Different Approaches for IDP Camp Analyses in West Darfur (Sudan) – a status report

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Abstract

In May 2009 the World Food Program (WFP) requested support for the estimation of population figures for three internally displaced person (IDP) camps in West Darfur based on very high resolution satellite data. Two of these camps are located close to El-Geneina, the provincial capital of West Darfur. Beyond the analysis of these camps the overall objective of the request was to assess appropriate methods and efforts for a frequent monitoring of all the IDP camps in West Darfur to be carried out by the European Commission Joint Research Centre (JRC).
In support of this task, the cluster *Humanitarian Relief & Reconstruction* of the GMES-Project LIMES (http://www.fp6-limes.eu/) was involved to jointly evaluating different approaches in an effort coupling classic production and R&D methods in close cooperation with WFP staff based in El-Geneina.
Analyses were performed using on the one hand, object-based image analysis combining segmentation, class modelling and knowledge representation techniques, while others were based on morphological image processing. For validation purposes statistical methods have been applied to compare the relative convergence of the results of all methods. In case of the future development of a transferable approach for building extraction, a validation based on ground truth data of several camps remains essential. This paper presents a status report of a study that has not been finalised yet.

1. Introduction

In May 2009 the World Food Program (WFP) requested support for the estimation of population figures for three IDP camps in West Darfur based on very high resolution satellite data. Two of these camps are located close to El-Geneina, the provincial capital of West Darfur.
Almost 50 % of Darfur's total population of about 6 million people were internally displaced by January 2009. An additional 250.000 people are living in refugee camps across the border in Chad (IDMC 2009).The estimation of the camp population is crucial not only for the management of the camps but also for the identification of potential sources of conflict. Beyond the analysis of these camps the overall objective of the request was to assess appropriate methods and efforts for a frequent monitoring of all the IDP camps in West Darfur to be carried out by the European Commission Joint Research Centre (JRC). In support of this task, the cluster *Humanitarian Relief & Reconstruction* of the GMES-Project LIMES [http://www.fp6-limes.eu/] was involved to jointly evaluate different approaches in an effort coupling classic production and R&D methods.
The same group of institutions[1] already analysed several IDP camps in West Darfur and Chad in 2008 based on requests from the External Relations Directorate-General (DG RELEX) and the European Forces in Chad (EUFOR) (Kranz et al. 2009, Kranz et al. 2010).
The idea of WFP is to launch a pilot-project for camp population estimate in three different camps of West Darfur, Sudan: Dorti, Ardamata and Um Dukhum. This case study is supposed to compare different methodologies for population estimation applied by JRC, DLR, SERTIT and Z_GIS. Later in the process, EUSC contributed with another monitoring applied to one of the camps. This study aims at a comparison of different approaches for IDP camp analyses to improve each of them and to finally come up with one that meets the requirements of WFP best in this particular region. The following chapters present a status report of an ongoing study. Due to security reasons GPS photographs were not provided yet and have therefore not been integrated into the analyses so far.

2. Situation and camps

Dorti and Ardamata are two camps almost connected to each other and about four kilometres north-east of the capital El Geneina. Due to the short distance to El Geneina these camps offer the possibility of field work under reasonable security conditions. The camp structures are similar and show living quarters consisting of huts, tents or tents covered by awning mostly separated by fences. Residential units are divided by small paths. The population estimate for Dorti is about 9,000 people and 27,000 people for Ardamata (WFP, unpublished). Um Dukhum is also situated in West Darfur about 250 km south of El Geneina close to the Chadian border.

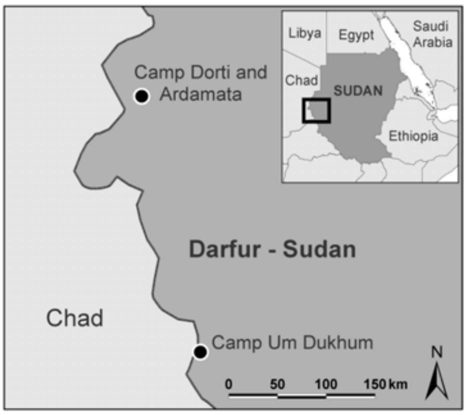

Figure 1. Overview of the IDP Camps analysed

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3. Data and Methods

3.1 Data

EUSC and JRC received two GeoEye-1 scenes (PAN, MSI) acquired on May 14, 2009. The data was delivered in WGS84, UTM zone 34 N with a pixel size of 0,5m. One image covers the camps Dorti and Ardamata as well as the city of El Geneina. The other image shows camp Um Dukhum. Administrative buildings, airfields, camp boundaries, road network and river network were extracted manually.

3.2 Methods

The first step of analysing remote sensing data is a visual inspection to get an overview and familiarise oneself with the area of interest. Based on this visual overview the camps are verbally characterised. This characterisation is used for a visual interpretation of a representative sample and it is translated in terms of image processing transformations enabling the automatic extraction of these dwellings. In this case visual interpretation was also used to create a reference dataset, since it was assumed being the most accurate method for extracting single buildings of the IDP camps and could serve for a comparison and quality control of the automatic approaches.

As reference, buildings of all three camps were digitised by DLR according to the following categories: huts, tents, large tents and other buildings (schools, local markets). The results are listed in table 1. In addition, two more visual interpretations have been carried out independently to get a better impression of the variance of results and an indication of the challenges to face with when doing the automatic analyses. The results of the different visual interpretations differ a lot from each other which is a considerable sign for further calibration not only of the interpreters but as well of the automatic approaches and stresses the need for profound ground truth information. Although ground control points were provided by WFP together with pictures for georeferencing they could not directly been used for calibration or validation purposes since just a few of them have been generated due to security reasons. However, the information supported the interpretation of building types and structures.

Table 1. Number of dwellings digitised as reference

	Dorti	**Ardamata**	**Um Dukhum**
Huts	2837	4588	10730
Tents	738	1701	3008
Large tents	17	5	385
Other	47	100	134
Total	***3639***	***6394***	***14257***

The results of the different automatic approaches carried out by DLR, SERTIT, Z_GIS, JRC and EUSC were compared to the visually identified dwellings.

Method 1

Method 1 is based on an object-based algorithm that was developed based on QuickBird data for the IDP camp Zam Zam in Westdarfur and reached very high accuracies for this particular camp. The intention was to apply this method to different camps and other very high resolution satellite data in order to test its transferability. The developed method uses the Definiens Developer software and starts with two image segmentations by analysing the homogeneity parameters “shape” versus “color” as well as “compactness” versus “smoothness” and two different scale parameters for each level. This local mutual best fitting approach (Baatz & Schäpe 2000, Benz et al. 2004) allows the analyses of very small objects, e.g. huts and tents as well as a quick classification of larger objects like wadis. The following steps include the identification and classification of huts, tents, fences and vegetation as well as wadis and urban areas in general. This procedure takes into account specific attributes of the objects like reflectance, indices, shapes and relations to neighbouring objects, but also leaves the opportunity to revise and refine the classification.

Method 2

This non-object based method was set up as an experiment to see how a relatively simple, pixel based, image processing method could lead to the mapping of buildings/huts within IDP camps. The idea was to compare this method with the most likely more sophisticated object orientated mapping carried out by our partners. A decision was made to be conservative meaning that it was decided to minimise the number of non building structures accepted as huts. This led to less roof surfaces being accepted as textural/spectral characteristics once they became mixed up with non roof surfaces. Hence, errors of omission were accepted more readily than commission.

This method involves textural enhancement, edge extraction, spectral and neighbourhood analyses. Neo-channels were developed to highlight and isolate certain spectral characteristics of particular building surfaces. Furthermore, pronounced edges were detected; their neighbourhoods' spectral and object sizes analysed. Blue-cyan, white, dark and brown buildings were extracted and then assembled together. Soil coloured and/or very small buildings were very difficult to discriminate with this method because the textural relationship of these buildings with their surroundings and their spectral characteristics were not pronounced enough. Again some of these could have been accepted but errors of commission would have increased beyond acceptable levels. Finally, it has to be stated that further work may help in improving the results.

Method 3

The method for extraction was originally developed for the Zam Zam camp in Westdarfur (Tiede & Lang 2009). Key element was the development of transferable, object-based image analysis (OBIA) algorithms for the extraction of different dwelling structures (Lang 2008). The rule-sets for information extraction were written using Cognition Network Language (CNL), a modular programming language implemented in the Definiens Developer software (Tiede & Hoffmann 2006). Rule-based classifiers are used for knowledge representation, making explicit the required spectral and geometrical properties as well as spatial relationships for advanced class modelling (Tiede et al. 2008). The latter enables operators for tailoring transformation of scene contents into ready-to-use information according to user requirements. Transferability has been improved by parameters mainly relying on spatial characteristics like shape, size, neighbourhood etc. and relative spectral differences between the delineated objects. In this case four different dwelling types were extracted (bright dwelling structures/tents; dark dwelling structures/

traditional round huts; corrugated-iron huts; and additional, not clearly assignable dwelling structures).

Method 4

The method is based on a translation of the visual characterisation of the searched structures into a morphological image processing chain. Two variants were tested. The first is fully automatic (Method 4a), while the second links the area covered by dwellings to visual interpretation results of representative samples (Method 4b).

Morphological area opening and closing suppress all bright and dark objects whose area is below a given threshold value (and considering a given connectivity rule such as the 4-or 8-connectivity). The suppressed objects are then retrieved by computing the difference between the original and the transformed image (top-hat operation) (Soille 2003). The union (i.e., point-wise maximum) of these 2 top-hat images correspond to an image containing bright as well as dark structures. The images were further improved using a filtering of the top-hat images and finally a thresholding of the previous images. The resulting binary mask still contains isolated trees since they correspond to dark structures in the panchromatic image. They are masked out by computing the intersection of the central point (centroid) of automatically extracted structures with the mask of vegetation obtained by thresholding the NDVI image computed on the multispectral image and resampled at the resolution of the panchromatic image (Kemper et al. 2010).

The second approach uses the previously derived dwellings in a regression to find the relation between the visually interpreted number of dwellings and the automatically extracted structures for a random sample. Based on that function the total number of dwellings for the entire camp is estimated.

Method 5

The method was based as well on segmentation. The objects produced were sliced in 4 different layers, grouped by reflectance in the infrared band. This was done to acknowledge the fact that, due to the different types of cover used by the dwellings, the refraction was different. Any filtering applied later based on the reflectance would run the risk of preserving one type of roof cover in favour of another.

Then, each of the object groups were filtered based on size, neighbourhood and reflection. All the information was integrated back together, simplified and smoothed.

4. Comparison of the results and Validation

4.1 Comparison to Manual Extraction

In order to determine the degree of accuracy of these different methods, the results were compared to the manual extraction of DLR, considered as "ground truth".

Figure 2 illustrates the comparison of the results of all applied methods with respect to the number of detected buildings. This comparison emphasizes the large variance amongst the results. The reasons will be discussed later in this article.

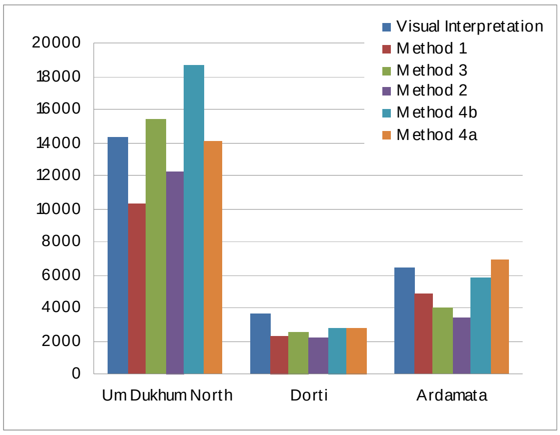

Figure 2. Comparison of the different results

Table 2 highlights the difference in the results between the automatic methods and the manual extraction of dwellings.

Table 2. Differences compared to the visual Interpretation

	Um Dukhum North	Dorti	Ardamata
Method 1	-27.9	-35.3	-23.9
Method 2	-13.9	-41.1	-47.3
Method 3	7.7	-30.6	-38.0
Method 4a	-1.6	-22.8	8.5
Method 4b	30.8	-23.0	-9.3
Method 5	-	-	-13.4

Figure 3 shows derived buildings by the visual interpretation (black points), derived dwellings by method 2 (purple polygons), derived non-dwellings (green polygons) and buildings missed out by the automatic method. This example shows that size as the only criterion for separating dwelling and non-dwelling can easily cause errors.

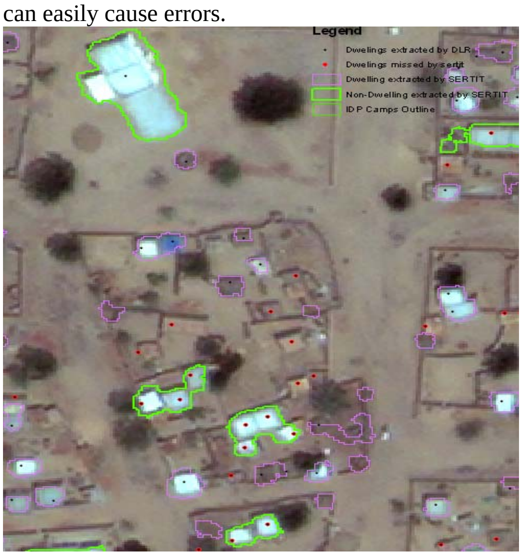

Figure 3. Example for comparing the different results

The results of method 2 show that about 50% of all buildings classified by the reference have not been detected. Missed out buildings seem to have similar refractions and shapes but since the percentage of these buildings differ from camp to camp, the accuracy also varies. Additionally this method classifies many buildings not indicated by the reference. These buildings turn out to be fences, shadows or bare soil (see figure 4).

Method 5 has the tendency to accept more false positives that the other methods. It is as bad to miss a feature that to extract something that is not. Unfortunately, the equilibrium between not missing features and not accepting errors is hard to meet.

Figure 4. Fences and bare soil classified as dwelling (green segments)

The number of correctly classified buildings by method 3 is higher compared to the results of method 2 and the number of missed buildings is lower for all three camps. Nearby dwellings are registered separately and single buildings are classified correctly if they are dark or very bright. This method often does not classify buildings with similar reflectance to bare soil, but classifies buildings that do not exist. Not merging single objects can also lead to false building numbers.

4.2 Relative Comparison of the different approaches

The results were also compared statistically to provide numbers measuring the differences between the different approaches. The statistical comparison is relative among different sets of results, although one particular set, the manual extraction of DLR is considered as the "ground truth", even though a manual extraction is also subject to errors.
The statistical comparison is based on the overlap of one product into the other. This way, two perfect products would have an overlap of 100% both ways. Both ways means that each overlap has to be calculated twice.

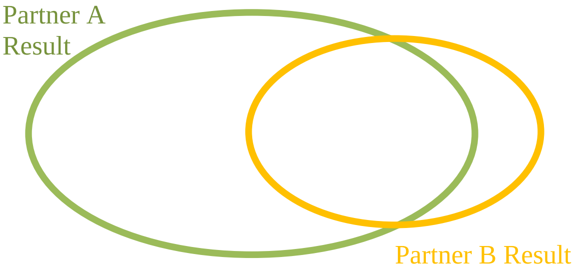

Figure 5. Scheme of overlapping of results

As visualised in figure 5, the results of one partner can be quite different. Whatever doesn't overlap might be either a false positive, or something detected only by that particular partner. As shown in the example, the overlapping of partner A means about a 70% of partner B total extraction. In the other direction, the overlap of partner B means roughly a 30% of partner A total extraction. This means that either partner B missed many building or Partner A committed many false positives.
Based on this, all partners' data were overlayed with each other, trying to find patterns that would allow determining the feasibility of the method. When overlaying the data, all extracted data from each partner were used, ignoring the different subtypes of information. The reason for this was that partners had classified the extracted data in different ways. Some partners discriminated the data based on reflectance, others tried to interpret the function of the building basing the analysis on the size. Figure 6 shows an overlay of the results of two partners for the same area as an example.
Figure 6.
As we pointed out, the DLR extraction considered in the statistical comparison is the manual extraction, considered also as ground truth. This extraction was performed using a point geometry, unlike a polygon geometry of the automated methods. In order to compare the Point geometry of DLR with the Polygon geometry of SERTIT, Z_GIS and EUSC, a buffer of 2 meters has been applied to avoid errors due to slight displacements.

Figure 6. Overlay of the results of two partners

The next graphs show the proportion of overlapping between partners in percent (figures 7 to 9).

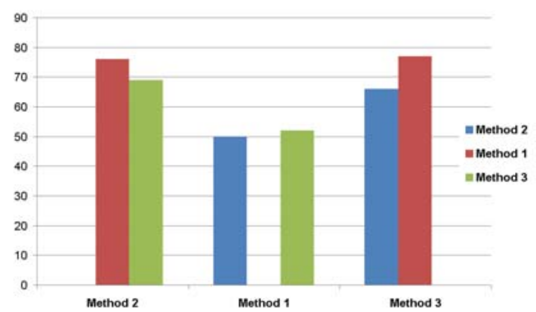

Figure 7. Comparison of results, Dorti

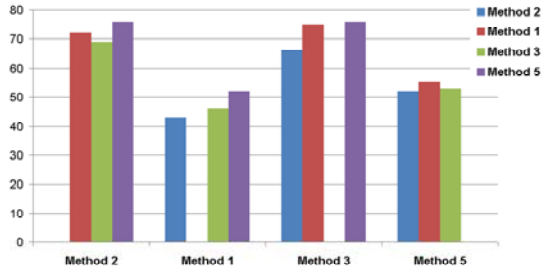

Figure 8. Comparison of results, Ardamata

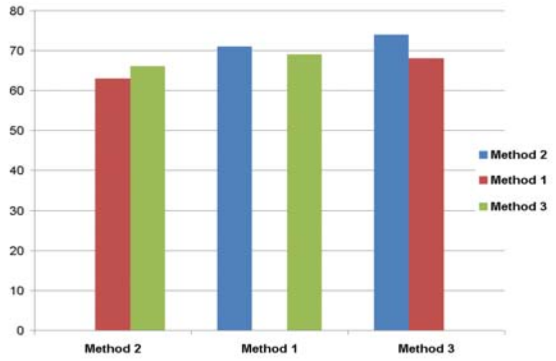

Figure 9. Comparison of results, Um Dukhum

These graphs show that:

- The results of method 2 and method 3 overlap about 50% of the manual reference in the camps of Dorti and Ardamata. In Um-Dhukum this overlap raises up to 70%.
- Method 1 overlaps about 75% of method 2.
- Method 2 and method 3 have a very similar overlap rate in both directions, about 70%.
- Method 5 was applied only to Ardamata. Each partner's result is well covered by the results of method 5, but the convergence is low when comparing the overlap in the opposite direction.
- Method 5 detected more dwellings present in the manual extraction, but resulted in more false positives.

The convergence of method 2 and method 3 is high and similar among them, but low compared to overlap with the manually generated reference. This indicates that both methods are somehow complementary (one method is finding what the other is missing). But both methods are running short in the total number of detected dwellings. Or the reverse is true, and the overlapping indicates false positives (both methods overlap on areas that look like dwellings, but are not).

In order to solve this question, we merged the data of both partners, and compare it again with the reference (table 3).

	Dorti	Ardamata
Reference overlapping combined result of method 2 and 3	62%	54%
combined result of method 2 and 3 overlapping reference	70%	68%

Table 3. Convergence of combined automatic methods

The results in table 3 show very similar values to the results of comparing single methods to the reference (table 2). This might be an indication that the overlapping part of method 2 and 3 which does not overlap with the reference is probably sharing false positives. This would mean that the combination of both methods would not improve the automatic extraction as supposed above.

5. Conclusions & Discussion

Remote sensing offers a promising way of analysing IDP camps and the information gathered can be an important contribution to logistical issues of relief organisations. Optical satellite data can be used for an extraction of camp extents, infrastructure, numbers and types of buildings as well as population estimations and monitoring of IDP camps and their structures. Nevertheless, visual analysts as well as developers of automatic methods encounter several challenges classifying buildings of IDP camps in environments like Darfur. Structures and materials of traditional dwellings are often indistinguishable from the ground and no information can be given whether the detected structure is a building or for example fenced space for goats. Using remote sensing data only it is almost always impossible to identify the function of specific buildings (storage, housing, etc.) and therefore it is difficult to classify the buildings correctly. The same is true for the number of people living in the dwellings at a given point of time.

Occupancy levels can only be at best interpreted or derived from ancillary sources that are not often very precise. This kind of work can then lead to scenarios that could help in camp management and planning. This couple with other post-disaster assessment work in LIMES where it is pointed out that combining in-field and remote sensing derived information can create good synergies.

It has to be considered that automatic algorithms always have to deal with the above mentioned difficulties in separating different objects in the imagery. Automatic approaches classify a certain amount of buildings correctly. Of course some buildings are mixed up with bare soil or shadows and will therefore not be detected as a single object. These errors are not constant and vary depending on the camp structure as well as on the satellite data. For example, different structures and environmental characteristics between Dorti/Ardamata and Um Dukhum can be observed highly influencing the automatic analyses.

As already mentioned it is often difficult to identify buildings as such and in case of complex building structures they might be split or nearby buildings might be merged into one large building falsifying the quantity of buildings. This results in an overall number of correctly classified dwellings that is below the expectations. Nevertheless, with respect to the overall goal of providing reliable estimates of population living in the camps the detection of single dwelling structures has just a minor priority.

The strength of the automatic feature extraction is based on the possibility to maintain a homogenous level of quality among all locations, not depending on the expertise of manual interpreters.

Automatic feature extraction will always be limited to the feasibility of extraction. If something is hard to extract to the human eye, it will be probably impossible for the automatic procedure. Automatic extraction works good when the complexity of work is simple, but too vast to be tackled by manual interpreters.

It has to be mentioned that the described analyses supported WFP in getting population estimates for a certain point of time without taking the risk of gathering these information directly in the field. Even relief organisations have to take the security aspects of conflict areas into account. Food and medical support are highly valuable in conflict situations and real circumstances are often hidden in order to get surplus of relief materials that can later on be used as tokens for interchange, hence taking it away from other IDPs that could need it. All information gathered remotely is information that was obtained without risk.

However, the estimation of population figures would highly benefit from ground truth information such as GPS photographs. This “real world” information would definitely improve the automatic detection algorithms and would result in much more reliable estimates.

IDP camps in Darfur are spread across a large area and each camp has to adapt to the different natural conditions. These conditions influence the materials some buildings are made of/covered by and the structures of the camps. The structures also depend on the political and historical background of the camps. Each camp has a different size; building density, sizes of buildings as well as the amount of certain buildings and the arrangement vary even if the traditional way of building residential stays mainly the same.

By covering a large number of IDP camps it is likely to receive very high resolution data of different sensors. Each sensor has its own characteristics displaying the situation in field. These characteristics have to be taken into account for the development of automatic methods and have to be adapted for each dataset. All the presented methods have already been tested on different IDP camps and with different sensors but there is still some space for further improvements with regard to a fully automatic analysis approach.

Under a time perspective, automatic methods are necessary for transferability to a larger scale. If it is true that the creation of one model will take as much time as manual extraction, other camps in the same region will require little change in the algorithms. In a scenario of time series monitoring, the same setting will work with almost no changes for the same camp in a different moment. The challenge is to identify parameters that can easily be adapted to other camps.

These aspects make it almost impossible to define constant rules for a transferable classification taking into account characteristics like reflectance, building size and proportion or distance. Even within one camp classification results can be non-uniform if one part of the camp shows different characteristics compared to another one.

In case of the future development of a transferable approach for building extraction, a validation based on ground truth data of several camps remains essential.

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