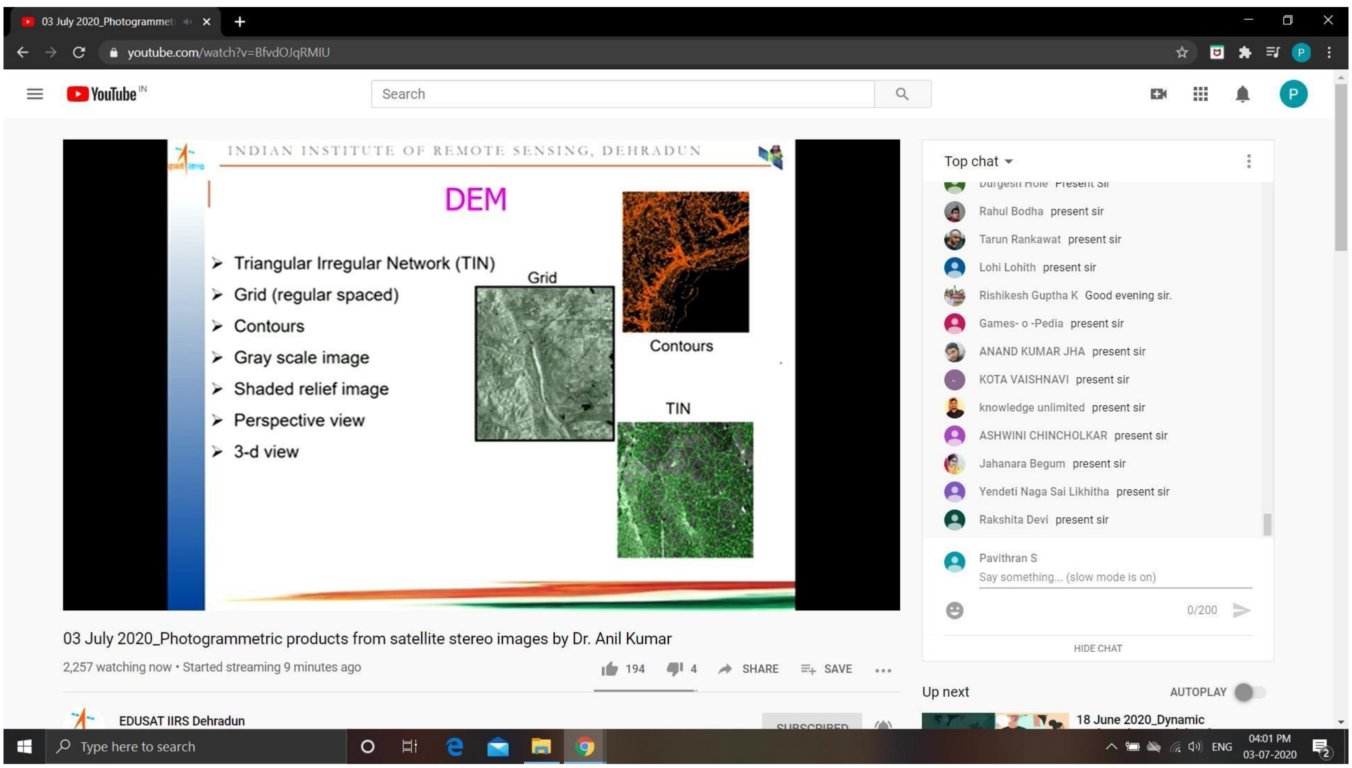
DAILY ASSESSMENT FORMAT

Date:	**03 JULY 2020**	**Name:**	Poorvi hj
Course:	**SATELLITE PHOTOGRAMMETRY AND ITS APPLICATION**	**USN:**	**4AL17EC071**
Topic:	**Photogrammetric products from satellite stereo images (DEM and derivatives & Orthoimage)**	**Semester & Section:**	**6TH B**
Github Repository:	Poorvi-2000		

FORENOON SESSION DETAILS
Image of session

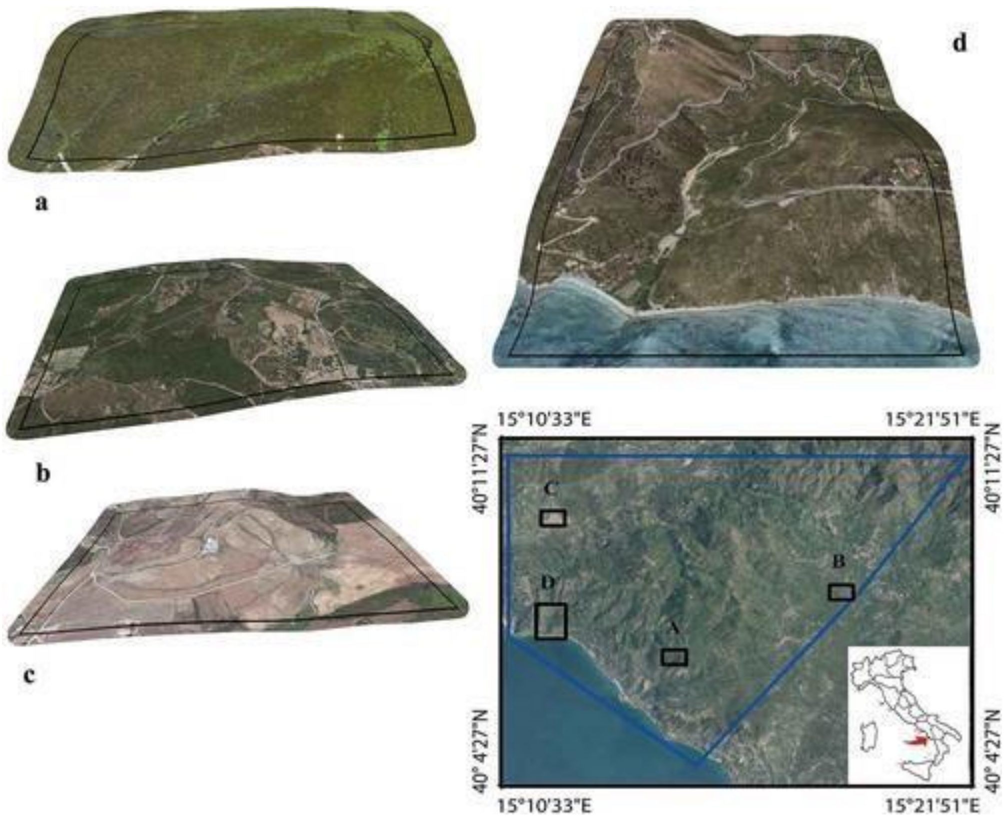


Report – Report can be typed or hand written for up to two pages.

Very high-resolution satellite stereo images play an important role in cartographical and geomorphological applications, provided that all the processing steps follow strict procedures and the result of each step is carefully assessed. We outline a general process for assessing a reliable analysis of terrain morphometry starting from a GeoEye-1 stereo-pair acquired on an area with different morphological features. The key steps were critically analysed to evaluate the uncertainty of the results. A number of maps of morphometric features were extracted from the digital elevation models in order to characterize a landslide; on the basis of the contour line and feature maps, we were able to accurately delimit the boundaries of the various landslide bodies.

Study site and material

The GeoEye-1 stereo image pair (Table 1) reports its characteristics which was captured in reverse scan mode with the panchromatic band and all four multispectral bands recorded. The site covered an area of 110 km$^{2.}$ One of the two GeoEye-1 images composing the stereo-pair represented in pan-sharpened mode. DATUM is ETRS89, frame ETRF00. The four areas highlighted and marked by letters have been studied in more detail: A mountain area (a), a hilly area (b), a flat area (c) and an area (d) of special geomorphological interest affected by an important active landslide compound system.



For the analysis described here, only the panchromatic level 1A imagery has been considered. The area covered by the stereo-pair is a coastal area of southern Italy. The topography is highly variable, ranging from sea level to altitudes of over 1000 m. Shrubs and isolated large trees cover most of the area, but there are also a few residential zones and isolated houses.

The whole satellite image was georeferenced and the DEM was extracted. Within the image, we have selected three subareas of different morphologies to study in greater detail. Figure 1 shows a mountain area (A), a hilly area (B) and a flat area (C). Area (D) is of special geomorphological interest as it is affected by an important active landslide compound system (Barbarella, Fiani, & Lugli, 2015; De Vita et al., 2013).

We carried out a number of tests with both Geomatica ver. 2013.0.0 and Socet Set ver. 5.8.0. They are both software packages that perform a variety of functions related to photogrammetry and remote sensing.

Methods

If the aim of the survey is landscape characterization in order to monitor changes over time, the outcome of any image elaboration step – georeferencing , image matching, DEM extraction and morphometrical feature extraction – should be subjected to critical analysis.

Georeferencing

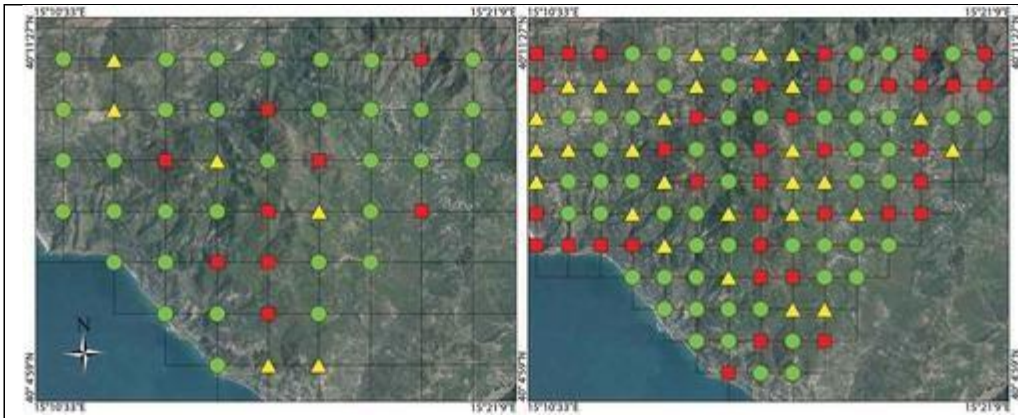
For geomorphological purposes, the image georeferencing phase is of primary importance. The georeferencing accuracy of high-resolution satellite imagery is not a function of spatial resolution alone, as it is also dependent upon radiometric image quality, satellite platform attitude and the precision of the GCPs survey. The most frequently used georeferencing algorithms are based on rigorous models or on use of RPFs.

In this work, we have tested the physical model embedded within the software Geomatica (called " Toutin' s model"), the physical one embedded in Socet Set (called "rigorous simultaneous") and the RPF model embedded in Geomatica (called "Rational Function").

The software user's guides suggest using only a few points (from 6 to 10 for Geomatica, even less for Socet) to geo-reference the image if the rigorous model is used. This is why we used only a small number of points as GCPs. The remaining were used as check points (CPs) for testing the accuracy of the output (e.g. to evaluate the difference between the value measured on the terrain and that measured on the georeferenced image).

In order to geo reference the image, we run a NRTK GPS surveying campaign. To obtain a homogeneous distribution of well-"matched" points, control points were chosen in close proximity to the nodes of a regular grid; grid spacing was fixed while bearing in mind the number of points required for image georeferencing, which depends on the type of mathematical transformation used. The grid was overlaid onto the image and the GCPs position was selected nearby these nodes taking care of choosing "stable" details clearly visible on the image, such as arti facts or natural objects (Figure 2, left panel). Due to the presence of many mountainous districts, devoid of any stable points that can be easily identified on the image, in some areas, there are no points in correspondence of the grid nodes.

Figure 2. Regular grids have been drawn on the image to obtain a homogeneous distribution of well" matched" points. Control points have been chosen in close proximity of the nodes of the grid. Green circles indicate areas on the images that are close to visible control points, yellow triangles indicate "bad" points with issue of collimation (since they are located in shady areas of the image), red squares are on the location of grid nodes where it was not possible to find a point to collimate (mountain areas and/or without arti facts). Left panel: GGCPs; right panel: MGCPs. DATUM is ETRS89, frame ETRF00.



In order to design the surveying campaign, it is necessary to consider whether the site offers good road access or it is isolated. In this case, neither a good cellular phone signal nor a good satellite DOP value, which are necessary conditions for the GPS NRTK survey, can be expected.

Thanks to the speed of the GPS measurements, once we had reached the survey area, we decided to measure several neighboring points in order to then choose which could be better collimated on the image and which was the best in terms of measurement quality.

A total of 29 points were deemed suitable for use as either GCPs or CPs in our experimental testing. The position accuracy for the points measured using the NRTK technique is estimated to be better than 10 cm.

Positions were directly obtained in the European Terrestrial Reference System 1989 (ETRS89), the European and National geodetic system, European Terrestrial Reference Frame 2000 (ETRF00).

A few other points were acquired from the latest available map, the Cartografia Tecnica Regionale at a scale of 1:5000. The cost of data acquisition from the map is obviously much lower than with the surveying campaign, so many more points were measured on the map. The point acquisition pattern was designed so as to have a homogeneous distribution (Figure 2, right panel). We have also taken care to ensure that the points whose coordinates were measured on the map correspond on the image to details that are both stable and well collimable.

Geomatica, if a geocoded map covering the area in the image is available, manages the geometric correction process through an OrthoEngine application which allows us to collect the GCPs directly on the map. The cursor must be positioned exactly over the location in the uncorrected image that we wish to use for control and later over the identical location in the geocoded image map. Good choices are road intersections in built-up areas or sharp river bends in natural environments. We have got our estimate for the elevation from a linear interpolation of the contour lines.

Obviously, the georeferenced map must have the coordinate system you have set for your image in the "set projection" panel.

Regarding the choice of the point location, besides the presence of homologous points on the image and on the map, a further necessary requirement is the possibility to acquire all three of their coordinates on the map with good accuracy; some areas lack points showing these features. The whole process would be improved if it were possible to give 2D (planimetric) and 1D (altimetric) point coordinates separately.

Unfortunately, this is not possible as both software packages demand 3D points.

The planimetric root mean square error ($RMSE_{(N,E)}$) of the map is about 1.2 m and the vertical error $RMSE_{(H)}$ is 0.75 m (Barbarella, Fiani, & Lugli, 2017). The accuracy of these points is clearly lower than the one of the points measured directly on the terrain.

In summary, the GCPS used for georeferencing the stereoimage consists of two different sets: GPS GCPs (from now on, called GGCPs) and mapping GCPs (from now on, called MGCPs).

In Figure 2, the green circles indicate areas on the images near to visible control points, to be measured on the terrain (left panel) or on the map (right panel), the yellow triangles indicate "bad" points with some collimation problems because they are located in shadowed areas of the image and the red squares indicate the location of grid nodes where it has not been possible to find a point to collimate (mountain areas and/or without artifacts).

We should also homogenize the geodetic reference systems used. In our case study, both cartography and NRTK are framed in ETRF00. Therefore, no datum transformation was needed for planimetry whereas the height needs a transformation from ellipsoidal to geoidal using an accurate geoid height model specific to Italy (Pepe & Prezioso, 2015).

In order to verify the numerical accuracy of the georeferencing, we provided the residual values computed by the software, i.e. the difference between the adjusted coordinates and the input ones, measured either on the ground or on the map. On the CPs, the software computed the shifts between the measured value of the coordinates and the value measured on the georeferenced image.

DEM extraction

In this phase, we studied the accuracy of the DEMs extracted using stereo-matching techniques from the stereo images. Two commercial software packages – Geomatica and SocetSet – were used for the image processing phases, including DEM extraction.

In both cases, the DEM extraction process makes use of image correlation to find matching features on the two images of a stereo pair, adopting strategies specific to the software used.

Geomatica used a feature-based matching model called normalized cross-correlation matching. This method finds the relative shift between two images by finding the shift that produces the maximum cross-correlation coefficient of the gray values in the images (Geomatics, 2010; Lewis, 1995).

The software requires epipolar images to extract the DEM, in order to reduce the time necessary to find corresponding points in image matching (Deilami & Hashim, 2011). At this stage, it is helpful to add some tie points to improve the digital matching in a few "critical" zones, mainly in the shadowed areas of the mountain slopes. A hierarchical approach using a pyramid of reduced resolution images was the method adopted in order to find these matching features.

In this phase, two parameters need to be chosen: "DEM resolution" (the size of the pixel in the final DEM) and "DEM detail". Specifically, the latter determines how precisely to represent the terrain in the DEM. Selecting "very high", "high", "medium" or "low" determines the time at which to stop the correlation process. In the case of failed correlation, in order to enhance the continuity of the DEM surface, we set the “fill holes” option so as to automatically filter the elevation values by interpolating the failed areas; however, this strongly influences the reliability of the resulting DEM.

With Geomatica, the first tests to verify the DEM accuracy were carried out by varying both the parameter “resolution” (from 0.5 m i.e. “very high” to 10 m i.e. “low”) and “detail”. Different levels of detail were set.

Moreover, we have made a number of tests using different types of terrain. Finally, we chose “mountanous” for the whole image because this choice gave us better results.

Socet Set (BAE Systems, 2007) used ATE (Automatic Terrain Extraction), an object-based areamatching model and Next Generation Automatic Terrain Extraction, a hybrid matching process (both edge and area based), which performs image correlation and edge-matching on each image pixel (Zhang, 2006). We used adaptive ATE, suitable for satellite imagery, mostly natural terrain.

When using Socet Set, some parameters also have to be set in order to create the DEM, including the number of pyramid levels on which the model is created, the resolution of the output DEM, the correlation strategy (adaptive or nonadaptive) and the use of some filters to remove artifacts such as trees or buildings.

We made a number of tests, varying some parameters. Finally, we set the following parameters: “high” for smoothing, “high” for precision, “low” for speed and “automatic” for seed DEM. The DEM grid size was fixed at 2, 1 and at 0.5 m, for testing purposes.

In order to transform the DEM from a DSM (digital surface model) into a DTM (digital terrain model), an automatic filter must be applied to the whole image in order to eliminate or reduce the presence of vegetation and artifacts.

For example with Geomatica, above-surface features such as trees and buildings were mostly removed (minimized) by running the “DSM2DTM” filter implemented in the software package. The filter searches for the local minimum based on a user-defined kernel (filter) size to obtain the bare soil profile (DTM). The kernel size was set to 10 × 10 m in planimetry. If the difference between the local height minimum and the average elevation is higher than 5 m, the related data are removed.

In order to verify the accuracy of the DTMs we produced, we run tests by comparing the coordinates measured on the ground with those measured either directly in stereoscopy on epipolar images with Geomatica or on the orthophotos with Socet Set.An overall check of the goodness of the results obtained in image processing can be carried out with Geomatica by analyzing the correlation score for each DEM pixel recorded by a score channel that is generated for each level of detail chosen. In the event of unsuccessful correlation (values less than 20), a failure value is assigned to those pixels in order to recognize them.

An analogue numerical value called “Figure Of Merit” (FOM) is computed in Socet Set.

An additional check of the output was performed by analyzing contour lines from a visual point of view as well as from a numerical one, in order to verify whether the model generated from the stereo pair is compliant with the actual terrain. On a small part of the image, representing an area whose morphology is well known to us, we were able to evaluate the compliance of the DEMs extracted with the morphology of the actual terrain.