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Field calibration of volcanic surveillance cameras.

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Abstract. In volcanic surveillance, cameras are largely used allowing amazing images of volcanic eruptions as well as beautiful views of these grand Earth constructions. The Colombian Geological Service through the Volcanological and Seismological Observatory of Popayán (OVSPo) have 10 surveillance cameras looking at three volcanoes present in Provinces of Cauca, Huila and Tolima. However, these cameras were not calibrated previously, which has limited the analysis and exploitation of the information up to now. The development of this work take into account that the calibration process should not change camera parameters like orientation and position and what's more, we consider the access difficulties to reach and stay at the camera stations (volcanic environment). A calibration methodology was developed and applied on three (3) cameras on field, achieving to improve the analysis and exploitation of information within images of volcanic surveillance cameras.

1. Introduction

Nowadays volcanic surveillance through images is largely used, based on satellites, overflights, in-situ pictures and images from surveillance cameras [1], including spectral ranges as IR, UV [2] and visible. Each one of these techniques have benefit, drawbacks and different complexity to get relevant information about volcanic activity. Concerning images achieved by surveillance cameras in visible spectra, the Colombian Geological Service (SGC) through the Volcanological and Seismological Observatories (from Manizales-OVSM, Pasto-OVSP and Popayán-OVSPo) has surveillance cameras installed on field on strategic places to register surface volcanic activity, and so with radio link is transmitted one image per minute. Once they are at office, analysis is established according with all techniques of volcanic surveillance (seismology, chemistry, deformation…), so a better comprehension of volcanic activity is achieved.

Until now, analysis methodology used include activities like visual identification and anomaly measurements as ash emissions, glows, pyroclastic flows, volcanic eruptions… Measurements at the OVSPo had been achieved based on known real points and its correspondence on the image [3], so when using cross multiplication or an analogical scale in a transparent film, they had estimates of the real dimensions in meters. Other way is the use of pixel measurements of phenomena. Despite of its useful these methods possess unknown accuracy because perspective, depth, distortions problems among others. In the OVSPo these problems have been addressed by some works [4][5] and approached by teams in other countries [6].

Camera calibration is a process that allows finding the relation between a 3D real point and a 2D image point; it can lead to distortion reduction because lenses and getting knowledge of camera installation parameters like orientation. Calibration methods with patterns [7] had been used on volcanic surveillance cameras like on Etna volcano Italy [8] to estimate eruption column height, in which known patterns are located in front of the camera for calibration. Although currently there is a broad variety of methods to facilitate this process, they depend on scene conditions sight by camera,

camera characteristics or the possibility to controllably and slightly move the camera [9], what is not easy on field cameras.

In the OVSPo, the cameras did not have calibration at installation moment, so measurements from its images have allowed seeing relative changes in time but not getting a coherent analysis with real phenomena measures. In this document, a field camera calibration method is presented and the results on three (3) of the 10 surveillance cameras in the OVSPo what has led to better volcanic phenomena analysis through image analysis.

2. Volcanic surveillance cameras at OVSPo

From 2008, when the OVSPo installed its first surveillance camera, it has increased the number of surveillance cameras up today we count with five looking at the Nevado del Huila volcano, four at the Puracé volcano and one at the Sotará volcano. Those cameras are installed on strategic places but geographically hard access, requiring up three days by foot to arrive the station, under severe weather conditions (figure 1). We took into account those conditions to create and apply the Calibration method.

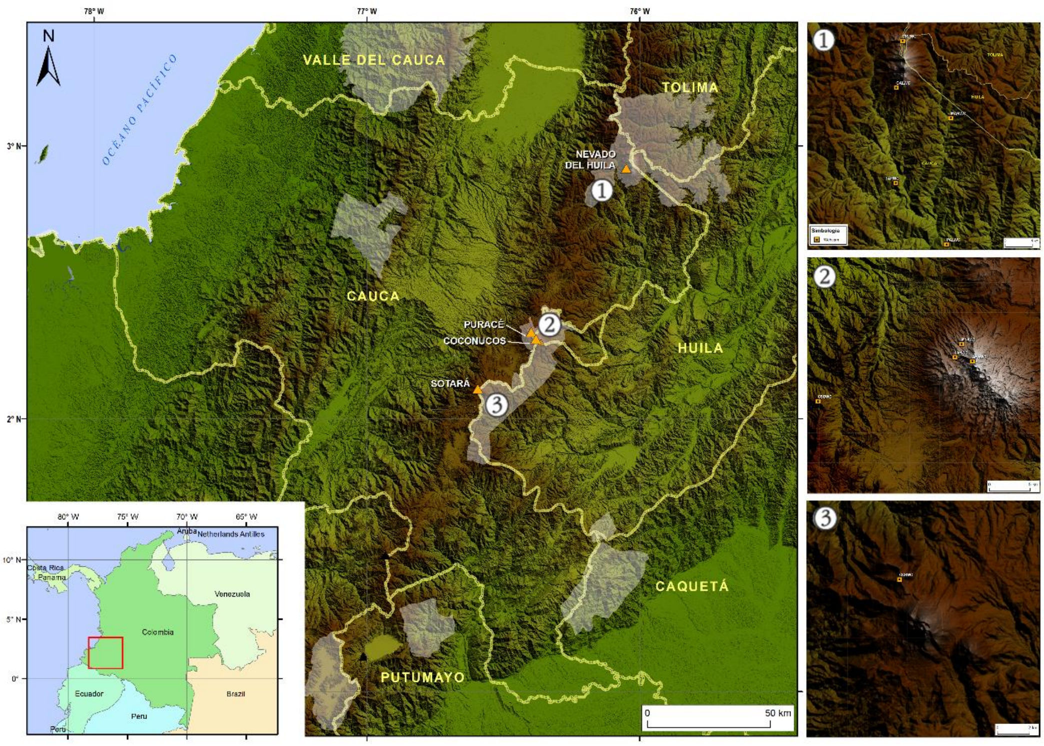

Figure 1. Location map of 1) Nevado del Huila, 2) Puracé and 3) Sotará volcanoes and its Net of Surveillance cameras at SGC (orange squares).

3. Traditional measurements methods of volcanic surface phenomena

On volcanic surveillance, is too much important to know the quiet times of the volcano and then make a comparison of time behaviour, to identify anomalies associated with volcanic changes. Regarding to volcanic surveillance cameras, observations and measurements on images, the situation is the same, it is important to know the volcanic behaviour through parameters like normal column height and its colouring.

Based on one image, is possible to develop measurements in pixels or meters if there is a calibrated camera. Pixel measurements are useful to identify anomalies through time, but off course is not enough to understand the real volcanic behaviour.

Other way to measure adapted at some volcanoes, is the use of a vertical analogical scale in a transparent film (figure 2). This scale fits in the same observation point at which a person is located to see the volcano through the transparent film and then make measurements based on the scale and the phenomenon behind. We saved a record data at the end.

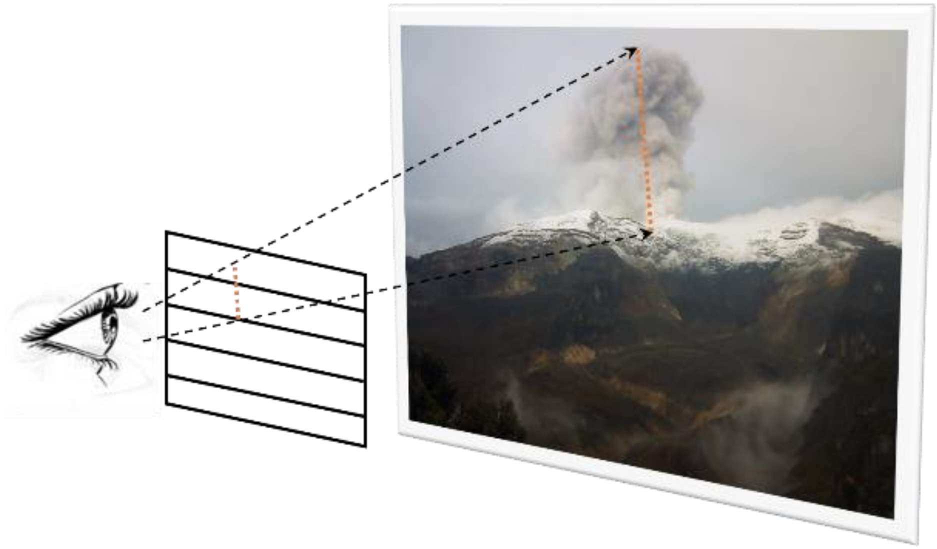

Figure 2. Measurements through analogical scale in a transparent film (left side) of volcanic phenomena (right side).

Last case is the use of known coordinate points that are visible on images, to get an approximate scale on the image. So using cross multiplication, they got an estimation of phenomenon real dimensions.

In all cases relative measurements are recorded, what allows identifying changes in volcanic activity; however, only real measurements serve to some institutions in charge of control and regulation aviation (Aerocivil en Colombia). Furthermore, all cases involve several problems that leads to unknown errors, problems like depth and parallax.

4. Field calibration of volcanic surveillance cameras

Camera calibration intend to find the existing relation between object coordinates and image coordinates. Therefore, it is possible to position an object or develop measurements on the image and calculate the real position and real measurements, based on image data.

One of the methods to develop real measures through images is based on pin-hole camera model and the knowledge of orientation, vertical and horizontal field of view (FOV), camera matrix and distortion parameters [10]. Method used on some volcanic surveillance cameras, like at Etna volcano [8] and selected for project too.

There are several approaches to achieve the camera matrix and distortion parameters, but here was used the chessboard pattern [7]. Furthermore, to get orientation and FOV was invented a pattern tool ("T") to be carried to camera stations on field. Next figure shows the pattern.

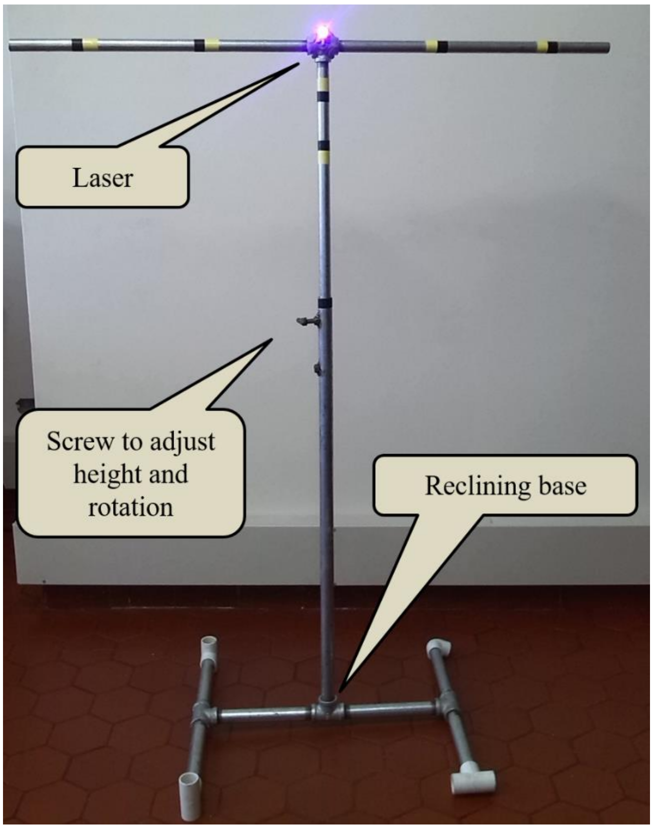

Figure 3. "T" pattern instrument. Yellow brands at T pattern are at known distance each other.

We also took into account the following facts to create the pattern:

- Field cameras should not be moved or even touched while calibration, because the results must serve to analysis older images.
- Field cameras could be installed on masts up to 4 meter height and "T" pattern should be in front of cameras.
- Pattern must be rigid enough to stand firm despite windy, damp and rainy weather.
- Technically, the pattern should be adjustable in such a way it forms a parallel plane to image plane. Therefore, the pattern need mobile parts to modify height, tilt and rotation.

That is why we thought of using galvanized pipe nipple forming a T what should be adjusted to be parallel to the image plane, helped by a laser in the pattern middle, perpendicular to T pattern, laser which will point to camera lenses (parallel to camera sight line) to validate that pattern is parallel to the image plane.

The proposed field camera calibration proceeding that considers next steps:

In office, before going field, the staff should identify and draw the image centre, because this point and the laser must match while calibrating.

Once at field:

1. Request to the office personnel, some snapshots of chessboard pattern in front of camera.
2. Locate T pattern in front of camera and make to fit the T pattern centre (laser) with image centre, before identified.
3. Turn on the laser and point it to camera lenses. Ensure second step is satisfied too.
4. Then, request to the office personnel some snapshots of T pattern in front of camera.
5. Followed, should be fastened a thread to the T pattern middle. Then it is stretched to reach the camera lenses or to set parallel to camera line sight.
6. On this thread, camera elevation and azimuth are measured.
7. In addition, thread distance (Dh) is needed for next processes.

Once the stuff returns to the office, may find the camera matrix and distortion parameters. We, compute the FOV through equations (1) for vertical axis and (2) for horizontal axis, represented in figure 4.

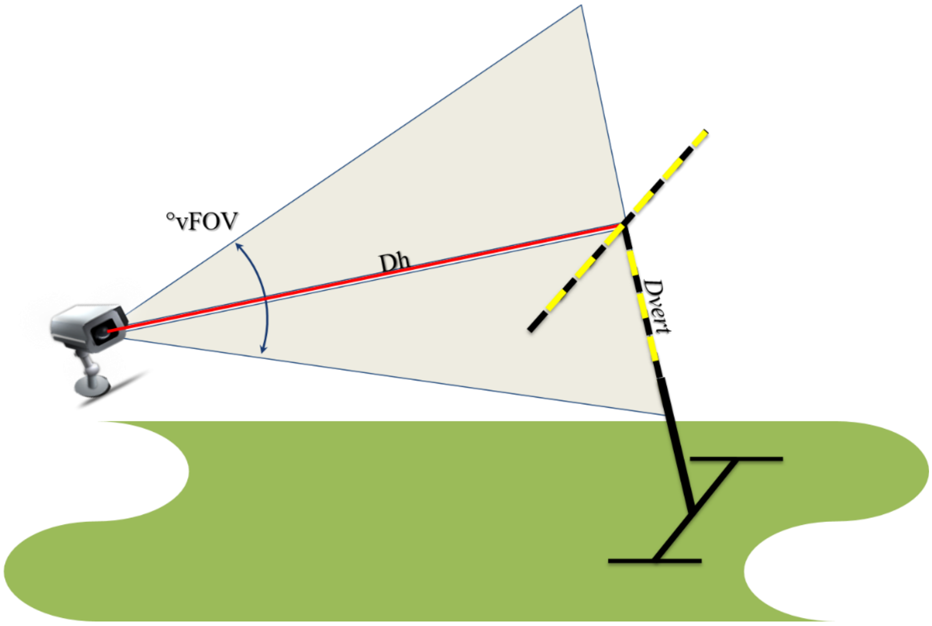

Figure 4. Process scheme of field calibration of surveillance cameras. Yellow marks at T pattern are at known distance each other. Red line indicates the pointing of laser.

$$vFOV = 2 * \tan^{-1}\left(\frac{D_{vert}}{2*Dh}\right) \quad (1)$$

$$hFOV = 2 * \tan^{-1}\left(\frac{D_{horiz}}{2*Dh}\right) \quad (2)$$

Now is possible to get the meters to pixels rate for each axis for a fixed depth *d*, what depends on image resolution, as equation (3) shows:

$$MetersPixRate = \frac{d*\tan(^{FOV}/_{2})}{^{resolution}/_{2}} \quad \frac{[\mathrm{m}]}{[\mathrm{pix}]} \quad (3)$$

Therefore, it is possible to know the dimensions of an object on the image plane at a depth *d* from camera, multiplying the size of the object, in pixels, by the meters pixels rate for each axis, once the image is undistorted and rotated.

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5. Results and conclusions

We tested the calibration process in three of the ten surveillance cameras of OVSPo. Next figure show some images recorded during calibration process of these three surveillance cameras and the results are in table 1.

Figure 5. Field calibration camera at three of ten volcanic surveillance cameras. a) Lavas Rojas (LARWC), b) Caloto (CALWC) and c) Mina (MNAWC).

Table 1. Calibration results in the three tested surveillance cameras tested at OVSPo.

	Caloto (CALWC)	**Mina (MNAWC)**	**Lavas Rojas (LARWC)**
Azimuth	35	138	100
Elevation	20	16	20
Rotation	8.5±0.5	-1.7±0.5	0±0.5
hFOV	60±2.1	34±1.3	72±2
vFOV	37.7±6.6	26.6±5	57.8±2.3

Orientation parameters: azimuth, elevation and rotation, in addition to horizontal and vertical field of view were found at three of the ten OVSPo volcanic surveillance cameras, reaching errors up to 18% of the measure in vFOV of Mina camera, what's is not so good yet. These measures represent the beginning on calibration methods at these cameras and will be used to record better phenomena measures than before, however there are still some challenges to be faced:

- Improve accuracy on all parameters.
- The installation of each camera changes its conditions and the T pattern might not be helpful in all of them.
- Some cameras are on masts of up to 4 meters of height and could oscillate with wind and

therefore orientation parameters could change, so measures on these images could have unpredictable errors.

- The zoom or focus at each camera could change and if it is modified, the calibration process should be applied again. Because of that, cameras with motorized lenses controlled remotely could not be exploited fully.
- The same situation happens when station maintenance require moving the camera.

Therefore, a versatile method should be the next step to take advantage of all situations and so achieve a better support to understand volcanic activity state. To achieve this, one possibility is using digital compass that could be incorporated to the camera installation and then know all the time the position. In addition, the physical location of a fixed pattern in front of each camera that would allow knowing the changes in orientation, zoom and focus in a certain time.

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