# A Boosting Algorithm for Crater Recognition

Ricardo Martins[1], Pedro Pina[2], Jorge S. Marques[3] and Margarida Silveira[3]

[1] *Instituto Superior Técnico, Lisboa, Portugal*
[2] *CERENA, Instituto Superior Técnico, Lisboa, Portugal*
[3] *ISR, Instituto Superior Técnico, Lisboa, Portugal*

## Abstract

*This paper applies the boosting classifier proposed by Viola and Jones to the detection of impact craters on the surface of Mars. The performance of the boosting algorithm is comparable to the best algorithms described in the literature.*

## 1. Introduction

Impact craters are a valuable source of information about the geological history of planetary surfaces. The size and number of craters is closely related to the age of the terrains and has been used to indirectly establish the chronology of the surface evolution.

Since crater detection is a difficult and time consuming operation, several automatic methods have been proposed to tackle the problem ranging from template matching to Hough transform and neural networks. Despite these recent advances the problem remains open since there is no automatic algorithm performing a robust detection of craters under different terrain conditions.

This is a challenging problem since there are a wide variety of terrains with visual and geometric features and the algorithm must also deal with craters with different dimensions. This paper applies the boosting algorithm proposed by Viola and Jones to the detection of craters in Mars images [1].

## 2. Crater Detection

Crater detection in images can be seen as a detection problem. We extract a block around each image pixel and apply a binary classifier to determine if it corresponds to a crater. The algorithm must deal with craters of different dimensions and with different types of textures and artifacts produced by terrains of different constitutions and origins. Three issues must be considered in the design of the detection algorithm: the image features, the classification procedure and the strategy to achieve robustness with respect to scale changes. The approach described in this paper is inspired in the algorithm proposed by Viola and Jones in the context of face detection [1].

**1. Image features**.

The features used in this work are obtained by filtering each block with ternary masks. These features where initially proposed by Papageorgiou et al. [2] and are also known as Haar-like features because they are similar to coefficients of the Haar Transform.

Five types of masks are considered (see Fig. 1). The position and size of the inner rectangle assumes all possible values. This procedure leads to 3216 features. Only a subset of these features is used for classification. Feature selection is performed by the boosting algorithm.

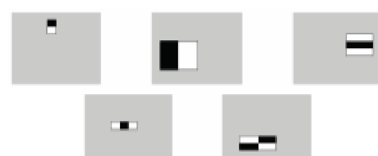

Figure 1 – Masks of Haar like features

**2. Binary classifier**

A boosting algorithm, similar to the one used in Viola and Jones, is used to select features and classify each block extracted from the image. We start by defining a set of weak classifiers (one classifier by feature) based on a thresholding operation and then select the subset of most useful classifiers by boosting.

**3 Multi-scale strategy**

The previous algorithm is scale dependent. In order to make it suitable for a wide range of scales each mask is scaled by different scale factors $S_i=1.25^i$. We compute the output of the classifier for each different scale and choose the scale which leads to the highest value.

During the training phase, we assume that the true scale is known. Therefore the classifier is trained with the features associated to the correct scale.

## 3. Experimental Results

The proposed algorithm was tested using a set of 101 images from 4 zones of Mars surface belonging to the Hesperian geological period. All the images were manually classified in order to produce the ground truth information with the center and diameter of all craters with diameter above 7 pixels. The algorithm was tested using 4 fold cross validation i.e., the whole set of images was divided in 4 parts, three of them were used for training and the other one for testing. This procedure was repeated 4 times.

Figure 2 shows the first 10 features selected by the boosting algorithm in one of these tests showing the type of transitions which were selected.

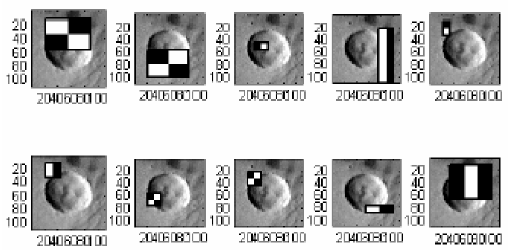

Figure 2 – First 10 features selected by boosting

Figure 3 shows two examples of the results obtained with the proposed algorithm showing the ability to cope with craters of different sizes and visual appearances. Green boxes correspond to correct detections, red boxes to detection errors and yellow squares correspond to misdetections in very small craters which were not included in the training set.

Figure 4 shows the receiver operating characteristic (ROC) as a function of the classifier threshold. This figure shows the trade-off between probability of true detection and false alarms. We obtained a detection rate of 88.5% for 23.2% of false alarms and a detection rate of 79.2% for 5.5% of false alarms. These results are comparable with the best performances achieved so far (e.g., see [3]).

**Acknowledgements**. This paper was partially funded by FCT under the project PDCTE/CTA/49724/03 and under ISR/IST pluriannual funding, POSC, FEDER.

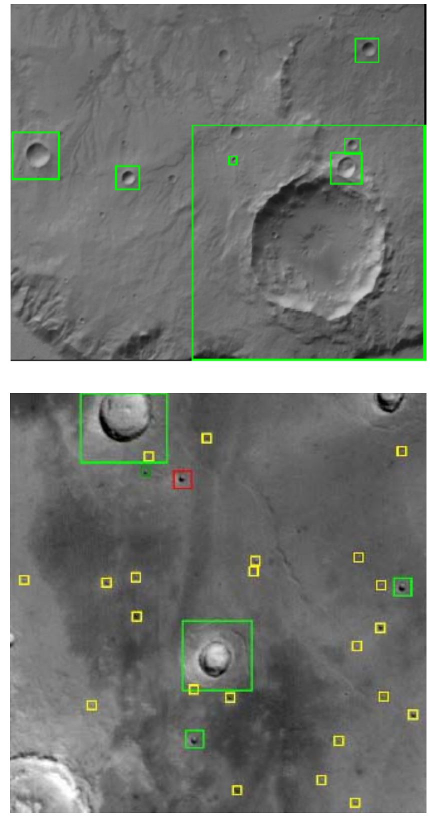

Figure 3 – Output of the classifier: green – correctly classified, red – detection errors, yellow – detection failures in very small craters (below 7 pixels of diameter).

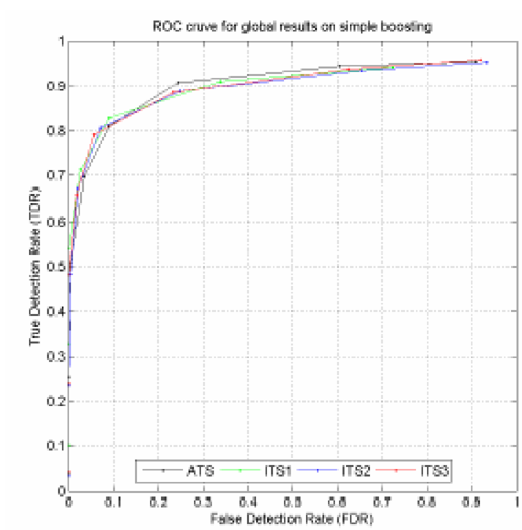


Figure 4 – ROC curve

## References

[1] Viola P, Jones MJ, Robust real-time face detection, *International Journal of Computer Vision*, 57(2): 137-154, 2004.

[2] C. Papageorgiou, M. Oren, and T. Poggio, A general framework for object detection, in *International Conference on Computer Vision*, 1998.

[3] L. Bandeira, J. Saraiva and P. Pina, Impact crater recognition on Mars based on a probability volume created by template matching, *IEEE Transactions on Geoscience and Remote Sensing*, 2007 (in press).