

## Mapping Areas using Computer Vision Algorithms and Drones

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### Abstract

The goal of this paper is to implement a system, titled as Drone Map Creator (DMC) using computer vision techniques. DMC can process visual information from HD camera in a drone and automatically create a map by stitching together visual information captured by a drone. The proposed approach employs Speeded Up Robust Features (SURF) method to detect the key points for each image frame; then the corresponding points between frames are identified by maximizing the determinant of a Hessian matrix. Finally, two images are stitched together by using the identified points. Our results show that despite some limitations from the external environment, i.e., real-time processing of the proposed algorithms using a flying drone, we could have successfully stitched images together along video sequences.

### Keywords

Image Stitching, Drone, OpenCV, BoofCV, JAVA

### 1. Introduction

Drones are getting popular in a wide range of research in recent years. Many companies have developed their own drone technology such as Google, Facebook, and Amazon. In addition, drones are used in “Drone Journalism” so they can obtain videos of areas that are hard to reach. Besides being used for commercial reasons, drones can be used for military, security, exploration, and surveillance. A quadcopter is one kind of drone that has four rotors. Two of them spin clockwise, and the other two spin counter-clockwise. They work in tandem to balance the drone. Additionally, a drone can fly autonomously based on a pre-entered program without piloting. Since most of drones carry video cameras with considerably high resolution, the use of them for image processing and computer vision techniques has become a very interesting topic. Applications using drones and cameras have been developed to solve many problems and make people’s lives easier. One of challenges of such drone applications is that a drone cannot work properly when a GPS signal or a pre-captured satellite map is not available. This research will address the limitation by proposing a drone map creator, i.e., DMC in short, which utilizes computer vision techniques for video streams captured by a drone.

In our research project, our environment was the university parking lot, and we used image processing techniques to reach our goal. In this paper, we show how we get the images by remotely controlling the AR-Drone to feed the image stitching algorithms, which generate a big image from the successive few images taken by drone.

## 2. Background

The aim of our research project is to come up with an image processing algorithm that will let us cover the University of Bridgeport parking lot, and this can be done by taking successive images and then combining these images into one large image. In order to have images with overlapped areas so that they can be combined, we needed a stable device with a good quality camera, which will capture the images in a certain order. For the drone, we selected AR-Drone 2.0.

The AR-Drone<sup>1</sup> operator can directly set its yaw, pitch, roll, and vertical speed, and the control board adjusts the motor speeds to stabilize the drone at the required pose. The first camera with approximately  $75^\circ \times 60^\circ$  field of view is aimed forward and provides a  $640 \times 480$  pixel color image. The second one is mounted on the bottom and provides color image with  $176 \times 144$  pixels and its field of view is approximately  $45^\circ \times 35^\circ$ . Therefore, the front camera of the drone will provide us with good quality stabilized overlapped images which can be combined into one image using the algorithm that we developed. Along with the AR-Drone 2.0, we also used existed free software libraries that we found helpful to develop our algorithm including OpenCV and BoofCV.

OpenCV<sup>2</sup> (Open Source Computer Vision Library) is an open source computer vision and machine learning software library. The library has many optimized algorithms, which can be used in many areas such as face recognition, identifying objects, tracking moving objects, and stitching images together to produce a high resolution image of an entire scene. OpenCV also leans mostly towards real-time vision applications and it has many available interfaces (C++, Python, Java, etc.). According to all of these properties, we used the Java interface of OpenCV, which is a primary component of our algorithm.

In addition to OpenCV and all the image processing features that it has, BoofCV<sup>3</sup> has also demonstrated very high-level image processing results. BoofCV is a Java library for real-time computer vision and robotics applications. It includes low-level image processing routines, feature tracking, and geometric computer vision. BoofCV is organized into several packages: image processing, features, geometric vision, calibration, recognition, visualize, and I/O. The library has also an example for an image stitching algorithm, which is the main goal of our research project.

Image stitching refers to combining two or more overlapping images together into a single large image. When stitching images together, the goal is to find a 2D geometric transform which minimizes the error (difference in appearance) in overlapping regions. There are many ways to do this. BoofCV uses an example where point image features are found, associated, and then a 2D transform is found robustly using the associated features.

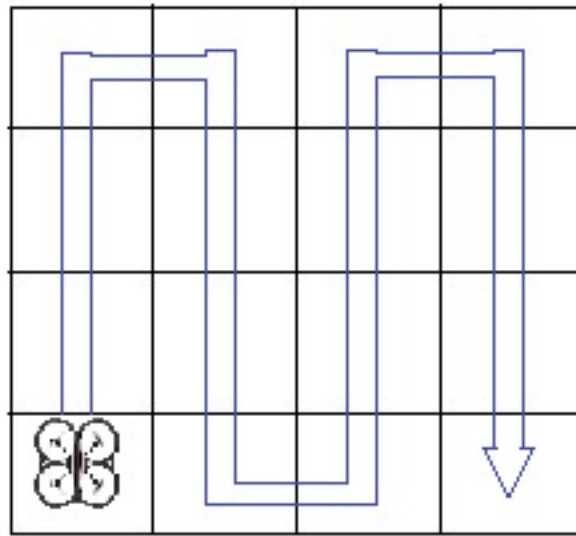
Another way to achieve image stitching is by the Scale Invariant Feature Transform (SIFT) algorithm. According to Andrea Vedaldi<sup>4</sup>, a SIFT feature is a selected image region (also called keypoint) with an associated descriptor. Additionally, there's another image stitching technique on which our algorithm is based on. This technique is called Speeded up robust features (SURF). The SURF and SIFT techniques are very similar but they have a few minor

differences in some details. The main concept of our image stitching algorithm is based on the OpenCV library as well as the SURF algorithm, which gave us the results that we were aiming for.

### 3. Objective and Approach

Our goal in this project is to use the drone's camera to take successive pictures from the university parking lot and blend those images together to build a new image, which will cover the entire parking lot. To do that, we implemented two approaches. First, we used the BoofCV library that has its own image stitching algorithm and features. Second, we developed our own algorithm based on the OpenCV library and the SURF algorithm.

The images were taken during certain periods of time so that the drone captures overlapped images. This way, we can identify and adjust these areas to create an image, which contains the previous image adding the new area resulting in a larger image. To perform our code in the field test, we divided our environment like the image bellow. We had the parking lot divided in a  $4 \times 4$  matrix so that we could organize and better control the drone's movement as shown in Figure 1.



*Figure 1 Drone's movement grid*

The first step in our approach is to take an image at our starting point. Then the drone will move forward taking pictures to cover the first column of our matrix. After completing the first column, the drone will move to realign with the next column, but now taking pictures in the opposite direction. We repeated these steps until the matrix was fully covered. Each column is composed by four smaller images that were stitched together, then we stitched columns together after receiving appropriate modifications, such as rotation of the images. To perform the stitch algorithm, we had two cases in our environment: First, stitch images from bottom to top. Second, stitch images from side to side.

### 3.1 First algorithm: BoofCV

The BoofCV library has its own image stitching algorithm. This algorithm, finds some image points features, associated, and then a 2D transform is found robustly using the associated features. This image stitching algorithm can be summarized as follows: first, detect and describe point features, which is the discovery of the best key points of each image. Then associate features together, only with the common key points between the images. After that, apply a robust fitting to find transform that will make the necessary changes in the images, such as rotations. The final step is to render the combined image to generate the final image. Figure 2 summarizes the BoofCV as the first algorithm.

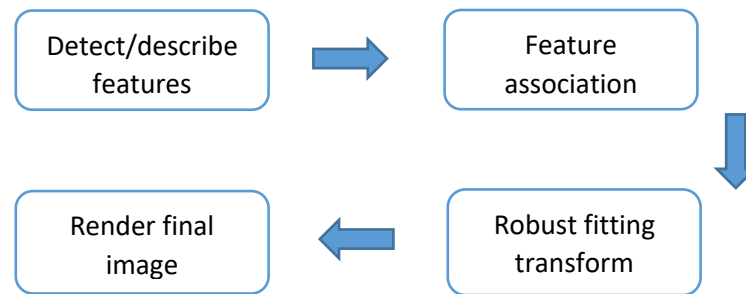


Figure 2 BoofCV algorithm steps

Once the BoofCV renders two images together, it generates a single image with a black background to complete the square referring to the image file itself. After that, when we try to stitch this result with a third image, we will not get the desired result. This happens because the black background will be considered a part of the image, so the algorithm will try to find a correspondence between the background and some feature of the third image and will not find the correct correlation between both images.

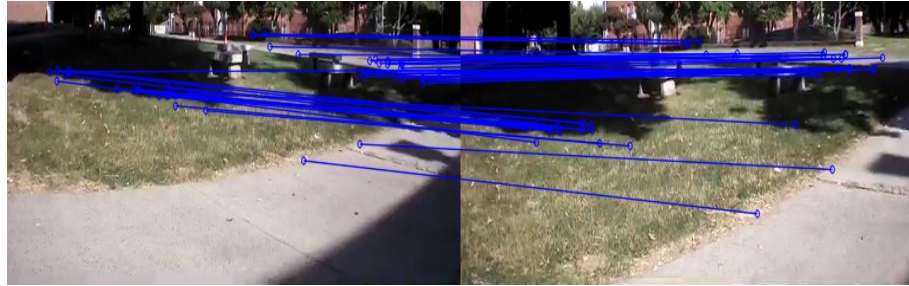
Even if we use some techniques to cut off the background, the result will still present distortions. This will happen because of the translations that the BoofCV does. These translations change the rectangular shape of the image, so there will always be some black background in the image. Thus, the result for a more than two image stitching using BoofCV will be a very distorted image. To avoid this problem, we decided to implement our own algorithm, using OpenCV.

### 3.2 Second Algorithm: Stich algorithm using OpenCV

Our stitch algorithm was developed based on the OpenCV library and mostly prepared using the image processing technique SURF. To perform the main feature of our algorithm, the key point detection using SURF is our first and main step.

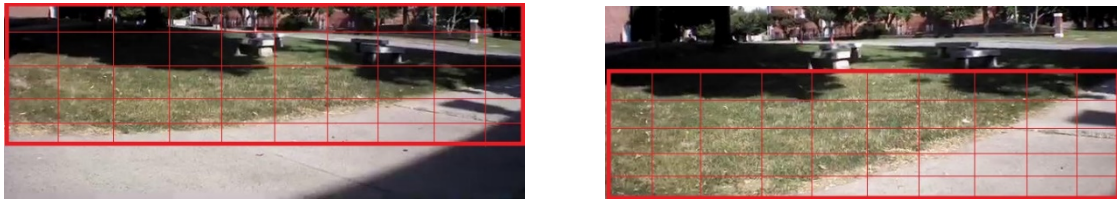
According to Herbert Bay<sup>5</sup>, the SURF algorithm is a local feature detector and descriptor that can be used for tasks such as object recognition or registration or classification or 3D reconstruction. It is partly inspired by the scale-invariant feature transform (SIFT) descriptor. The SURF algorithm is based on the same principles and steps as the SIFT, but details in each step are different. The algorithm has three main parts: interest point detection, local neighborhood description and matching. SURF uses a blob detector based on the Hessian matrix

to find points of interest. The determinant of the Hessian matrix is used as a measure of local change around the point and points are chosen where this determinant is maximal. Figure 3 shows the key points from two consecutive images.



*Figure 3 Key points and feature detection from two consecutive images*

After identifying the key points and matching them between the images, we must identify the common area between these images and crop that intersection area as shown in Figure 4.



*Figure 4 Intersection in the first input and the second input*

Now, the first image has only the part that is not included in the second image. We always keep the last image for performance and level detail. The next step is simply to blend those two images together - the first in the bottom and the second in the top. The result of this rendering will be the first input on the algorithm with the following picture take when the drone move forward. Figure 5 shows the final image after the stitching algorithm.



*Figure 5 Final image after the stitching algorithm*

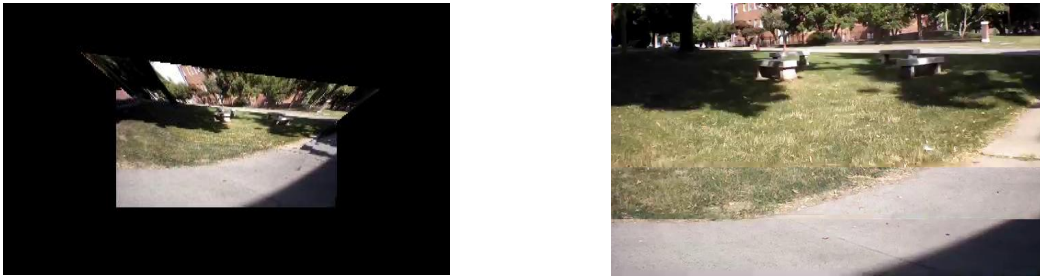
#### 4. Results

We took three pictures in Figure 6 with the front camera of the drone and cut them to feed the algorithms. We were able to get two satisfactory results, even though they have very visible differences, as shown in Figure 6.



*Figure 6. Three sample images taken by a drone*

The stitching algorithm provided by the BoofCV library does not have a complete rectangle image because it rotates the images to bind them better, which means that the image presents gaps completed by a dark background, as shown in the Figure 7. On the other hand, the algorithm implemented by us simply binding the cut images together has as a result a complete image without gaps and dark backgrounds, as shown in the Figure 7.



*Figure 7. BoofCV Result and combined Images*

It is clear that the BoofCV algorithm binds two images with more precision than our implementation, and we barely see the transition between these two images, but it will present a lot of distortions because the translations made by it as soon as we attempt to stitch a higher number of images. This distortion makes it difficult to bind more images because increasing the amount of images will increase the amount of distortions, which will decrease the accuracy of future image processes fed from this result. The other algorithm will not present distortions, but it will have clear lines of transitions between the bound images. This will also affect the accuracy of future image processes that are fed from this result, once some important aspects from the image might be cut in a way that difficult its recognition. Therefore, classifying which algorithm works better for this problem is a difficult decision.

## 5. Conclusion

The goal of this paper is to implement a system, titled as Drone Map Creator (DMC) using computer vision techniques to create a large combined image from several images taken by a drone. Although the BoofCV can fit two images with better accuracy, the drone mapping will have a large number of images to stitch, and BoofCV results would be impracticable because of the amount of distortion that it would have. Therefore, we algorithm developed in this project is a good candidate for the task proposed.

One of limitations in this project is the low stability of the drone. Because of the wind, the pictures took by the drone are often without a common area, so the algorithm could not work. Therefore, the best drone to be used in such project is one with not only a high quality camera, but also with a good stability. With the correct resources, a parking lot mapping can be complete, and it can be used to create a very efficient vigilance system.

## References

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