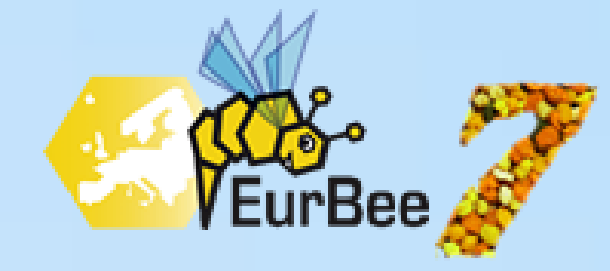


# Geometric contrast feature for automatic visual counting of honey bee brood capped cells



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## 1 - Introduction

Assessment of honey bee colony strength by measuring adults or brood is often required for ecological studies. The brood has typically been estimated through a subjective mode (Lieberfelder method), although it can also be objectively determined by counting (manually or automatically) the brood cells (capped or uncapped) from digital images. The manual counting of capped cells is highly prone to errors and a time-consuming and tedious task. An automatic way to accomplish that task allows reducing those drawbacks.

## 2 - Image Capture Setup

The main challenge for developing an automatic method is the presence of intraclass color variation. It is important to minimize this issue at early stages. Another problem is related to the preservation of the visual information contained in the cells. Concerning those problems an image capture setup was built (Figure 1).

Main features:

- **sealed box** to avoid the external light;
- illumination with two **LED diffuse light panels** (7W) posed at **30cm@45°**, related to the hive frame, to reduce reflection and shadows;
- **digital camera** (24MPixels, **f=10**, **ISO=100**, **Shutter Speed = 1/60**, **HDR**);
- to obtain the complete visual information, the **distance** of the camera to the hive frame is **2m**, also, from the side cells.

The captured images are processed on a computer Intel® Core(TM) I7-4510U@2.6GHz /w 8GBytes of RAM. The code implementation, in C++, is done using the **OpenCV 3.1** [1].



Figure 1 – Image capture setup.

## 3 - ROI

It is a good approach to establish a Region of Interest (ROI) manually to reduce the computation cost by decreasing the capped cells searching space (Figure 2).

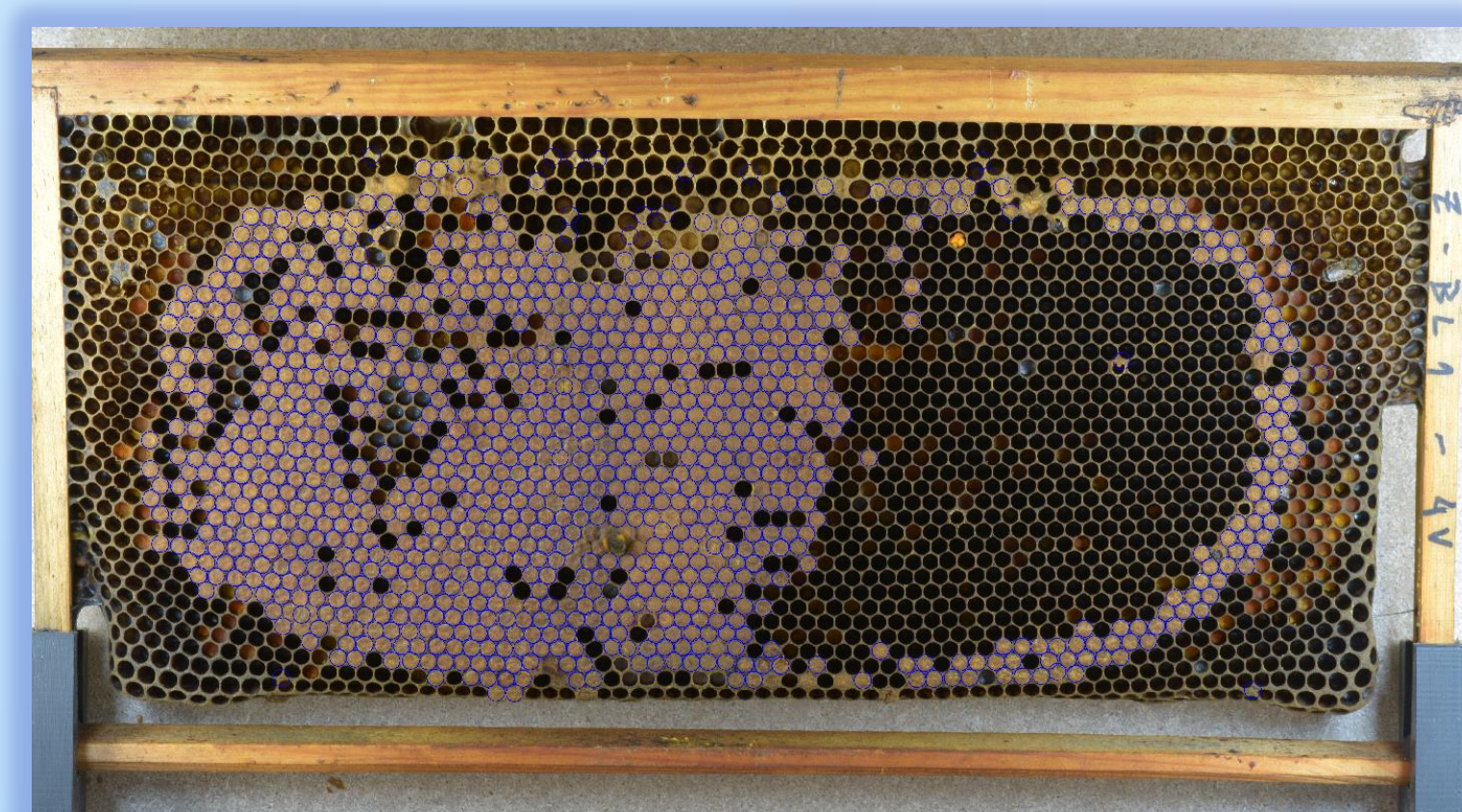


Figure 2 – ROI example.

## 4 - Cells Detection

It is not possible to make a reliable detection based just on the pixel color exhibited by the capped cells. While several researchers are using the Hough Transform [2] to solve this problem, at some light conditions, noise level, and surface conditions the automatic detection fails. After carefully observing the cell regions of several combs, we identified a set of geometrical relations that could be used to build a consistent contrast feature. That feature is the key to detect the cells with a high accuracy in our work. A functional optimizer is performing a searching on the image looking for locations that **maximize the contrast** on that feature. That contrast is the **hypothetical difference** between the average brightness inside the **cell surface** and the average brightness inside the **cell border**. The feature is described by the equation below and can be used to detect several classes of cells when the **surface** is brighter than the **border**:

$$F = -\frac{1}{l(B)} \oint_B b ds + \frac{1}{a(R)} \iint_R r d\Sigma$$

Letter **B** represents the set of points that are forming the hypothetical **border**, **b** is the function that gives the brightness for these points, **l** is the function that returns the **border** length, **R** represents the set of points that are forming the hypothetical **cell surface**, **r** is the function that gives the brightness for these points and **a** is the function that returns the area of that **surface**. The border **B** and the surface **R** relation can be pictured in the Figure 3 for three cases.

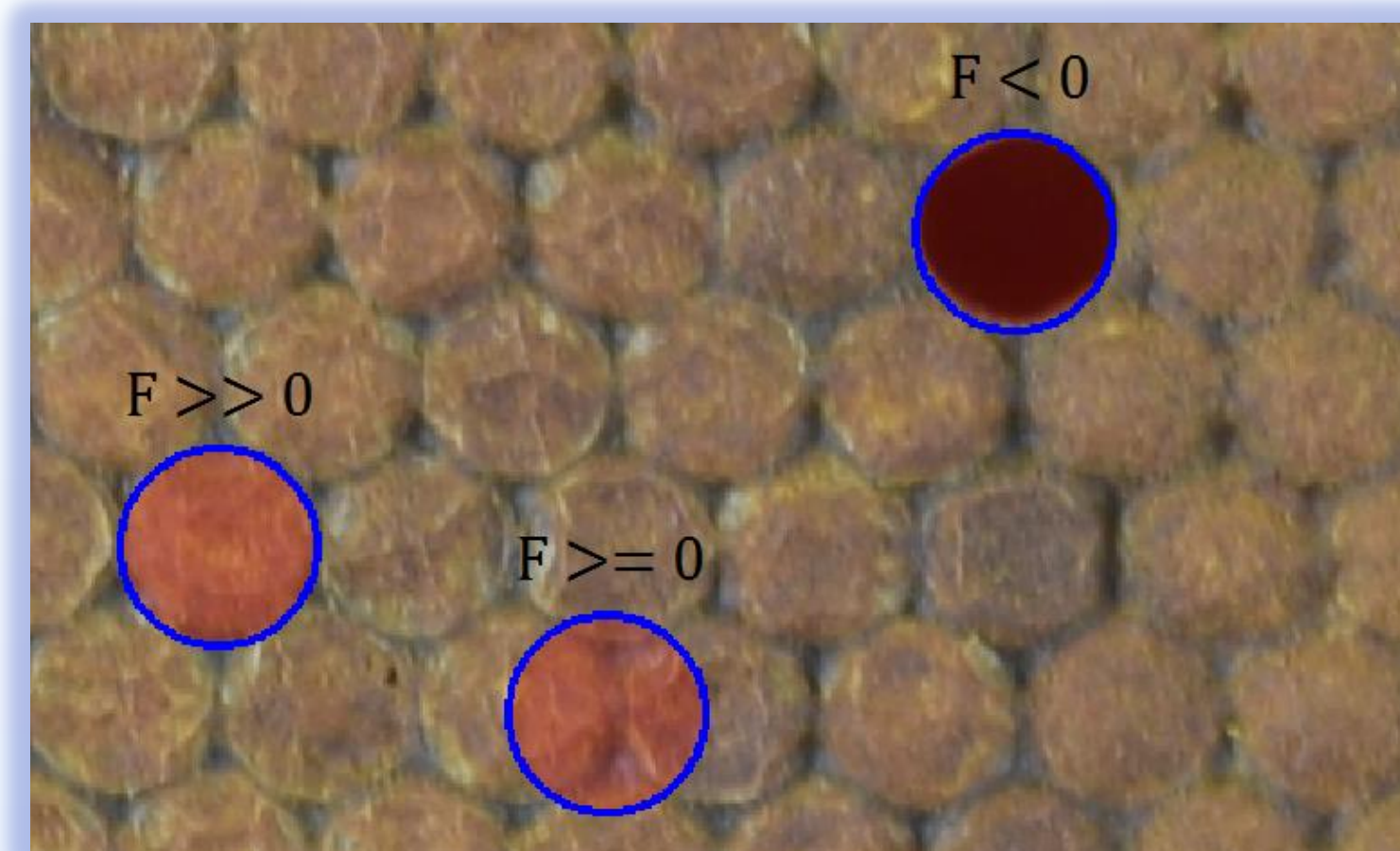


Figure 3 – Different relations border/surface.

## 5 - Capped Cells Classification

Once the cells are detected it is needed to know their classes; In this case we are dealing with the capped class.

The process compares the histograms of all detected cells to the histogram of the well known cells. Thus, some examples of cells have to be acquired previously (Figure 4). The comparisons are done by using the Bhattacharyya distance and the cells that are returning a high matching level are marked as capped cells (Figure 5).

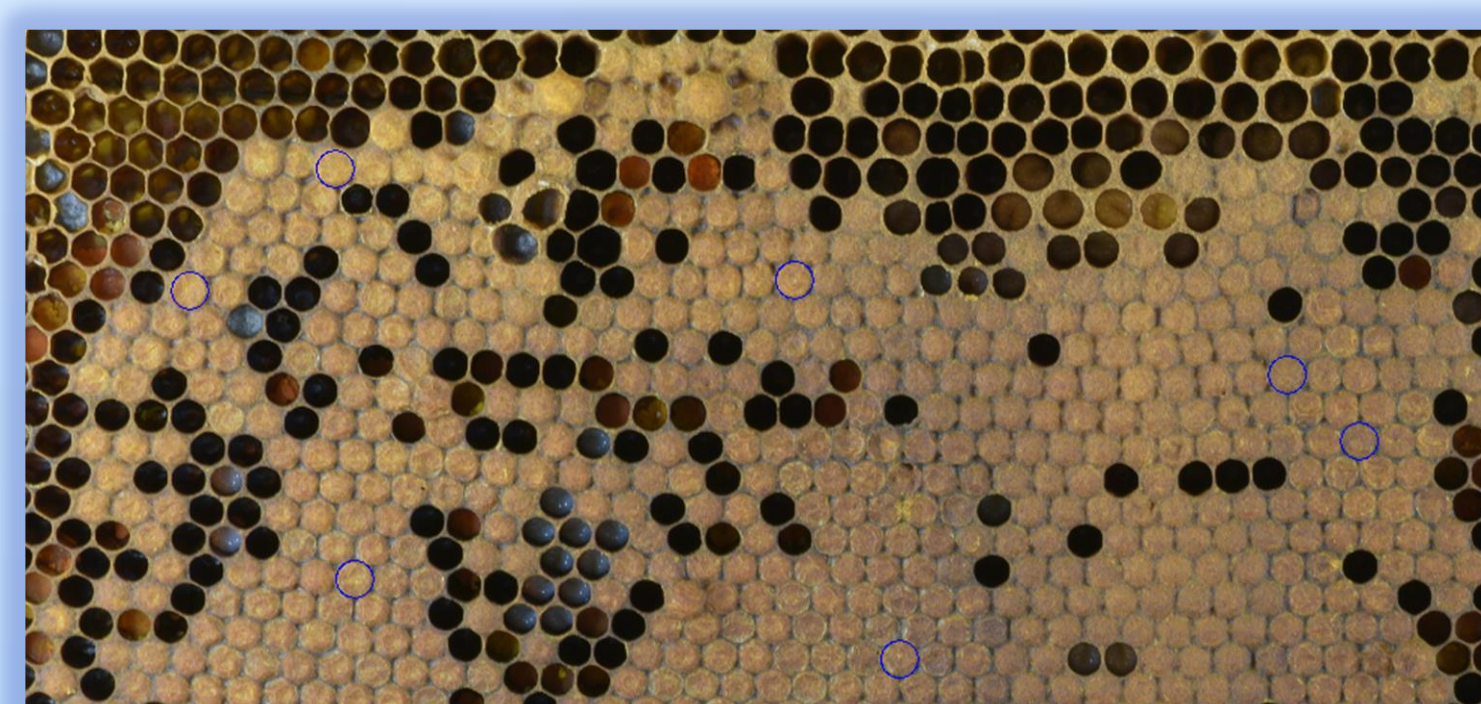


Figure 4 – Examples of capped cells to be learnt by the software.



Figure 5 – Final result of the whole process.

## 6 - Results

The evaluation of the overall process was done calculating the **precision** and the **recall** using the false positive numbers, the false negative numbers and the true positive numbers of the processed cells (Figure 6):

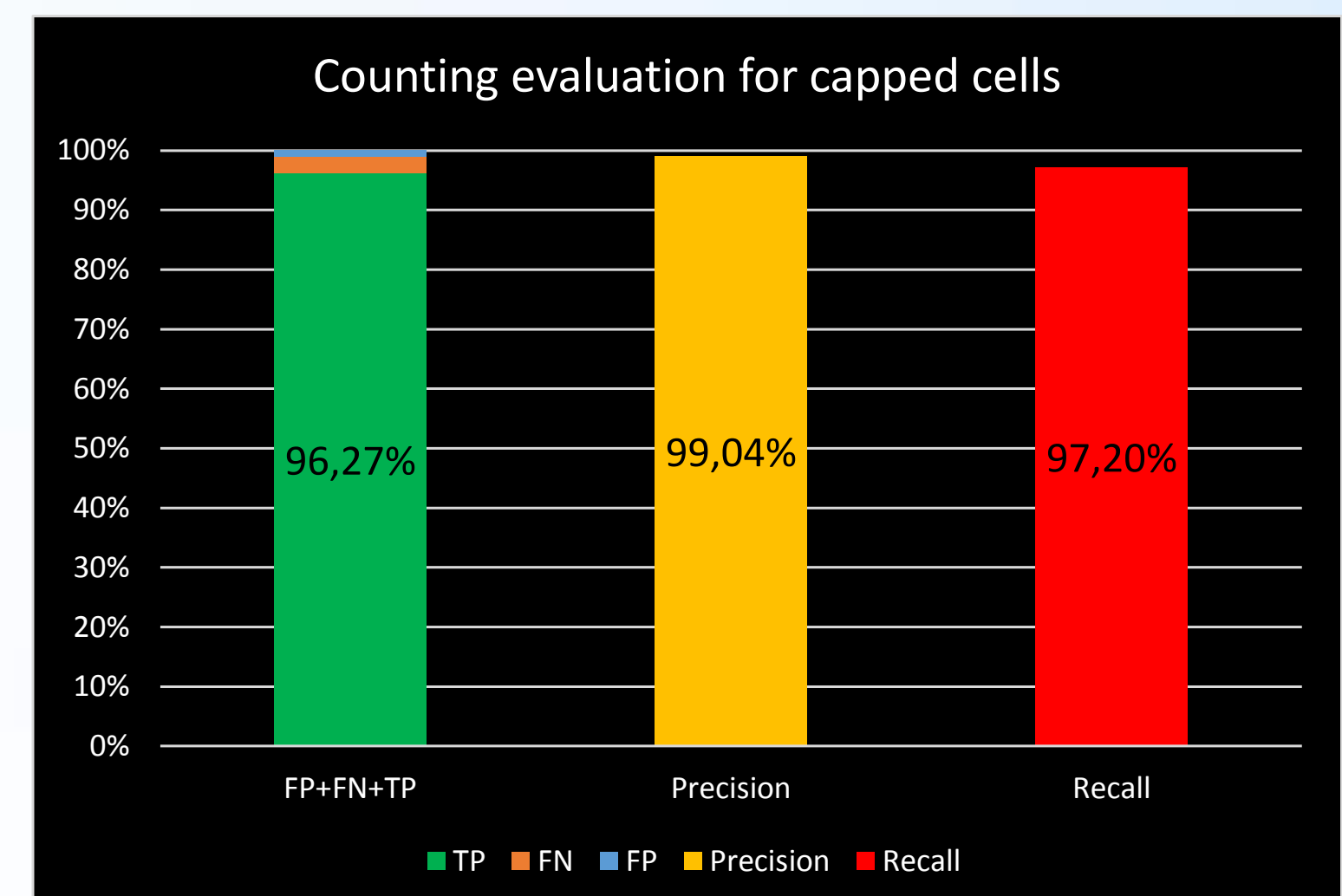


Figure 6 – Counting evaluation.

## 7 - Conclusions

The main finding of this work is the contrast feature that allows detection of the cells with a geometrical position of high precision. This is a fundamental issue to get good classification rates of the capped cells or even of other type of cells. Our experimental results are showing interesting values for precision and recall in detecting the capped cells, despite the wide intraclass color variation.

In the next future we will evaluate the same cell detection process to classify other type of cells (e.g. brood cells, pollen cells).

The processing time for a ROI of 4700px by 2400px is 3 minutes.

## References

- [1] Itseez, Open Source Computer Vision Library. <https://github.com/itseez/opencv> (2016).
- [2] Matas, J. and Galambos, C. and Kittler, J.V., Robust Detection of Lines Using the Progressive Probabilistic Hough Transform. CVIU 78 1, pp 119-137 (2000).

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