POST-EVENT DAMAGE ASSESSMENT USING MORPHOLOGICAL METHODOLOGY ON 0.5M RESOLUTION SATELLITE DATA

Jenerowicz, M., Kemper, T., Pesaresi, M., and Soille, P.

Institute for the Protection and Security of the Citizen (IPSC)
Joint Research Centre, European Commission
via E. Fermi 2749, I-21027 Ispra (Italy)

KEY WORDS: image analysis, mathematical morphology, image interpretation, WorldView-1, damage assessment

ABSTRACT

This paper presents the results of the application of mathematical morphology techniques for a semi-automatic quantification of the number of dwellings in an IDP camp in Sri Lanka. The specific assessment was undertaken based on a WorldView-1 satellite image (0.5m). First, an area opening was used to suppress all bright objects whose area was below a given threshold value. These objects were then revealed by computing the difference between the original and the transformed images, considering at the final stage a given size criterion. In a second step, the extracted structures were counted in a GIS using the centroids of the dwellings and limited visual interpretation.
The assessment for the IDP camp indicates an overall number of 10,138 tents on the 10th of May, 2009. After the 10th of May 2009, the camp had been abandoned and was destroyed to a large extend.

1 INTRODUCTION

The conflict between the Tamil separatists of the LTTE (Liberation Tigers of Tamil Eelam), which fought to create an independent Tamil state, and the Sri Lanka army culminated the first half of 2009. The hostilities caused new waves of Internally Displacement Persons (IDPs). According to United Nation High Commissioner of Refugee (UNHCR) at the beginning of 2009 the number of IDPs in Sri Lanka reached 504,800. The displaced population was usually moved to camps in non-fighting zones agreed by the fighting parties. On the 5th of April 2009, one of the non-fighting zones located in the Puthukkudiyirippu area was caught in the fighting between the Sri Lanka government and the LTTE.

This study assesses the number of tents in the non-fighting zone as part of the humanitarian relief efforts. After the 10th of May 2009, the camp have been abandoned and is destroyed to a large extend. The analysis was conducted based on VHRS (Very High Resolution Satellite) imagery, which due to the ground pixel size of half a meter provide an effective means for the identification of each dwelling. This study used a methodology developed for estimating the population in the Lukole IDP camp in Tanzania (Giada et al., 2003) and was also modified and applied for the enumeration of population in the Dorti, Ardamata, Um Dukhun (Kemper et al., 2009) IDP camps in Darfur, Sudan. The goal is to apply mathematical morphology techniques (Soille, 2003) in order to extract information revealing the presence of IDP tents occurring in the satellite image. By comparing this information to the post event image of the destructed camp, this approach can be used to rapidly assess the damage in the camp.

2 AREA OF INTEREST AND DATA

Research was carried out in a narrow 14 square kilometre patch of land between the Puthumathalan and Amplalavanpokkani along the coast of the Mullaittivu district, 395 km northeast of the capital (Fig. 1). This area was initially declared by the government as non-fighting zone for the protection of the civilian population but finally was included in the conflict. The analysis was undertaken for the 'Civilian Safety Zone'(CSZ) (around 3 square kilometres) on WorldView-1 satellite imagery acquired on the 10th of May 2009 at a spatial resolution of 0.5 meters.

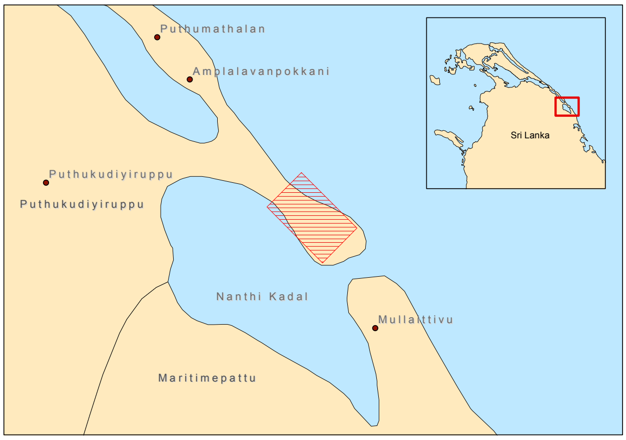

Figure 1: Location of the IDP camp in Mullaitivu region, Sri Lanka.

3 METHODOLOGY

The methodology consists of four successive steps: tent characterisation (Sec. 3.1), tent extraction (Sec. 3.2), random sampling and visual interpretation (Sec. 3.3), and regression analysis (Sec. 3.4).

3.1 Tent characterisation

The available imagery consists of a panchromatic image at a spatial resolution of 0.5m. Tents appear as rectangular objects that are brighter than their surrounding. They are

Figure 2: IDP tents in the Mullaittivu region in Sri Lanka. Left: in formerly inhabited areas. Right: in a village with houses and roads containing a series of vehicles.

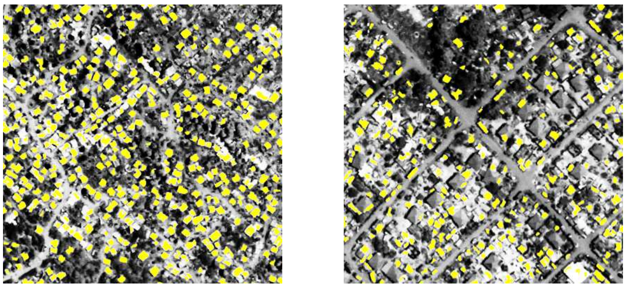

Figure 3: Detected IDP tents in the Mullaittivu region in Sri Lanka (yellow overlaid on input images also shown in Fig. 2). Left: in formerly inhabited areas. Right: in a village.

scattered over a large area. Two distinct patterns can be observed: IDP tents in formerly inhabited areas and IDP tents in villages with roads and houses. These patterns are illustrated in Fig. 2. Note also the presence of some bright elongated objects on the roads and corresponding to bright trucks or buses.

Similarly to initial experiments performed on the Lukole refugee camp in Tanzania (Giada et al., 2003), the IDP tents in the Mullaittivu region appear all as bright objects over a darker background. More precisely, the following observations can be made:

- most tents appear as bright objects over a darker background;
- the footprint of most tents appear as rectangles with a length to width ratio lower than 3/2. The use of this a priori knowledge requires the detection of the complete footprint of the image objects. Because the proposed procedure at this stage often only provide a subset of the footprints (corresponding to the brightest part of the tents), this criterion will not be used;
- bright thin elongated structures (length to width ratio greater than 3/2 often correspond to the bright top of trucks, buses, or other vehicles). Again, to exploit this criterion, a full detection of the footprints of the objects would be necessary.
- it is reasonable to consider that the footprint of a tent must be compact enough to contain a square of 2m$\times$2m, i.e., 4$\times$4 pixels. In addition, it is expected that its area does not exceed that of a square of side 6m, i.e., 144 pixels.

3.2 Tent extraction

The image processing chains detailed hereafter aim at automatically extracting structures corresponding to tents. This extraction relies on the characterisation of tents described in Sec. 3.1.

An area opening (Soille, 2003)is used to suppress all bright objects whose area is below a given threshold value (and considering a given connectivity rule). These objects can then be revealed by computing the difference between the original and the transformed images. The following images have been calculated (the threshold values have been set manually):

- 8-connected area opening with an area of 144 pixels. This operation suppresses all bright objects with an extent less than 144 pixels;
- top-hat by 8-connected area opening with an area of 144 pixels (i.e., arithmetic difference between input image and area opening of the input image). This image highlights bright objects;
- threshold of the previous image for all intensity values greater than or equal to 16;
- threshold of the top-hat image for all intensity values greater than or equal to 10;
- double threshold of the top-hat by opening using the upper and lower thresholds defined previously;
- filtering of the previous image using size criterion: each structure must contain at least 16 pixels. The containment of a square of side 4 pixels has not been used because it leads to the removal of many actual tents that are only partially detected.

Results obtained on the two images shown in Fig. 2 are displayed in Fig. 3. Figure 4 illustrates the main steps of this procedure.

3.3 Random sampling and visual interpretation

The visual interpretation is used for a verification of the results. It was performed on randomly selected samples spread over the camp area. The camp area was overlaid with a grid of 50m by 50m in order to select randomly representative group of data for visual analysis. Figure 5 illustrates the location of randomly selected cells.

The focus of the interpretation is the enumeration of tents as a basis for the damage assessment inside the camp. Consequently, large structures such as buildings were not included into the modelling process Fig. 2. The visual counting of the tents was based on the tents characterisation described in Sec. 3.1. Each individual tent was stored as a single central point.

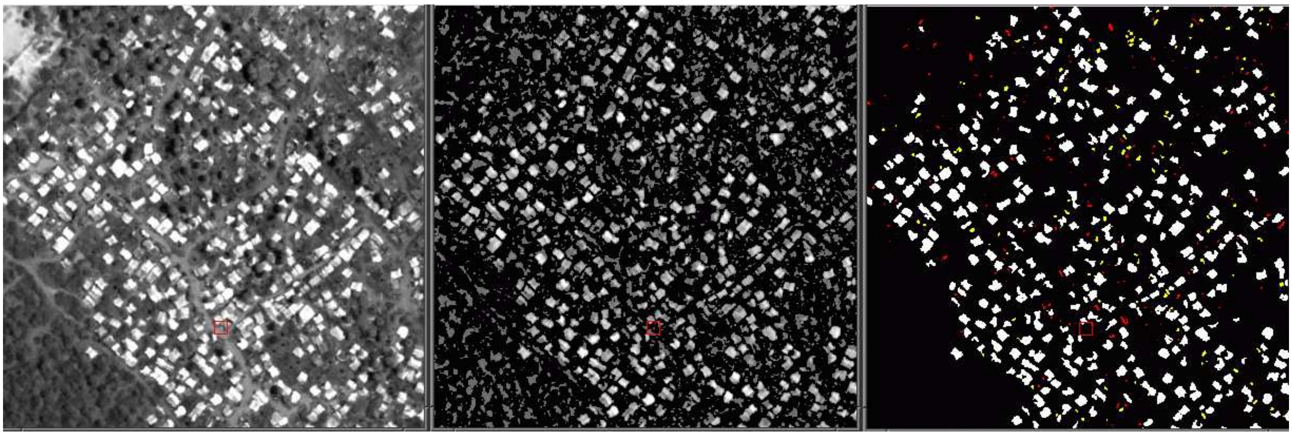

Figure 4: Extraction of tents. Left: original image. Middle: top-hat by area opening. Right: final results (white for mask of tents, red for objects removed following the application of a size criterion, and yellow for regions removed following the double threshold criterion).

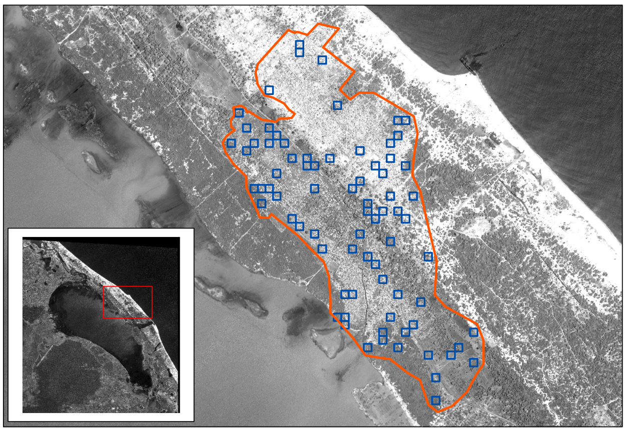

Figure 5: Randomly selected cells of the IDP camp's area in Mullaittivu region, Sri Lanka.

3.4 Regression analysis

A statistic regression approach has been used to find the relation between the visually interpreted number of tents and the automatically extracted structures for the random sample. Based on that function the total number of tents for the entire camp is estimated. Since the goal of this study is to develop a robust methodology that provides stable results in different environmental conditions, the regression model uses the numbers of dwellings (independent variable) and relates this to the visually interpreted number of structures (dependent variable). Using this approach overcomes the problem with false positive results (brighter dry soil and track along the roads have been detected as single dwellings structure) and false negative results (structures which are close to each other or attached have been detected as a single structure). The stability of the regression model was tested using different numbers of samples for calibration and validation, respectively. The number of samples ranges from 10 to 90% with 10% intervals. The remainder of the samples was used for validation. Each model was repeated 500 times with a different random selection in each run. The final regression coefficients for the estimation of total number of dwellings in the camp are the average of coefficients derived in each step.

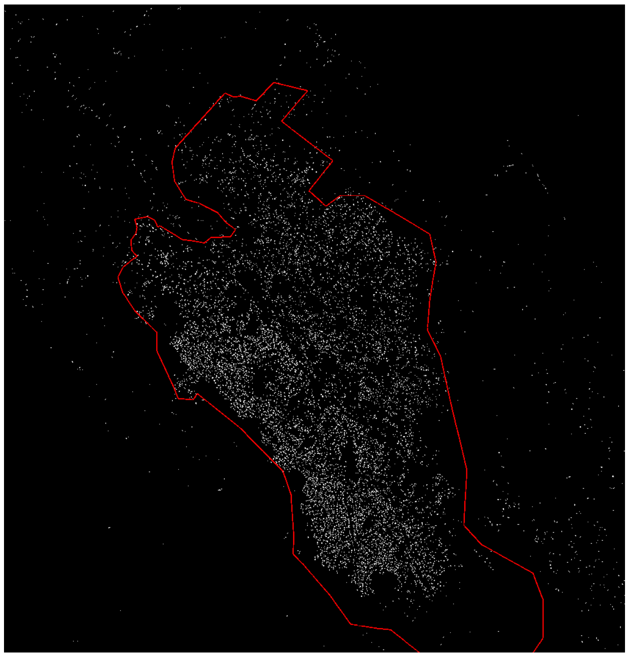

Figure 6: The automatically generated binary mask of dwelling structures with the camp outline.

4 RESULTS

For the random selection approximately 5% of the cells were selected, in total 77 cells. The total number of tents marked in visual interpretation process in the randomly selected cells for the camp area was 1,035 (see also Table 2). Figure 6 shows the final binary mask for the IDP camp with the automatically extracted bright structures. The mask highlights clearly the camp area. Lack of the automatically extracted tents can be observed in the southern part of the camp due to the fact that this area was inhabited after the 10th of May 2009. Objects outside the camp area are mainly dry soil (bright sandy ground) surrounded by darker vegetation.

The number of tents was derived automatically for the area inside the camp borders. This was achieved by reducing each connected component of the calculated binary mask

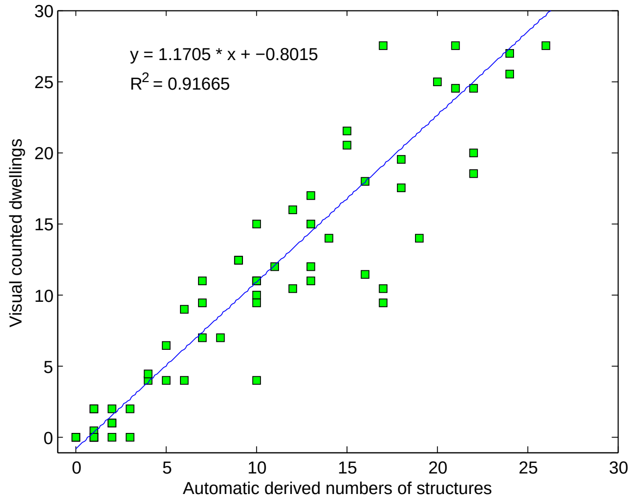

Figure 7: Comparison between automatically derived number of structures (method 1) and visually counted number of dwellings for the randomly selected cells

Table 1: Results for IDP Camp in Mullaittivu district: numbers based on automatically extracted structures (method 1) and regression based estimation (method 2).

IDP Camp	Method 1	Method 2
Mullaittivu	8,667	10,138

of dwellings to its centroid point and then counting the number of points falling within the camp polygon. Results are presented in Table 1, where the proposed automatic method is referred to as Method 1, and Fig. 7.

The regression model was first tested using different numbers of samples in the regression in order to identify a robust sample size with an acceptable maximum error. Based on Fig. 8, a model with 46 samples was selected. This model produced a mean error of 25 structures (4.5%) and a maximum error of 81 structures (8.7%) in the sensitivity analysis. The scatter plots of calibration and validation model of the regression analysis are shown in Fig. 9 and Fig. 10. The total number of dwellings for each camp are presented in Table 1 (here referred to as method 2).

Comparing the results of the automated dwellings extraction and the visual interpretation inside the randomly selected cells, an overall good match is observed (see table 2).

The correspondence between the automatically and visually detected tents was analysed by performing distance measurements. Four buffer zones with interval 1 meter were considered. The distance was counted from each manually marked tent derived from visual interpretation in randomly selected cells. The number of automatically extracted structures was grouped in the class corresponding to the intersection with each buffer zone. Figure 11 presents the results. 90 % of automatically extracted structures were detected in the distance range of 4 meters. Taking into account the average size of tent the acceptable distance between automatically and manually derived structures should not extend 2 meters, what gave us 83% of results.

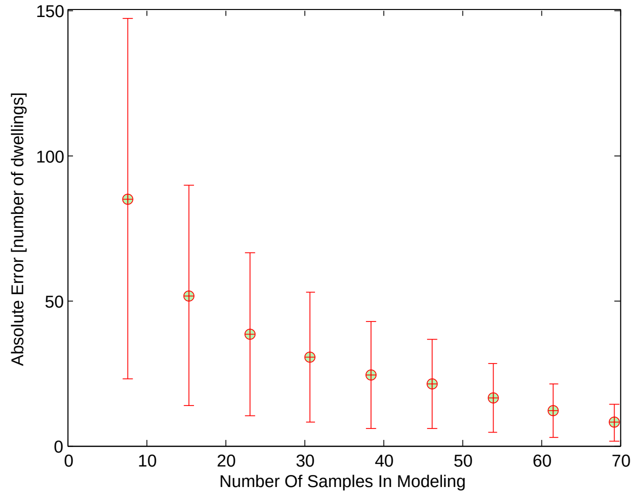

Figure 8: Sensitivity analysis of the regression model. The graph shows the mean, minimum and maximum error [number of structures] for each step based on 500 calculations.

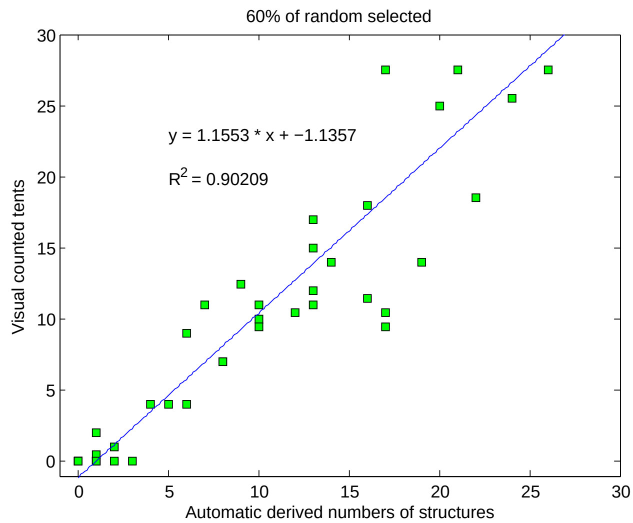

Figure 9: Calibration model for the regression between area of dwellings and visually interpreted number of dwellings per randomly selected cell. The model uses 46 samples (60% of the randomly selected cells).

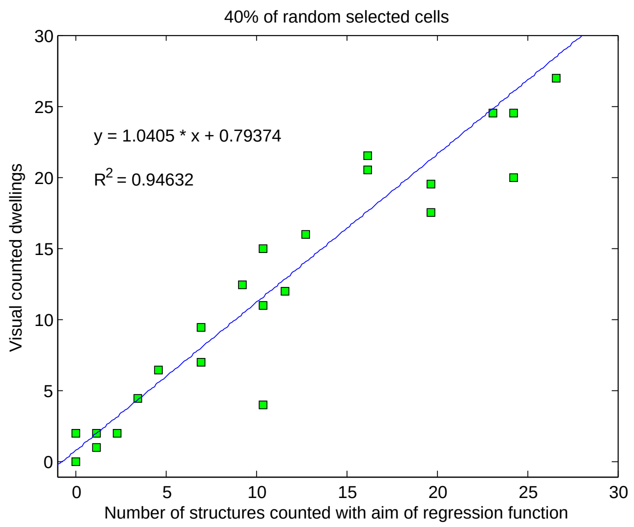

Figure 10: Validation model for the regression between area of dwellings and visually interpreted number of dwellings per randomly selected cell. The model uses 31 samples (40% of the randomly selected cells).

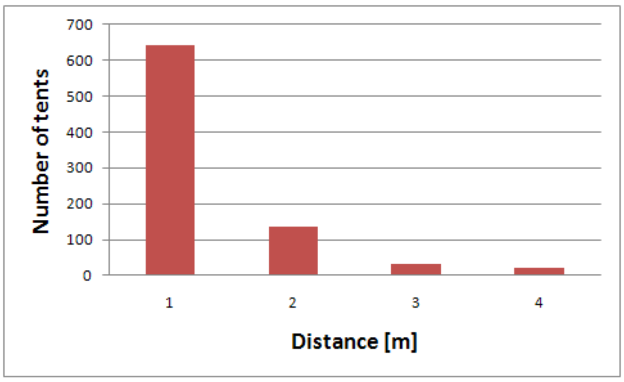

Figure 11: Spatial correspondence between automatically and visually detected tents. The centroid of the tents was considered for both the automatic and visual interpretation. The graph shows the number of automatically detected tent centroids falling within a distance buffer from the visually defined tent centroids.

Table 2: Comparison of visual interpretation and results of method 1 for the randomly selected cells inside camp

IDP Camp	Visual Int.	Method 1
Mullaittivu	1,035	937

5 CONCLUSION

The structure of the Mullaittivu camp consists mostly of bright rectangular tents. In the part of the north we can observe an area with a network of roads and houses. This latter were excluded from automated extraction, because they are not directly linked to the IDP population. Moreover this part of the camp is characterised by high density of tents. This made already the visual interpretation very difficult despite the spatial resolution of 0.5m. The results derived from automatic extraction and visual interpretation are matching well and are confirmed by an independent assessment carried out by UNOSAT, with the total number of 11,500 shelters (UNOSAT, 2009). It could be demonstrated that the implementation of a robust and consistent method for the estimation of the total number of dwellings is possible. The advantage of the proposed method is the limited number of parameters that have to be taken into account and the straightforward model development based on a verbal characterisation of the dwelling structure. This opens possibilities to adapt it easily to different environmental conditions. Additional information could be derived from the tents' shadow detection.

REFERENCES

Giada, S., De Groeve, T., Ehrlich, D. and Soille, P., 2003. Information extraction from very high resolution satellite images over Lukole refugee camp, Tanzania. International Journal of Remote Sensing 24(22), pp. 4251–4266.

Kemper, T., Jenerowicz, M. and Soille, P., 2009. Counting people in refugee/IDP camps in Darfur/Sudan: what error is acceptable? In: C. Corbane, M. Broglia, D. Carrion, G. Lemoine and M. Pesaresi (eds), Proc. of VALgEO'2009, European Commission, Joint Research Centre, pp. 153–155.

Soille, P., 2003. Morphological Image Analysis: Principles and Applications. 2nd edn, Springer-Verlag, Berlin Heidelberg New York.

UNOSAT, 2009. Newly erected IDP shelters located within New Safety Zone (NSZ), Mulattivu district, Sri Lanka. UNOSAT map. Product ID: 1359, 13 May 2009, GLIDE: SE-2009-000011-LKA, see also `http://unosat.web.cern.ch/unosat/freeproducts/srilanka/2009/Mulattivu/UNOSAT_SriLanka_IDPSheltersLocatedWithinNSZ_6May2009_lowres.pdf`.