system of recognition of tattoo images automatically in a database, which can be used to help in the correct identification of criminals who have this type of body mark, its meaning and the possible identification of criminal factions to which they belong. The technique of parameter extraction and image recognition is based on the Scale Invariant Feature Transform (SIFT) algorithm. This work describes the experimental protocols and test cases that must be followed and that will allow the comparison of consistent performance of tattoo recognition methods.

Keywords: SIFT. Tattoos. Automatic recognition.

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Revista ARACÊ
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INTRODUCTION

Tattoos can be a very useful tool for identifying people in criminal applications, and are even used to identify victims or suspects using false identities. Its use has been more widespread today, when other types of biological identification, such as fingerprints, are not available.

For use in criminal identification, its use makes it possible to obtain discriminatory information such as criminal group, religion, criminal record and others.

While a tattoo alone may not be enough to differentiate between two individuals, it can help narrow the identity of suspects or victims in investigations. A tattoo is an option and a biometric trait that may contain more discriminative characteristics and features for person identification than traditional soft biometrics, such as age, gender, race, height, and weight (Beauthier, 2011).

Additionally, tattoos can provide valuable information about an individual's affiliations or expressed beliefs and can support the verification of an individual's identity.

In development since 2014, in a joint work with the National Institute of Standards and Technology (NIST), the FBI uses a technology, called just "Tatt-C", capable not only of recognizing tattoos, but also of identifying their meaning and thus discovering a suspect's personal, political, social and even religious inclinations.

Although some research has been done in the area of image-based tattoo recognition (Jain, Lee, and Jin, 2007; Acton and Rossi, 2008; Allen, Zhao and Yuan, 2011; Manger, 2012; Heflin, Scheirer and Boult, 2012; Duangphasuk and Kurutach, 2013), this type of study is not yet a consolidated product in the industry and deserves a more detailed study for the development of systems for next-generation government applications.

The operational nature of the problem proposed in this work imposes challenges on traditional image retrieval methodologies, given the great variation in the environment and in the capture process and in the content and quality of tattoos. Examples of such challenges are:

- Variation of illumination and scale of the image;
- Partial occlusions of clothing and noisy background images;
- Variations around tattoos;
- Merged images or multiple tattoos into a single image;
- Inconsistent image orientation (rotation and shear);
- Extremely faded tattoos;

Revista ARACÊ
ISSN: 2358-2472

- Ambiguous or unknown abstractions.

Tattoo recognition techniques, for criminal identification use, are based on photographs and brief descriptions, such as the ANSI/NIST-ITL system, I-2007 (2016). In this system, a search for tattoos is done manually, through keywords inserted in the context of each tattoo. This system tends to be quite rudimentary and slow in searching for and identifying tattoos, as it relies on an exhaustive manual search. Automatic recognition systems can be implemented in order to facilitate this work.

Jain (2007) proposed an image recognition system, based on the extraction of visual characteristics such as color, texture and shape for image identification, which was improved in Jain (2008) with the use of techniques of invariance of image characteristics.

As the number of people who use tattoos is currently quite significant, especially among criminals, a system to determine tattoos quickly and efficiently becomes very promising for society.

The idea is that the proposed system can identify in criminal scenes, through images from security cameras, possible tattoos on people who can carry their identification. In addition to identifying religious, political, personal and social inclinations, in tattoos of criminals, which means that the method developed will not serve as a simple database.

THEORETICAL REFERENCE

DATABASE

First, a database was built to test the proposed system. The use of social media sites as the collection data medium was utilized to test the system, in addition, the information gathered on social networks is frequently used to identify an individual. This is one of the products of this work, that is, the creation of a database available for testing, since no public database was found for testing. Although provided for by law in Brazil by Law 12.037/09, the only news of the creation of a database found was from the Phoenix System of the São Paulo Public Security Secretariat (Grosso, 2021).

The tattoo bank aims to keep the tattoos of criminals who would have photos taken of their tattoos in their first stint with the police. In this way, in the investigation of a crime, when it was possible to identify a tattoo on the criminal, through a surveillance camera, for example. This image would be used in the search for a repeat offender at the bank.

Revista ARACÊ
ISSN: 2358-2472

Therefore, these two images would have, for the most part, large differences in lighting, scale and especially angle of view.

According to Lordelo (2018), tattoos, in addition to pointing out personality traits, can have various information, such as:

- What crime is it used to commit
- Degree of danger
- If you've ever been in jail
- Which criminal faction does it belong to
- Demonstration of power or hierarchy

Thus, a database of tattoos was built, initially containing 2500 images, focusing on types of tattoos listed in Lordelo (2018), which defines the tattoos used in the world of crime.

The database (containing 2500 images), which is one of the products from this work, is available on GitLab, at: https://gitlab.com/tattoo-uerj/reconhecimento-de-tatuagens/-/tree/main.

SIFT ALGORITHM

The characteristics of the images were obtained using the *Scale Invariant Feature Transform* (SIFT) algorithm that extracts key points, called *keypoints,* from the image under analysis and generates descriptors about these points that describe the texture around them. These key points are invariant to the scale and rotation of the image and sufficiently robust in terms of distortions, angle of view and noise. The work proposed by Jain (2008) uses the same algorithm for trait extraction, obtaining excellent results.

The SIFT algorithm corresponds to a technique that allows extracting the distinctive characteristics of images, and is widely used for the recognition and classification of objects in different points of view. In this case, we found that the extracted characteristics are invariant in relation to the scale and orientation of the image.

The process of extracting characteristics goes through four phases. The first corresponds to the phase where the locations of possible points of interest invariant to scale and orientation are detected. It consists of detecting extremes (maxima and minimum) in a pyramid of the image convoluted with the Gaussian Difference (DoG) function. Key points correspond to these extremes for different scales.

Revista ARACÊ
ISSN: 2358-2472

A Gaussian low pass filter is given by the convolution of an image *I* with the function *G*:

$$L(x,\ y,\sigma) = G(x,\ y,\sigma) * I(x,\ y) \qquad (1)$$

Where:

$$G(x,y,\sigma) = \frac{1}{2\pi\sigma^2} e^{-(x^2+y^2)/2\sigma^2} \qquad (2)$$

The DoG function is given by the difference of images filtered at close scales separated by a constant *k.* The result of convoluting an image with the DoG filter is given by:

$$D(x,y,\sigma) = (G(x,y,k\sigma) - G(x,y,\sigma)) * I(x,y) = L(x,y,k\sigma) - L(x,y,\sigma) \qquad (3)$$

That is, it is the difference between images blurred by a Gaussian filter at scales σ and *kσ*. This filter can detect variations in intensity in the image, such as contours. By varying the σ, it is possible to find descriptors for variations at different spatial scales. Lowe (2004) considers that it is necessary to convolute the image up to 2σ in order to be able to construct invariable descriptors at scale. The DoG set and smoothed images are given the name octave.

In this study, the standard parameters described by Lowe in the use of the SIFT were used, such as the number of octaves and intervals.

In the second phase, previously detected candidate points are examined in greater detail and filtered. In this case, the information from the neighbors is analyzed in more detail and a model is adjusted in order to correctly determine the location and scale. With this information, points with low contrast and that are thus sensitive to noise are discarded.

In the next phase, an orientation is defined for each key point. In this case, all the properties of the key point are measured in relation to its orientation, thus making it possible for them to be invariant with respect to rotation.

The last step is to calculate a descriptor associated with each of the key points. This descriptor corresponds to a fixed-size vector that is normalized in order to be invariant with

Revista ARACÊ
ISSN: 2358-2472

respect to lighting changes, Figure 1 shows an image and its key points extracted by the use of SIFT.

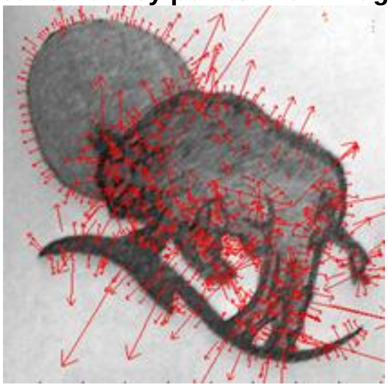
Thus, based on the descriptors extracted, it is possible to perform the correspondence between two images.

The process of comparing two images becomes a comparison of key points based on their descriptors.

The best candidate for each key point is found by identifying its nearest neighbor in the reference image, stored in the database, which contains all the key points of each image to be compared. The nearest neighbors are defined as the key points, with minimum Euclidean distance from the given descriptor vector. The probability that a match is correct can be determined by using the ratio of distance from the nearest neighbor to the distance from the second nearest neighbor.

In the proposed system, all matches in which the distance ratio is greater than 0.8 will be rejected, which according to Lowe (2004) eliminates 90% of false matches while discarding less than 5% of correct results.

Figure 1 – Location of key points in an image using SIFT.



Source: The authors, (2021).

The metric used for comparison between the images is based on the number of matches between the key points of the two images under analysis, as seen in Figure 2.

Revista ARACÊ
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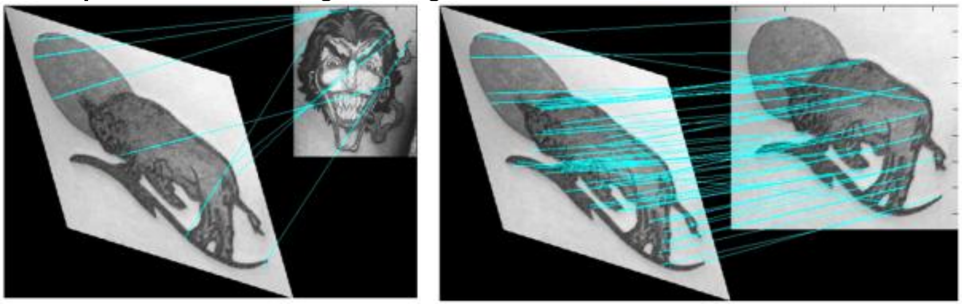
Figure 2 – comparison of two images using the number of matches between their key points.



8 matches **50 matches**

Source: The authors, (2021).

In the comparison between two images, multiple correspondences between different key points may occur, which possibly lead to errors in the correct search for the image, due to the generation of a high number of false matches in different images, this can be especially noticed in very distorted images with few key points. In this project, the original SIFT algorithm was modified in order to eliminate these multiple correspondences, thus increasing the effectiveness of the proposed system.

In the comparison between two images, multiple correspondences between different key points may occur, which possibly lead to errors in the correct search for the image, due to the generation of a high number of false matches in different images, this can be especially noticed in very distorted images with few key points.

By eliminating these multiple correspondences, one can improve the correct choice of image.

As can be seen in Figure 3(a), which presents an image where eleven matches occur, one of which is duplicate, and in the image presented in Figure 3(b) there are twelve matches and six duplicates, the image to be chosen as correct would be (b) - greater number of matches, but with the elimination of duplicate matches it is possible to select the correct image.

Revista ARACÊ
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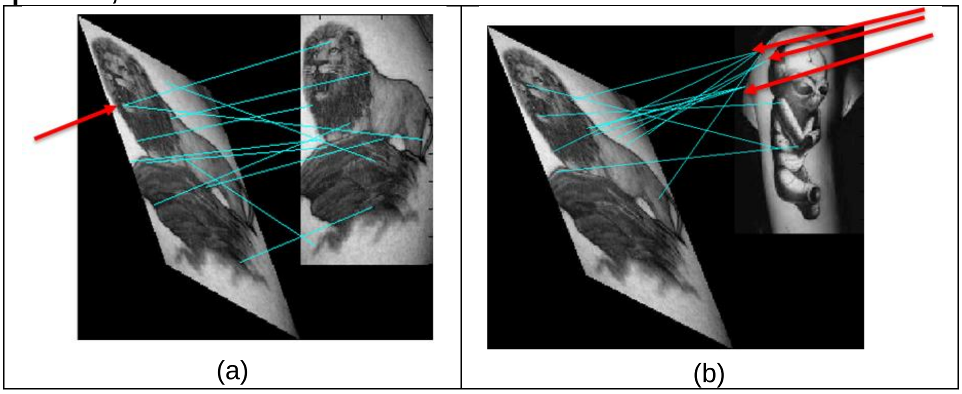
Figure 3 – Elimination of multiple correspondences. In (a) 11 matches, 1 duplicate, total = 10, in (b) 12 matches, 6 duplicates, total = 6.



Source: The authors, (2021).

METHODOLOGY

The characterization of tattoos is almost unique, because even if two people have the same tattoo, the uniqueness of each one is practically guaranteed, as they are handmade.

The proposed system is robust enough to disregard small variations in the searched image, providing in its response a list of similar tattoos, in descending order, found in its database, see Figure 4, with the final decision, regarding similarity, made by the human element.

Figure 4 – Expected result of the proposed system.

Source: The authors (2021).

The proposed system for automatic tattoo recognition can be seen in Figure 5, where two distinct phases in the creation process are identified:

- Archiving: when the image feature database is created;
- Analysis: retrieves the image in the database that is most similar to the one you are looking for.

In the two phases of the system, characteristics inherent to the images are extracted for storage and comparison.

Revista ARACÊ
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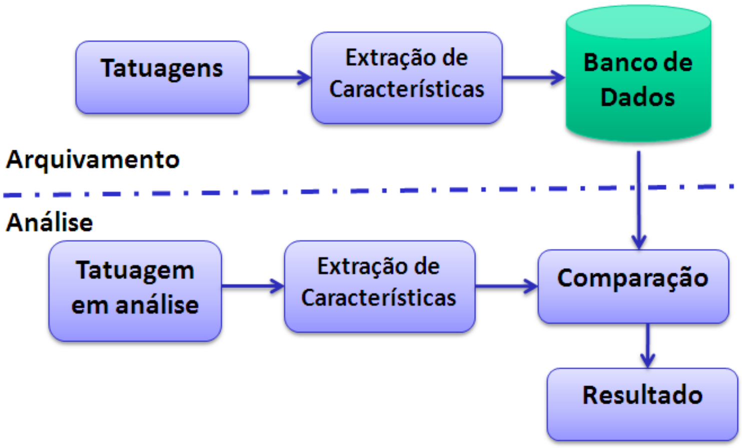
In the process of image analysis, the image in focus may generally present several differences, during its photographic capture process, in relation to lighting, noise and position, and the proposed system should obtain a recognition that is robust enough to these various variations in the images under analysis. To achieve this goal, the method of extracting characteristics from the images used must be robust enough to provide good accuracy.

In addition, additional information (metadata) such as tattoo type, owner, criminal faction, meaning, and many others can be added.

The characteristics of the images will be obtained using the SIFT algorithm, which extracts key points, called keypoints, from the image under analysis and generates descriptors on these points that describe the texture around them. These key points are invariant to the scale and rotation of the image and sufficiently robust in terms of distortions, angle of view and noise.

The search algorithm then goes through the database making a comparison with the descriptor of the image you want to search for. In each comparison the number of common characteristic points is saved, at the end of the algorithm a ranking of the most similar images is generated according to the number of characteristic points found.

Figure 5 – Tattoo recognition system.



Source – The Authors (2021).

RESULTS AND DISCUSSION

For the test of the proposed system, several changes in the original images were made through transformations such as: blurring, change in luminosity, rotation, scale and shear.

Revista ARACÊ
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500 images were randomly selected from the database described above, manual cutouts were made to isolate the tattoos and then the five transformations were applied, thus generating 2500 images for initial testing of the system.

The operations performed can be seen in Figure 6, which shows different images belonging to the same class.

500 different tattoo images from the database were used and each of them generated five different variations through blur transformations, changes in luminosity, scale, rotation and shear, thus generating 2500 test images, which will be compared to the original 500 images.

To evaluate the performance of the proposed system, a distance metric called rank was used, where for each correctly identified tattoo it receives the label of rank-1, if the tattoo is the second best option identified by the system, it receives the label of rank-2 and so on up to the maximum of rank-500, then receiving the worst identification.

In the test of the 2500 images, a performance of 99.65% was obtained in rank-1. The performance graph is shown in Figure 7.

Figure 6 – Operations performed on the images for testing the proposed system.

Source: The Authors (2021).

In the test of the 2500 images, a performance of 99.65% was obtained in rank-1. The performance graph is shown in Figure 7.

The system execution time for analyzing the 2500 tattoos was approximately 7 hours, using an Intel Server machine with Core i9 7920X processor, 12 processing cores,

Revista ARACÊ
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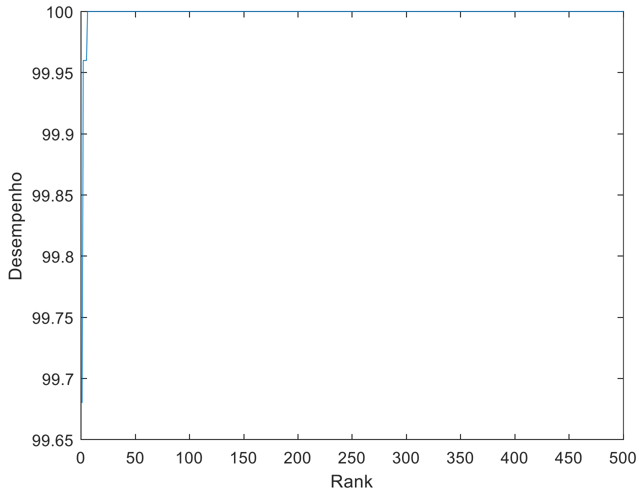
128GB/DDR4/2666GHz Hyper X memory and Nvidia GeForce RTX2080/11GB graphics card, without the use of multiprocessing, using Matlab software (R2022a). The average time to identify each tattoo was approximately 10 seconds.

As a conclusion, the reported performance values show that the system based on the SIFT algorithm, with the necessary modifications, presented excellent results, 99.65% accuracy of the images used.

Figure 7 – System performance.



Source: The Authors (2021).

CONCLUSION

The reported performance values show that the system based on the SIFT algorithm, with the necessary modifications, presents excellent results, 99.65% accuracy of the images used. It can be used, with some implementations, for the application for which it is intended, that is, identification of criminals through their tattoos.

The relatively long time to identify tattoos can be reduced by coding the system in compiled language, such as C.

Finally, the development of the system can evolve in order to allow the identification of criminals by urban control cameras or by the use of drones, minimizing armed confrontation and strengthening police intelligence for monitoring and/or locating criminals through the use of tattoos. Unlike color and haircut, use of beard or mustache, tattoos remain intact in order to lend themselves to the identification of people in different situations. The development of a tattoo recognition system by images that is robust in the face of environmental variations brings a unique differential to Forensic Science in the state

Revista ARACÊ
ISSN: 2358-2472

of Rio de Janeiro and at the national level as an instrument that allows peaceful and efficient actions in the control of urban violence.

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Revista ARACÊ
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