Measuring The Surfaces On Mars

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Introduction:

A number of images from Mars Rovers contain apparently flat surfaces. We measure them and calculate how flat they actually are. The results show that within the range of error some surfaces are quite flat.

Measurements and calculations:

We work with a stereo pairs of images. Pixel coordinates are measured for each point in selected group containing 4 or more of them. These points must be well identifiable on both images of stereo pair, and have to be sufficiently representative of the surface.

Three points of a group are used to define basis plane, from which the offsets of other group members are calculated. The calculations are based on the rover geometry and its cameras' resolution. We use precise formulas, so no additional errors are caused by their approximate nature.

All calculations are performed by specially developed software, which takes as an input text file that describes the pictures and point sets, producing point offsets and their error margins, along with the graphs of probability distribution of errors.

Error margin estimates:

To obtain probability distribution of errors, we use digital experiments performed by software on each measured point set. Every offset measurement is followed by 200 digital experiments, which answer the question what would happen to the obtained offset value, if the point set observed was in slightly different position.

The experiment models errors, caused by the integer nature of pixel measurements, and by the limited to 15 decimal digits mantissa precision used by software.

This graph was produced for the 'concrete' object that we discuss first in the next section.
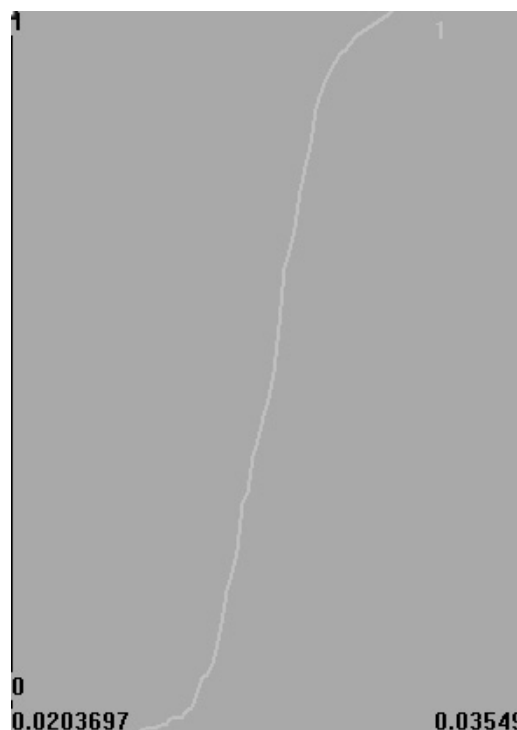
The obtained distribution of errors in most cases comes out pretty close to the normal distribution, so we can use 3 sigma rule to evaluate the likely margin of error.

The results for actual imagery:

We have applied the above methodology to a number of surfaces, which appear to be flat. Let us take a look at some of them.

Concrete. This object's pictures were taken by the Navcam on Opportunity,
1N143188963EFF3243P1961L0M1 ,
1N143188963EFF3243P1961R0M1 , Sol 169

The view size = 60 cm by 40 cm
Distance=1.64,   Max Offset = 0.028
Error Margin=0.004,   Pixel Error=0.0012

Although not being very flat, this object is still interesting because in addition it has straight edges with a corner of about right angle.

Plate. This is an another example of a apparently flat area, its picture taken by Pancam on the Opportunity,
1P143541398EFF3300P2401L7M1,
1P143541398EFF3300P2401R1M1, Sol 173
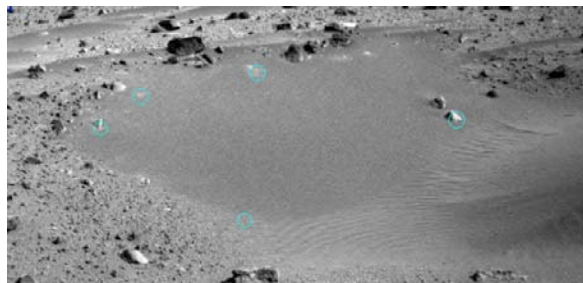

The   view size = 1 m by 1 m
Distance = 3.31,   Max Offset = -0.011
Error Margin = 0.015,   Pixel Error=0.001

Frozen lake. This is an example of an apparently flat area, its pictures taken by Navcam on the Spirit,
2N129837705EFF0500P1835L0M1.JPG,
2N129837705EFF0500P1835R0M1.JPG, Sol 173

The size is about 90 cm by 50 cm
Distance = 5.193,   Max Offset = 0.371
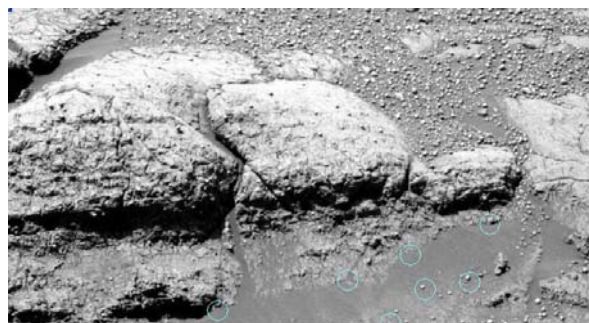Error Margin = 0.08,   Pixel Error=0.004

The offset shows that the spot is not flat.

Niagara. This is an example of what appears to be a very small stream by our standards, which nevertheless can be a river by the Martian standards. It appears to have a decent geological history, with its bed cut through rocky landscape. The images has been acquired by PANCAM on the MER Opportunity
1P130497910EFF0442P2384L7M1.JPG,
1P130497910EFF0442P2384R1M1.JPG, Sol 26
The shore is curved, and our goal was to establish whether it belongs to the same nearly horizontal plane, possibly representing water level.

The area is about 30 cm by 20 cm in size.
Distance = 2.26,   Max Offset = 0
Error Margin = 0.005,   Pixel Error=0.0006

This really flat spot deserves attention of the geologists.

References:

[1] Bell III J.F. at all. (2003) The Mars Exploration Rover Athena Panoramic Camera (PANCAM) Investigation, JGR, Special issue on the Mars Exploration Rover mission, 74-76.
[2] Setan H. et al. (2004) Application of Digital Programmatic Systems for Dimensional Measurement and 3D Modeling, 3rd FIG regional conference in Jakarta, Indonesia, October 3-7 2004.