SEMI-AUTOMATIC OBJECT EXTRACTION – LESSONS LEARNED

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ABSTRACT:

This paper summarizes experiences and views gained through development and application of semi-automatic object extraction and gives recommendations for further developments. The last decade has seen a lot of research efforts in the field of object extraction from aerial imagery and digital surface models from airborne laser scanning. Despite these tremendous efforts, very few approaches are commercially available and used in practice. There are probably many reasons for this. Amongst others we can find: economic crisis of many states and cities and a general decrease in photogrammetric applications in many countries, which are both external factors and hardly can be changed, but which increase the need to look for new markets. On the other hand, we can observe internal problems as well: too high expectations which are not fulfilled, quickly changing focus in developments on automated feature extraction modules for real world applications, lack of standards, few empirical comparisons etc. In this respect there is a need to bundle expertise and resources and ISPRS and EuroSDR (European Spatial Data Research, formerly OEEPE) are two organizations, that are capable of providing the necessary platform to give a new push to research and development in reliable automated feature extraction.

1. INTRODUCTION

In practice the extraction of topographic objects from images for generating and updating GIS databases is carried out interactively based on mono or stereo plotting. By the tremendous success of mobile phones the need to have real 3D data in city areas had put a big push to photogrammetric applications and to research and development. Having made digital orthophotos, aerial triangulation and to a certain extent also the DTM matching more or less automatic, the automation of feature extraction is still unsolved and thus interesting for research.

Numerous efforts have been made in the past to automate the acquisition of point, line, and area features in aerial imagery. Overviews are e.g. given in (Gülch 2000, Grün & Baltsavias 2001, Ohlhof et al. 2000). Fully automated (autonomous) systems, however, are until now in the research stage or can be only used for limited purposes (Grün& Baltsavias 2001). Semi-automatic systems are e.g. described in (Gülch et al. 2000, Gülch&Müller 2001, Inpho 2004, CyberCity 2004, Ulm 2002).

This paper summarizes experiences and views gained through some years of development and application of semi-automatic object extraction. The program inJECT has been introduced by Inpho GmbH some years ago to open the field of semi-automatic object extraction with a focus on the extraction of buildings from aerial imagery. This software has lately been enhanced substantially to include other objects as well. A specific application is described in (Ohlhof et al. 2004) with very advanced automated tools.

We will present some of the basic features of this software and include them in our discussion on lessons learned. Finally, conclusions are drawn and recommendations are given for further developments in this field.

2. SYSTEMS AND DEVELOPMENTS

We have seen more than a decade of development in automated feature extraction in photogrammetry with numerous efforts on a broad range of applications, but despite high expectations after the good experiences with e.g. automatic aerial triangulation, there are practically only three or four commercially available systems on the market that are specifically designed to deal with photogrammetric automated feature extraction for a wider range of applications and a wider range of objects (cf. Gülch et al. 2000, Gülch&Müller 2001, Ulm 2002). Some specific semi-automatic object extraction systems are used by institutions for own production purposes and are not for sale. Concerning the automated feature extraction there is a tendency for stand-alone modules, which are not depending on stereo viewing capabilities. Lately there is a trend to support the extraction of a variety of features, not only for buildings, but also linear or area features. With some few exceptions we can not find classical Digital Photogrammetric Workstation extended with substantial modules to support semi-automatic feature extraction. This puts several questions: Is there no market, are the tools not good enough, or?

> LESSON 1: Despite the huge expectations, feature extraction has so far not attracted enough attention or even succeeded in practice like e.g. automatic aerial triangulation. The reasons for this can be partly found below.

2.1 Where are the users?

One aspect is certainly the decline in economics for many cities and states. There are also the current problems of major players

in the mobile phone market which were pushing the development of automated methods rather hard and many pilot projects were performed, but with some few exceptions the major parts were performed with classical stereo measurements. We can see applications of semi-automatic methods in the private sector focusing on small building projects in central city areas for planning purposes or on larger downtown areas for animation purposes, but very few cities have so far gathered their own 3D city models for planning purposes. It is often bound to the mayor or a certain city department to push this development. In this regard it is a difficult business rather than a common trend on the geoinformation market.
Some state authorities focus on parcel and road extraction in high resolution satellite data or on building extraction in aerial imagery and are using building models as control structures for automated image orientation. The good news is that automated feature extraction is increasingly used in education on university level.

2.2 Commercial systems and research

Most of the approaches presented in the first “high” time of research on feature extraction from Aerial and Satellite data and Laser scanning DSMs (e.g. Grün et. al. 2001) have not reached a practical level, but have disappeared completely due to the end of a research project, change of staff or interest.
Other reasons were the often not very practical requirements of some research prototypes, like e.g. 6-8 overlapping excellent photographs in colour. This is simply not realistic in practice and these huge extra costs were never really justified by overwhelming results and empirical proof. Another reason was in most cases the lack of reliability. Algorithms which fail when changing to a new set of real input data are not useful for cartographic feature extraction at all. There was quite late an insight of Computer Vision people, that full automation does simply at the moment not work for real world applications, so they changed to semi-automatic approaches, but adapted very quickly and showed very promising results. Another observation is still the lack of editing tools in the so-called automatic approaches to finalize the job, when automation did not succeed.

> LESSON 2: Full automation of cartographic feature extraction is not yet possible. Semi-automatic systems assisted by an operator seem to be the best solution for the near future. Editing capabilities of results are an indispensable requirement.

2.3 Modelling 3D worlds – Standards?

Other major obstacles encountered were the problems of missing standards for 3D modelling in GIS and CAD, but simply also the lack of standards for the orientation data of input images.
The standardization in this field is something which must be urgently attacked by international organizations and vendors. It is only economically acceptable if there a handful of standards for image orientation data to be addressed by the vendors. In this respect EuroSDR has taken an initiative and opened a project on InterOCI - Interoperability for Orientation and Calibration data of Photogrammetric Images (EuroSDR, 2004).
Concerning the output the implemented GML functionality is regarded as the most feasible solution in the future as it allows the storage of geometry, topology and thematic features in a common framework, which is not possible by DXF and other CAD formats. Especially for the integration into a distributed web architecture GML is the preferred exchange standard for services like the Web Feature Service (WFS) of the Open GIS Consortium (OGC). In this context a Special Interest Group 3D of the GDI in Northrhine-Westphalia (SIG3D, 2004) is elaborating on 3D standards and visualization, which is increasingly asked for by many users. Detailed geometrical-topological base models and LoD definitions have been elaborated and are tested in 3D pilots. An interesting extension is the automated linkage with terrestrial sensors (cameras and laser), which should be one of the major research issues for the forthcoming years.

2.4 Automated modules for feature extraction in digital aerial imagery

inJECT (Gülch et al. 2000, Gülch and Müller, 2001) was originally designed for semi-automatic feature extraction in aerial imagery. It has been substantially improved not only to be able to support parametric 3D building models, but also polyhedral objects. Figure 1 shows the Senaatti test site of EuroSDR´s project on building extraction. Two students have derived the complex buildings in 3D using a pre-release version of inJECT 1.9. The result is shown in Figure 2 as a textured VRML model.
inJECT has been lately enhanced by automated modules for linear and area features specifically in orthophotos and geocoded satellite imagery. They are described in more detail in (Ohlhof et al., 2004). In addition to this the introduction of attributes is now available. inJECT is used by companies and administrative authorities as well as in academia for teaching purposes.

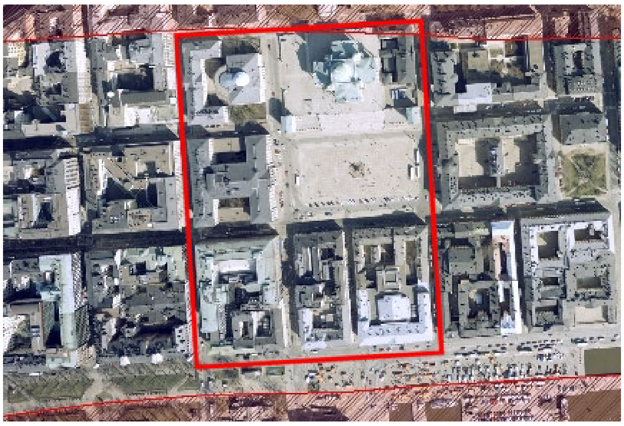


Figure 1 Senaatti test site of EuroSDR´s building extraction project.

Concerning area features an approach has been implemented in a special version to automatically derive the outline of areas in orthophotos by giving only a start polygon (e.g. triangle) inside such an area. The approach is a combination of deformable models and region growing techniques in a statistical framework under the Minimum Description Cost environment. This approach is called region competition. In a final processing step the parcel contours are smoothed. An example of a start situation, the result of region growing and a final generalization of the contour is given in Figure 3. Other parcels are shown in Figure 4.
The tool for the measurement of linear features (in particular road networks) is based on a line tracking algorithm, where the user first defines a starting point and the measurement direction in the image. After that the procedure starts and measures automatically points along the middle axis of the particular line.

Existing lines and crossings are snapped and nodes are generated, leading to a topologically connected network, which is very important in the case of road network.
The user is supported by a traffic light implementation which informs about problems encountered in the extraction process. The lines are smoothed and the average width of the line segments is computed automatically. The resulting topologically connected road network is smoothed and the operator can key in or select missing GIS attribute values.

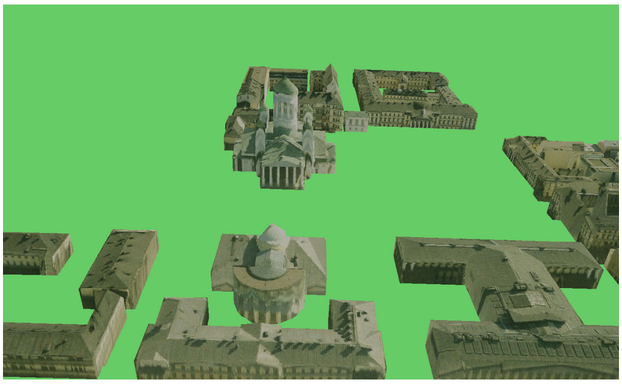
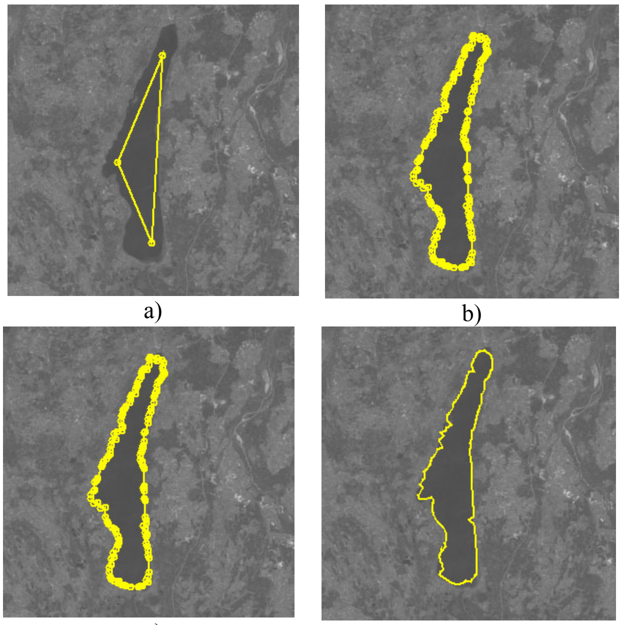


Figure 2 3D VRML model derived with inject of a part of Senaatti test site (by A. Novacheva and S.H. Foo)



a) b) c) d)

Figure 3 2D-parcel extraction for a lake feature in an IKONOS scene. a) Start position by operator. b) Result after first run. c) slight improvement after 2nd run. d) Final result with strong generalization.

An example of linear and area features extracted in an orthophoto from an aerial image is given in Figure 4. Existing vector data can be imported via a GML2 format using a GIS import filter. Besides geometry the imported GML data contains complex information about feature semantics, which is read by inJECT as well.
The feature extraction on line and area features can be done in digital orthophotos for the capture of 2D GIS vector data as described above. In addition, the software is available for the capture of 3D features using oriented aerial imagery. Here the automation part consists currently of the on-line z measurement functionality which automatically derives the height of each vertex point of a line feature or the contour of an area feature. The automated algorithms have been extensively tested with IKONOS 2 and IRS satellite imagery as well as with orthophotos from aerial imagery.

Figure 4 Linear network and area features in an orthophoto derived from an aerial image. Features (blue for water, green for fields, red for settlement, yellow for roads) have been derived semi-automatically.

If we look at other automation approaches we can see, that new feature extraction modules offered for integration into existing platforms often lack standards for exchange and/or they lack practical feasibility tests on a larger variety of input data.
The usage of colour imagery is not yet fully exploited. The usage of existing ground data, often propagated, is in many cases not feasible, as economically too expensive and for nationwide applications in federal states much too complicated due to too many standards. There are increasing efforts to fully automate road extraction from aerial imagery, but there is no broad application on the horizon except for some specific authorities or agencies. However, if using high resolution satellite data, like Quickbird2, Ikonos2 or IRS there is a need for automated road extraction and parcel extraction. inJECT has been extended to those object types and allow their derivation in ortho images in a semi-automatic fashion. There is a need to add new modules to those procedures to further increase the amount of automation. These could be partly based on interesting research results concerning vegetation extraction depending on public acceptance and potential users.

LESSON 3: Semi-automatic feature extraction from digital aerial imagery is introduced to practice. The extension to a wider range of features is important. The testing of new automation modules for practical applications requires a good platform which allows easy implementation and easy integration as well as full control and checking capabilities in empirical investigations.

2.5 Feature extraction in digital surface models

There seems to be a new push for the development of feature extraction by using airborne laser scanning data and possibly imagery for extraction. However research is mainly focusing on full automation which is not very realistic in our experience and should be directed more to a stepwise semi-automatic approach. The usage of existing ground data (footprints of buildings), often propagated, has shown extremely good results, despite still required substantial editing efforts. The major problem with this approach is the dependency on map data which is in many cases not feasible, as already discussed above.

It should be also noted, that airborne laser scanner data has limited XY resolution and requires reliable automatic break-line detection for usage in urban areas, if no ground information is available. Such break line detection can be combined with analysis of image data to support the hypothesis when checking for edges in the aerial imagery. As classical film cameras are not practical to fly in parallel to laser flights which require usually flying heights below 2000m above ground, the focus is on the increasing usage of small to medium format digital airborne cameras on the same platform. A seldom discussed issue is also the usage of the intensity "image" of the laser system, which has of course a low planimetric resolution, but which can provide substantial support for the feature extraction (Arefi et al., 2003).

> LESSON 4: The usage of airborne laser scanner data can increase the automation, however, currently depends on existing map data or tedious manual delineation of building footprints. Using laser scanner data alone is regarded as not sufficient to solve the derivation of features in complex areas in practice, the current development aims at sensor fusion with digital images. First examples of automated breakline detection are available.

2.6 GIS Interface

For the handling of the GIS vector data an interface between inJECT and the GIS software packages Dynamo and GeoMedia (Intergraph) has been developed in a special version (Ohlhof et al., 2004) based on the GML2 format standard from the Open GIS Consortium (OGC). With this interface the vector data and the associated XML schemes can be automatically imported and exported. Imported features can be edited within inJECT, the user can modify the geometry and can select or key in the attribute values of each GIS object.

For the import of GML data into GeoMedia the existing GML data server can be used, whereas the export of GML data from GeoMedia can be carried out with Intergraph's GML export module. The resulting GML can be transformed to DXF or VRML using XSLT stylesheets. In case of a 3D extraction GML3 is offered by inJECT without a specific interface to GIS. GML can be applied for interoperability between different organisations and companies, which has already been successfully tested.

> LESSON 5: There is an uncertainty on how to model buildings and how to store this data in a GIS or CAD system. It is certainly advantageous to have a defined standard for this, which does not exist yet. However, the GML 3 standard defined by OGC seems to be a vehicle for a broad range of users.

2.7 Empirical investigations and comparisons

There is still a great lack of knowledge on performance of such systems in various image scales and object densities. EuroSDR has started an initiative to investigate the current status of automated building extraction in this respect (EuroSDR, 2004). Four data sets with aerial images, laser scan data and building footprints have been provided to test feature extraction from aerial images and digital surface models.

ISPRS has several working groups dealing with those issues (e.g. Sithole and Vosselman, 2003). ISPRS WGIII/8 works on the reliability and performance of algorithms and which has prepared comprehensive test data sets with ground truth information (ISPRS WGIII/8, 2004)

There is also an observation, that many users simply want visualization results and do not aim at the highest possible geometric quality, which in turn is not supporting the need to really look at those geometric aspects in more detail. But there are not even comparisons on the efforts needed to measure buildings or parcels with different tools. Requests are made to measure 100 buildings, but a description of the level of detail is missing, or there is no information on complexity of buildings or density. Sometimes the information about the number of measured buildings per second is only an academic issue, as it might take much less time to measure those 100 buildings in a stereo model, compared to the time to get access to the orientation data of those images or the GCP´s to orientate the images in a digital photogrammetric workstation.

> LESSON 6: The investigations conducted by organizations like ISPRS or EuroSDR should be supported much more by agencies and companies. It is vital for further success, that there is a thorough evaluation of the performance on an objective basis.

3. DISCUSSION

Some few software developments in automated feature extraction have been implemented as commercial systems. They have shown that there is a potential on a small but growing market. It is recognized, that there is a need for further development adapting to currently developed standards. inJECT as one example has been substantially extended with new automation modules and a strong GIS interface. Not only inJECT, but also other systems have shown, that the concept of semi-automation is excellent for practical applications, as there is always an editing option, if some automation fails due to low image quality, disturbances and other effects. The extraction of complex polyhedral roof structures in inJECT is now highly supported. The possibility to measure roads and parcels with a high level of automation has substantially increased the applicability for a wide range of users. The automated 2D extraction modules used for that purpose has been tested with several types of satellite imagery having a ground pixel size of 0.8 to 5 m as well as aerial orthophotos of about 0.5 m ground resolution. The operator is well supported during the measuring phase. In case of the road tracker, a traffic light approach is used as guidance. The software has been proven to be an excellent platform to add and test external software modules that increase the automation level significantly. By adapting the OGC-defined GML standards the field for future applications is wide spread. Compared to many GIS systems inJECT has major advantages in data capturing and editing especially in 3D. Since there is in 2D and even in 3D extraction no need for stereo viewing, the system is more open also to professionals outside the photogrammetric world which have here an easy-to-learn tool at hand to carry out basic feature extraction tasks with high accuracy and reliability.

4. CONCLUSIONS

We can summarize the experiences during the last decade with the following statements:

- The semi-automatic approach has proven to be the right way for practical applications. Also nonphotogrammetrists can measure buildings, bridges, streets and parcels, if provided with easy-to-use interfaces.

- Very few research efforts have found their way to a commercial system. This is surprising, but most efforts have been put either to unrealistic full automation or to improve GUIs, input-output functionality and not to extend basic kernel software for automation.
- The lack of standards for object modelling still hinders a wider range of applications and the exchange and re-usage of 3D data, but emerging standards like GML3 could fill this gap.
- There is still no common language or model for a building, but initiatives like SIG3D allow deep inside and provide excellent ideas in this context.
- There is an increasing tendency to rely on unrealistic types and amount of a priori information for real work applications. If the approach is too limited the usage for nation wide or world wide application is limited as well. There can be observed a new promising trend to use image analysis to support the feature extraction in airborne laser scanning data.
- It is still completely unclear, how updating of 3D city models is to be performed. Some first ideas and approaches have been presented, but real world experience is not yet gathered on a broader scale.
- There are some few empirical investigations on international level to test and compare feature extraction software in an independent way. Organizations like ISPRS and EuroSDR should be supported much more to conduct those tests and to be able to disseminate the results. With additional help those organizations larger empirical tests can be performed, which have shown in the past the tremendous impact like in automated AT and direct georeferencing.

There is on-going research and development in automated feature extraction. New ideas are presented and it seems that a new step of development has been reached to combine new resources and groups to work together towards the common goal of a reliable automate feature extraction from aerial imagery and airborne laser scanning data.

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