Crater Recognition

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The Recognition Problem

Introduction

The recognition problem is of great importance in all situations where automatic decisions must be made without the intervention of the man. Recognition is one of the most studied problems in computer vision.

Recognition in Remote Sensing

In computer vision applications the image data are characterized by low level of white additive noise and distortions due to the camera, while the object searched has sharp edges and a well identified shape.

In remote sensing applications, in addition to the fact that the images are corrupted by different types of noise or distortions, often the features of the object searched itself cannot be well defined, or his outlines can be known only with a poor approximation.

Automatic recognition can allow to analyze the larger and larger amount of remote sensing data available.

Main Recognition Methods

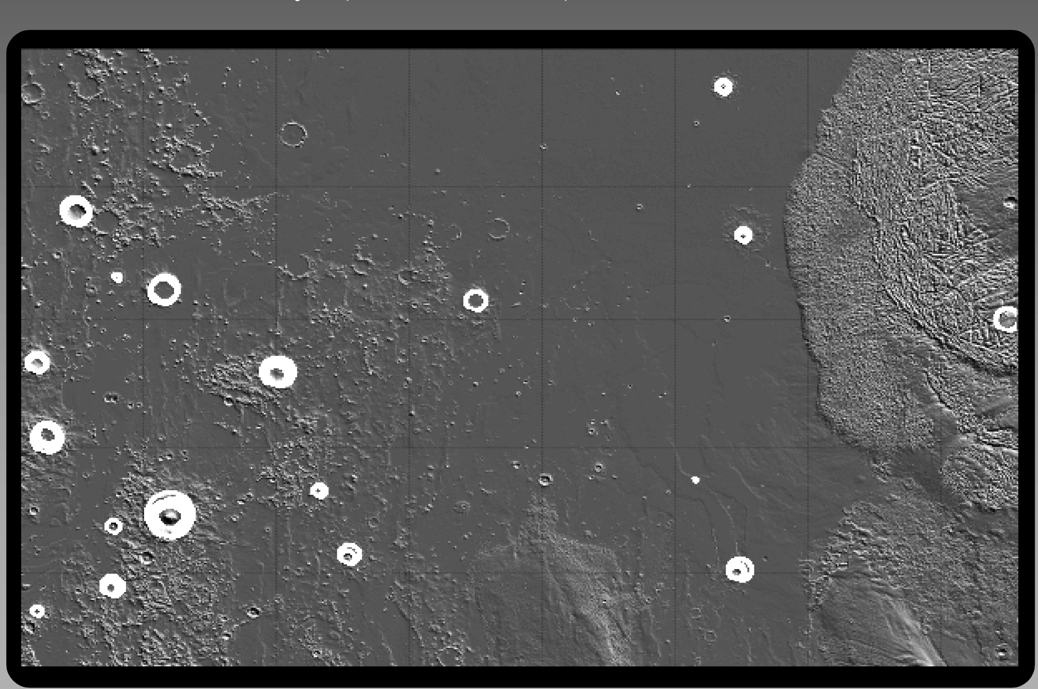
Different techniques have been developed for recognition of objects. Two important families are the matching algorithms and the voting techniques. Matching algorithms use a copy opportunely simplified (template including the more relevant features) of the object to be detected. In voting techniques a schematic shape model of the object is used. Our approch to craters recognition uses the Hough Transform (a voting technique) modified with significant improvements.

Feature Space

An important step, in the recognition process, is the definition of the object to be detected. A representation of this object can be made only by using an ideal model that includes the most relevant discriminating features. Information characterizing the model of the object to be recognized is entirely contained in the Features Space.

Interplanetary Applications: Test on Mars images

On planet images, craters can be detected quite easily. Automatic recognition can allow comprehensive planet surface surveys (Mars, Moon,..)



Hough Transform

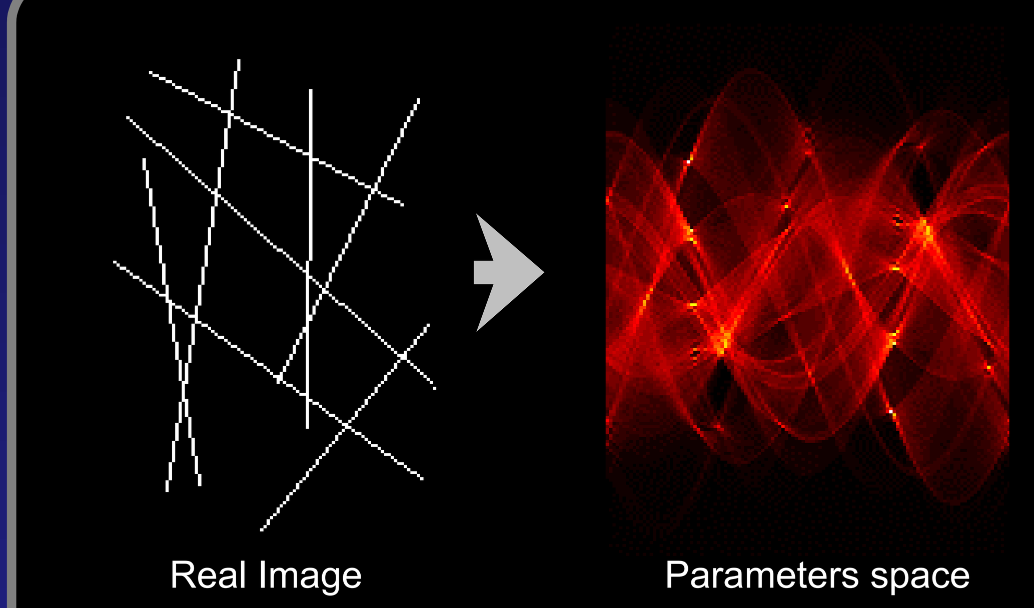
The Hough transform can be considered the discrete version of the Radon transform. Let ***z=f(x,y)*** be a 2D signal defined on a domain ***A***. Given a parametric curve ***g(x, y; p_1, p_2,..,p_k)***, we define the Radon transform as the transformation between the space ***A*** and the space of parameters ***R^2*** in this way:

$$\hat{f}(p_1, p_2, \cdots, p_k) = \iint f(x,y)\cdot\delta(g(x,y,p_1,p_2,\cdots,p_k))dxdy$$

where δ(∗) is the Dirac function.

The Hough Transform is based on the the idea of building a parameter space where the detection is computationally easier. The fundamental algorithms consists of three basic steps:

- One pixel of the image space is transformed into a curve in the parameter space
- The parameter space is divided in cells. Each pixel of the image give one score to the cells lying on the transformed curve.
- The cell with maximum scores is selected and its coordinates in the parameter space are used to identify the curve to be found in the image space.



Hough transform for straight lines

Hough transform drawbacks

Standard Hough transform presents different problems:

- Computational complexity
- Sensitivity to the differences between the shape in the image and the parametric curves used as model for the detection

Hough transform for circles

By means of the Hough Transform, each point in the image corresponds to a cone in parameter space, while each point in parameter space characterizes a circle in the image. The mapping is invertible.

$$(x_0, y_0, r) \rightarrow \Gamma(x,y): \begin{cases} x = x_0 + r\cos(\theta) \\ y = y_0 + r\sin(\theta) \end{cases}$$

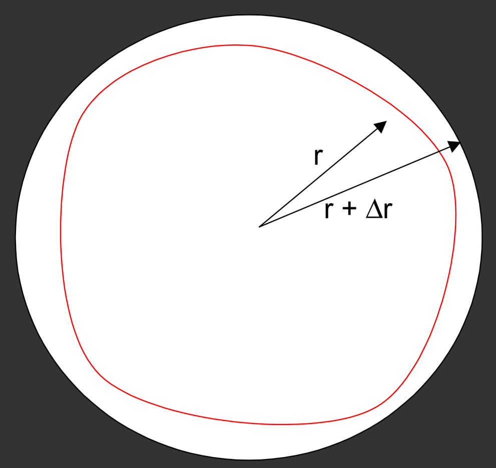
$$(x,y) \rightarrow H(x_0, y_0, r): \begin{cases} x_0 = x - r\cos(\theta) \\ y_0 = y - r\sin(\theta) \end{cases}$$

Proposed Improvements

Parameter space "resolution"

By reducing the parameter space "resolution" as the radius increases it is possible to improve the detection of particularly corrupted shapes (and to reduce the size of the parameter space).

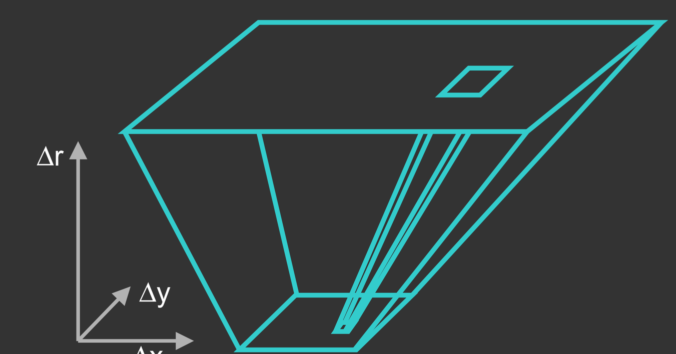
A shape is recognized as a circle when the shape fits a perfect circle with an error Δr=f(r) that is an increasing function of the radius: larger circular structures admit a radius error Δr higher than small circles.



Scaling Technique

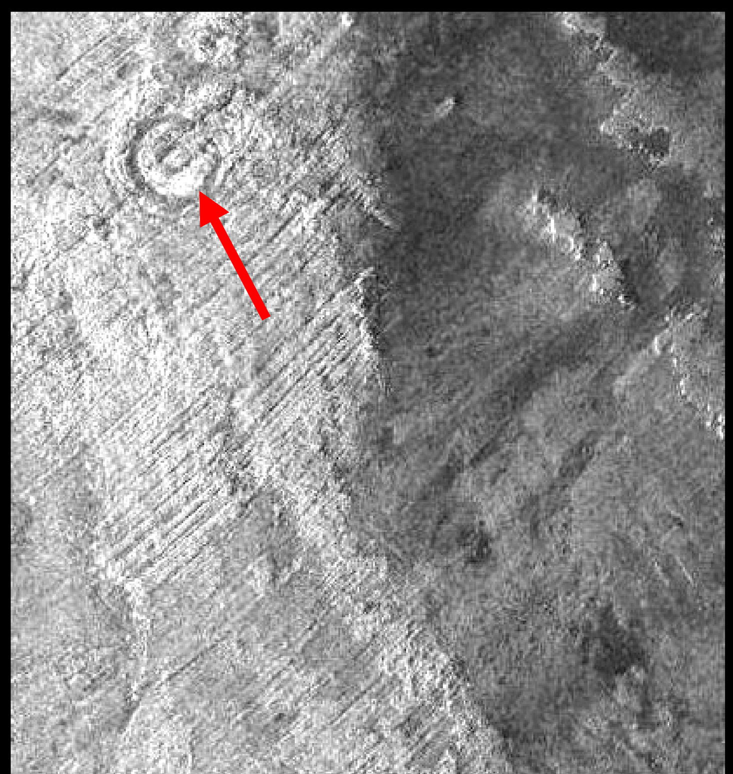
It is important to introduce a method to scale the cells of the parameter space depending on the radius values, that is a non-uniform sampling of the parameter space.

Δr, ***Δx*** and ***Δy*** define the size of a single cell in the parameter space and characterize the admitted errors on the radius and center values. Different tests suggest to scale the volume of the cells linearly with the radius: Δx Δy Δr ~ r

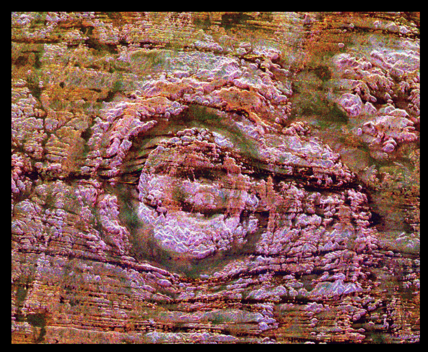


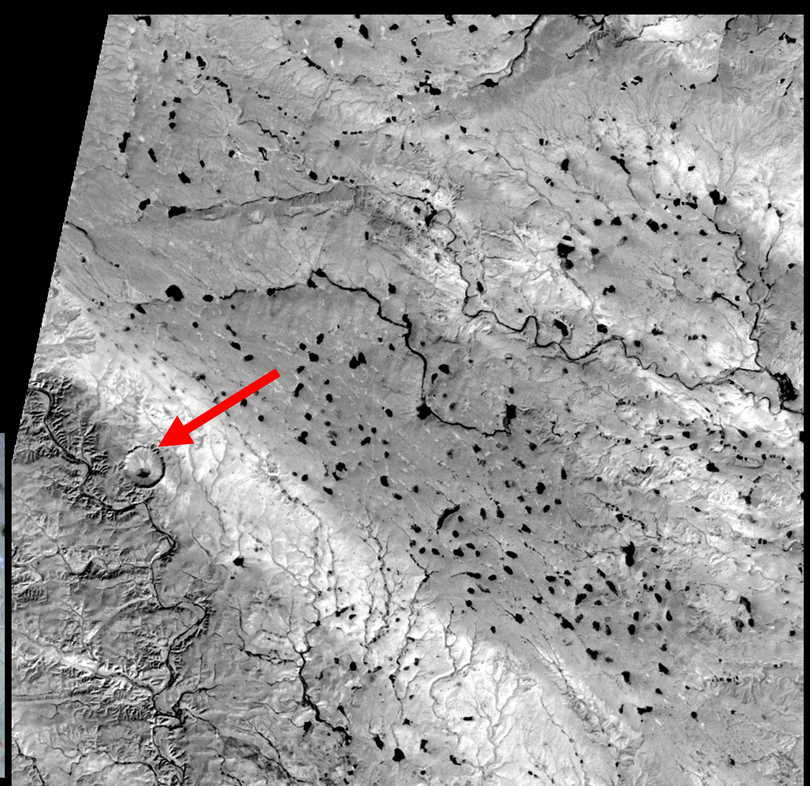
Craters on the Earth: detected craters on test images

Aid tool for recognition of craters. On the Earth surface, recent or well conserved craters have an evident circular shape, while old and very degraded craters are often characterized by complex concentric circular patterns. The proposed algorithm showed promising results for recognition of both kind of craters. The Aorounga and Talemzane are two very different examples of craters on the Earth.



Aorounga crater, Chad





Talemzane crater, Algeria