

3D data acquisition and modelling in a Topographic Information System

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ABSTRACT

The acquisition of 3D data and their integration in information systems which are mainly used for topographic issues are very increasing in the last years. The enlarged needs in 3D information appear with the development of the complexity of the processings in topographic information systems. The middle-sized and big cities, which have a large extent, have also important care for fitting out and want to dispose and make use of as complete as possible datasets. These datasets should integrate the third dimension.

For responding to such a sort of new needs, the group "Photogrammetry and Geomatics" of the LERGEC-ENSAIS Laboratory of the ENSAIS works in the definition and the testing a 3D modelling of objects in urban landscapes. This modelling is then implemented and tested in a topographic information system coupled with an experimental digital stereophotogrammetry software, TIPHON developed at ENSAIS. This digital system makes it possible to acquire rationally geometric data, and in the same way to learn the different steps of the orientation of the digital stereopairs and the processing of stereoplotting.

RESUME

La saisie de données 3D et leur intégration dans un Système d'Information à caractère Topographique est en plein essor de nos jours. Les besoins croissants en information à 3 dimensions apparaissent par le fait de la complexité croissante des traitements que l'on veut pouvoir réaliser avec les SIT. Les communes assez importantes ou ayant un développement important ont de nombreux soucis d'aménagements et veulent offrir aux bureaux d'études des données aussi complètes que possibles et intégrant notamment la troisième dimension.

C'est pour essayer de répondre à ce genre de nouveaux besoins que nous travaillons au sein de l'équipe photogrammétrie et géomatique du LERGEC de l'ENSAIS à la mise en place d'une modélisation tridimensionnelle des objets en milieu urbain. Cette modélisation est ensuite mise en œuvre et testée sur un système d'information topographique qui est couplé au système de photogrammétrie numérique, le logiciel TIPHON permettant une saisie rationnelle des données tout en permettant d'appréhender les différentes phases de l'acquisition de données par voie photogrammétrique.

ZUSAMMENFASSUNG

Die Erfassung von 3 dimensionalen Daten und ihre Integrierung in ein topographisches Informationssystem ist heutzutage eine immer mehr gefragte Angelegenheit. Der zunehmende Bedarf nach Informationen mit 3 Dimensionen liegt an die immer komplexeren Bearbeitungen der Daten die man von einem Topographischen Informationssystem erwarten kann. Die mittleren Städten oder die Städten die eine grosse Entwicklung oder Ausdehnung kennen brauchen für ihre Planung sehr genaue und komplexe Daten die in diesem Fall meistens auch die dritte Dimension einschliessen. Um solchen Bedürfnisse entgegen zu kommen arbeiten wir, in der Gruppe "Photogrammetrie und Geomatik" von dem LERGEC an der ENSAIS, an dem Aufbau einer dreidimensionalen Modelierung von Objekten in einer Stadtlandschaft. Diese Modelierung wird dann in einem Topographischen Informationssystem das mit einem experimentalen numerischen Photogrammetrie Softwarepaket TIPHON gekoppelt ist. Tiphon erlaubt uns die Daten rational zu erfassen und gleichzeitig die verschiedene Erfassungsetapen in einem numerischen Photogrammetrie System zu verstehen.

1 INTRODUCTION

1.1 Preliminary considerations

CAD tools in association with the tools of digital photogrammetry are currently very efficient and offer the possibilities to acquire, to reconstruct and to represent very complex and detailed 3-D objects. But the moving from a 2-D system to 3-D system is not a very simple case. In fact, in 3-D there are a lot of parts and faces which are not visible from any point of the operators or users view. In this case it is necessary to dispose in a full 3D system of tools for efficient 3D drawing and of tools that makes it possible to compute element by using extrapolation algorithms.

The operator who wants to acquire 3D data has to see the objects in 3D, has to represent them in 3D onto a 2D screen and has to be aware of the depth onto digital images. These different problems are solved by using CAD software which can represent complete 3D objects. In this case, the using of algorithms to eliminate hidden lines for example allows to distinguish and to be aware of the 3 dimensions of the objects. But these tools are wholly functioning only in the case of the objects drawn with strict specifications like the using of only solids or faces.

The meaning of these first considerations is that the representation of 3D objects needs a big work of structuration and reconstruction.

To reach this goal of having complete reconstructed and CAD compatible objects, the operator has to be supported in the different steps of 3D data acquisition.

- An example of this support can be the superimposition of the CAD drawing onto the digital images.
- A second way to support the operator during the data acquisition is to propose him the definition of a library of generic objects that are, for example, deduced from the geometry of the building rooftops.
- A last help to the operator can be the implicit structuration of these different generic objects, so that they are compatible with the system as soon as they are acquired.

1.2 The 3D objects in urban landscapes

Like in the aerial photographs used in photogrammetry, a 3D object in an urban landscape, even in a not very dense built city, has often hidden parts that can not be directly acquired. But in many cases the objects (for example the buildings) are composed of elements that could be easily rebuilt by using of extrapolation tools like horizontal or vertical projections, like orthogonality or parallelity constraints.

The tools of photogrammetry coupled with a CAD engine are in this case very interesting to be used. In fact, they allow in a first step to acquire interactively and in a easy way the "visible" parts of the objects, and then to achieve the reconstruction by using the 3D CAD tools and the extrapolation tools.

1.3 Workstation

In our project, we choose to work with the well known CAD software package Microstation from Bentley which is very well working in 3D and offers a large frame of 3D tools.

The Microstation environment is running onto the most of the computers platforms and is very efficient by using a PC with Windows 95 or NT. Like other CAD engine, Microstation can be coupled to external applications which can be used to the digitizing of the data points.

At the ENSAIS, in the "Photogrammetry and Geomatics" group we develop since 1996 a software application for digital stereophotogrammetry : TIPHON (Traitement d'Image et PHOTogramm trie Num rique).

This software application allows to realize measurements into digital images. This application will be described in a next section. It was at first developed in the goal of teaching digital photogrammetry at ENSAIS.

In our project we can use TIPHON to acquire the characteristic visible endpoints of our 3D objects in a scanned pair of digital images. In this way we can develop and test our system in a very simple PC environment.

2 THREE DIMENSIONAL MODELLING

The 3D modelling deals in the same time with geometric modelling, topologic and thematic modelling of objects.

2.1 The geometric modelling

The geometric modelling is based on a dominant hierarchical structure of complex objects which are composed and made (aggregation) of basic geometric elements.

The 3-D objects, which are in our case mostly building components or road infrastructures (bridges) are incorporated in a surface model composed of a Digital Terrain Model (DTM). This DTM is the ground surface onto which all the complex 3-D objects are projected. Some 3-D objects like buildings are completed under the DTM with an inferior ground surface that simulates the vault (Figure 1).

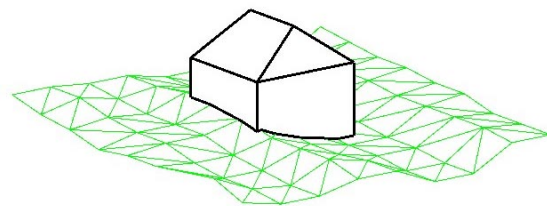


Figure 1 : DTM and a 3D object projected on it

The geometric modelling is realized by the using of a library of 3-D objects which is mostly composed with models of rooftops.

A building object is, for instance, an extrapolation (vertical projection on the DTM) of the rooves limits (Figure 2).

A bridge is constructed with a surface (runway) that has a thickness, and with pilars which are projected on the ground DTM.

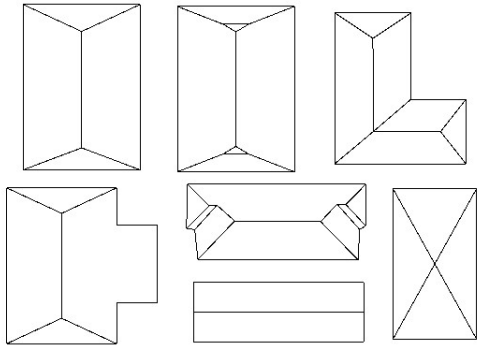


Figure 2 : Common models of rooves

2.2 The data acquisition

The data acquisition is done in two ways :

- In the first case, the objects are completely defined in graphic cells and are arranged in a library of objects. The operator has here to select the complex object with its geometry and the different associated themes. Afterwards, he has to pick up the geometry in the images of the real world. A second step consists to decompose the cells automatically into elementary objects and elements of objects. This first modus is used in the case of classical shapes. The acquisition of data is here very efficient but needs a long step for initial conception and modelling. This modelling will revolve with new classical objects or if the operator wants to enlarge his library of objects.

This acquisition is performed in the following steps :

- 1/ Creation of the object library. Each object has an implicit topology.
- 2/ Linking of the objects and components of objects with thematic attribute tables in a database.
- 3/ Acquisition of the complex objects in the way of the constraint determination.
- 4*/ Decomposition of the object into single elements.
- 5*/ Creation of the topologic relations.
- 6*/ Association between the object components and their thematic definitions.

(the steps followed by a * are made automatically)

- In the second case, the objects are not completely complexed, their aggregation is not totally predefined, and they are not stored in an initial object library. The operator has here to compose step for step the objects and the different themes that are associated to them. He can occasionally supplement the library of objects but this will need another long step of modelling. This second method is used in the case of non common and not repeating objects.
- For the acquisition of a particular, unique and specific object, there exists also the common way of acquisition which is used in classical G.I.Ss. The structure of the object is given them by following the steps described below :
 - 1/ Acquisition of the geometry.
 - 2/ Transformation of the geometric CAD elements into object features.

- 3/ Association of thematic attributes by using of links with a database.

Here we can only find automation by using of a codification or a classification of the elements which are based on the CAD attributes of the drawn elements.

2.3 The geometric data acquisition supported by the using of objects described by a generic shape.

2.3.1 Predefined ordered shapes

A first form allows to acquire these generic shapes by following a predefined order of points.

This is a fast method, but needs a great apprenticeship of the acquisition methods for the operator and needs, above all, the possibility to acquire all the points defined during the conception of the generic shape (Figure 3).

The operator has to insert the primitive in the ground coordinate system, to orient it and to redimension it by measuring its parameters.

This method is an efficient data acquisition method for none accurate but regular and basic objects.

All the generic shapes which are acquired in this way exist in two versions : in a first version, the shape is constructed with the minimum number of points, without any redundancy and no adjustment is available ; in a second version, the structural lines can be constructed and adjusted by using redundant measures.

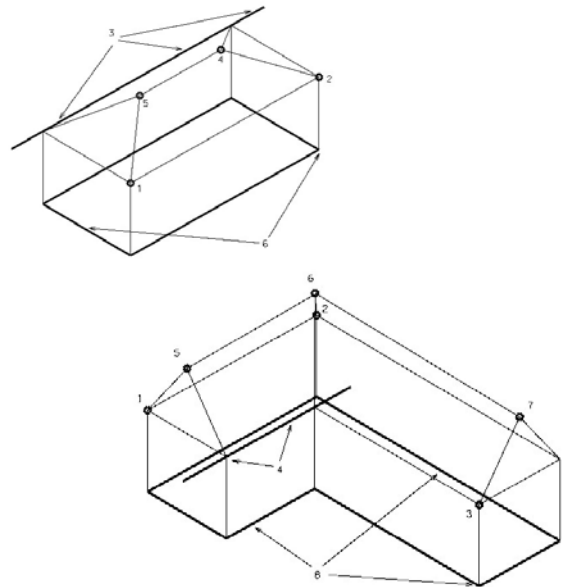


Figure 3a – 3b : Predefined ordered shapes

2.3.2 Constraint cells

A second way allows to acquire objects in form of constrained or dimension-driven cells. The cells are predefined in topologic terms of nodes, arcs, loops and faces. This approach allows to be independent from the order of acquisition of the object points or the parameters of the primitive (Figure 4).

2.3.3 Codified primitives

A last method uses generic shapes which are codified and in which the operator has to identify the significant endpoints or keypoints that he will measure on the real object. Each primitive includes characteristic elements and construction rules. This method of acquisition needs a great interactivity between the system and the operator. The acquisition of the data is interactively made by the identification of a constitutive element on a model of the codified primitive (Figure 5).

The interactivity could be very unefficient if it is used all the time. In another way, it allows to acquire objects without following the order that was predefined in the generic shape, and above all, it allows also to acquire the object even if not all predefined points are visible or measurable.

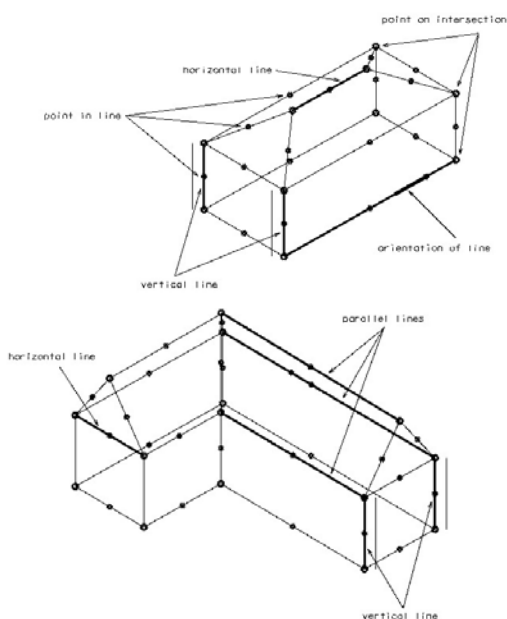


Figure 4a – 4b : Constraint cell

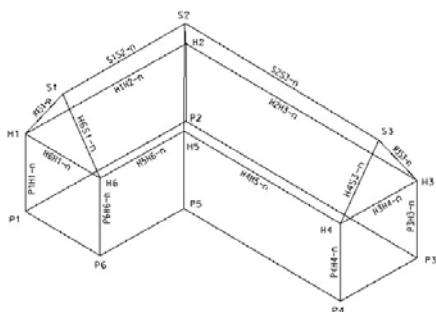


Figure 5 : Codified primitive

The two last approaches could be very efficient in most cases, particularly if the primitive can not be captured in one time because of failing of visibility in the stereopair for example.

3 THE THEMATIC MODELLING

The thematic modelling is implemented and tested by using a relational database. The generic shapes (complex objects) are structured as aggregations of objects and elements of objects which have themselves a thematic signification attached. At the time of acquisition, the operator has the possibility to redefine the thematic structuration of each object, but this will prejudice the automation of the acquisition. The modelling is applied to a testfield which is a part of the city of Metz (France) where we can find the most of the specific objects that constitute an urban environment. (see below the testfield).

The thematic structuration is defined into categories (set of objects with a predominant thematic). The different kinds of objects are classified in such a predominant thematic class, but this means not that the objects can not share different thematics or that the object components can not be connected to different thematics. A strict hierarchic structuration of the themes would be here an important limitation of the management possibilities which are offered by such a system. The objects which are classified into different categories enclose an own internal thematic structure which is also predominantly hierarchic. This internal structure is defined by the user at the creation of the different generic forms or step by step at the creation of a non previously registered form. An object instance can in this way contain object element from all, a part or none of the different hierarchic thematic levels. (Figure 6)

4 THE TOPOLOGIC MODELLING

4.1 The definition of the topology and its dimension

The topologic modelling is only realized for objects with a real third dimension. In reference to the following described testfield (see paragraph 6.2), the topologic modelling concerns in the general case only the objects of the categories 1 to 4 and 7 and 8. The topology of the elements of the first 4 categories (Relief, Hydrology, Roads, Vegetation) is a classical topology which has mainly 2 dimensions. The topology of the element from the categories 7 (Buildings) and 8 (Constructions) has 3 dimensions. The specific elements of the topology are nodes, arcs, faces and loops for the first categories and are completed with the bodies which concerne the second categories.

4.2 Topologic decomposition

In some cases, the topology is known in an implicit way because of the decomposition of generic complex objects as defined above. In this case, the creation and the recording of the topology is automatically performed. There exists a second way of topologic decomposition which works locally. Each 3-D complex object is automatically codified and topologically decomposed into nodes, arcs, loops and faces. This way of decomposition is running only in a local area but can take in account local adjacencies.

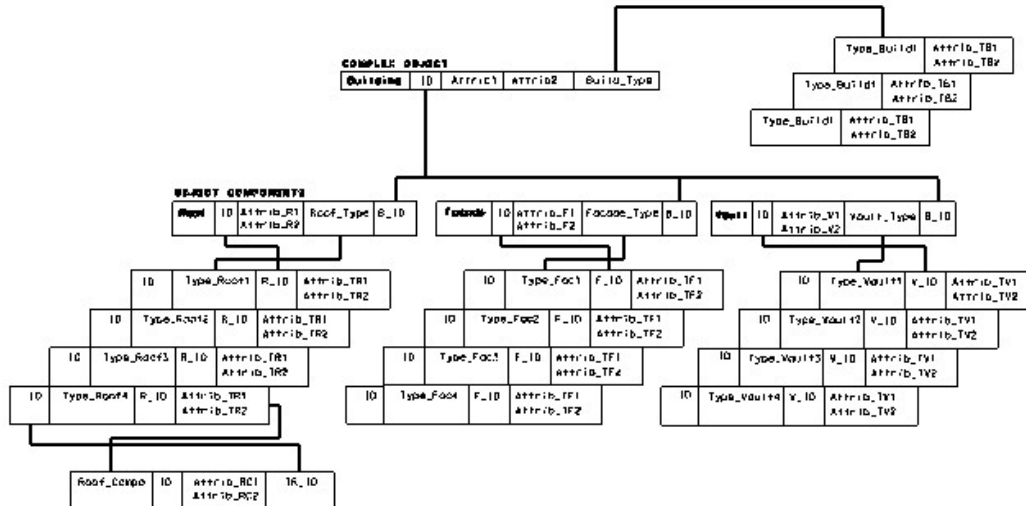


Figure 6 : Thematic structure

This topologic decomposition offers the possibility to create a file containing the topologic structure of a 3-D complex object which allows to manage the vicinity. At this time the topology is a redundant information. In fact, all the topologic informations are treated in a specific database which contains redundant information in comparison to the different design files.

5 SOFTWARE APPLICATION FOR THE GEOMETRIC DATA ACQUISITION

The data acquisition is realized by using an experimental, PC and Windows based system for digital stereophotogrammetry : "TIPHON" (Traitement d'Image et

PHOTogrammétrie Numérique) developed at ENSAIS. This system is used for the practical work of terrestrial and aerial stereophotogrammetry with all kinds of cameras.

In this study about 3D modelling, the objects are measured on aerial photographs at the scale of 1/2500. The TIPHON software allows the different steps of the orientation of a digital stereopair. The measurement on the images are manual or semiautomatic by correlation. The stereoplotting of points, lines and polylines is directly superimposed on the images on the screen. TIPHON is interconnected to the CAD-GIS software package Microstation/Geographics from Bentley where the modelling and the structuration are implemented.

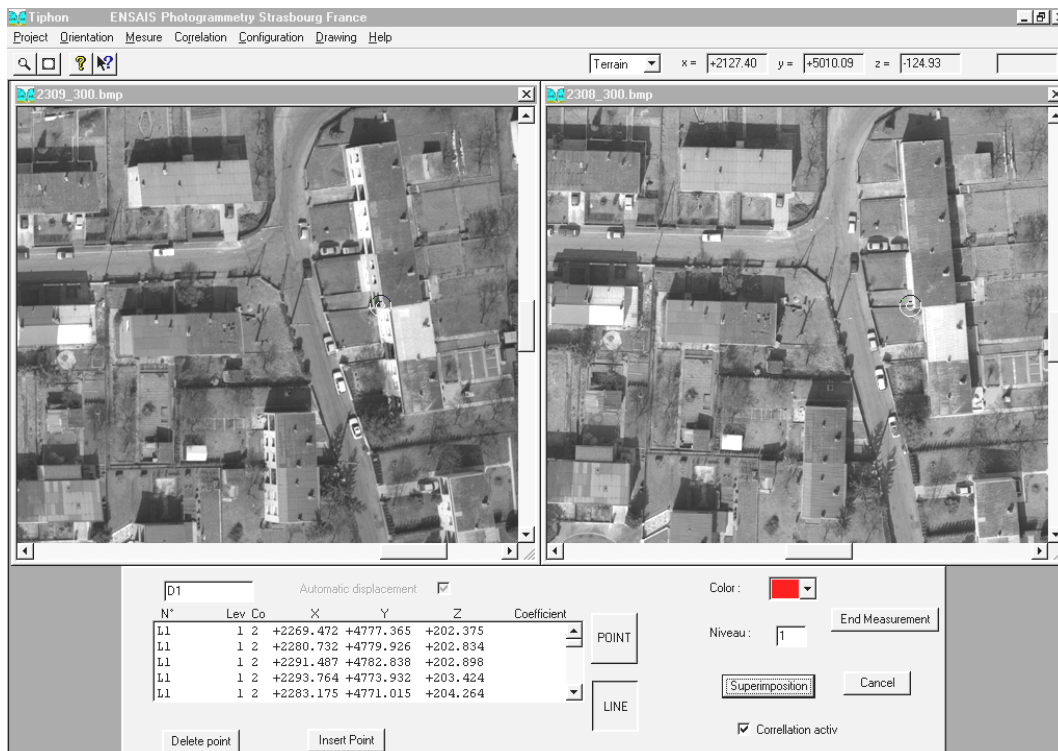


Figure 7 : TIPHON software for digital photogrammetry

6 TEST FIELD

6.1 Test field

To realize the tests of the different steps of the modelling and the data acquisition we use a test field from the city of Metz in France. For this area we have got a set of aerial photographs in the scale of 1/2500. These images have a relativ great scale. This allows us to acquire differents levels of details in the photographs. It allows us also to see very precisely what kind of problem we will encounter when we acquire 3-D datasets.

The test field has great height differences and encloses dense built areas, middle dense built areas and not build areas. It offers also great roads infrastructures.

In this test field, the 2-D elements were acquired by using an analytical stereoplotter ZEISS P33. These elements were directly structured into different levels.

The 3-D elements were digitized by using the TIPHON software and the different geometric, topologic and thematic tools described in this work.

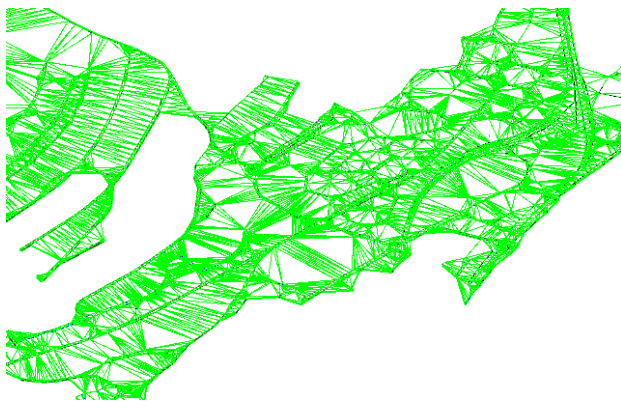


Figure 7 : DTM built from Relief, Hydrology and Roads

6.2 Modelling

For the thematic structuration of the project we have built 9 Categories :

- 1/ Relief (*)
- 2/ Hydrology (*)
- 3/ Roads (*)
- 4/ Vegetation (**)
- 5/ Signals (**)
- 6/ Urban furniture (**)
- 7/ Buildings (***)
- 8/ Constructions (***)
- 9/ Setting (****)

(*) The elements of the first 3 categories are used to build the D.T.M.

(**) The elements of the categories 4 to 6 makes it possible to ornament the 3-D visualizations by using 3D point and line objects but which have no real interests in 3-D modelling.

(***) The categories 7 and 8 contain the principal reasons of this work because they contain mainly 3-D complex objects.

(****) The last categorie offers the possibility of the representation and the geolocalisation into the workspace.

7 CONCLUSION

The integration of 3D instances of complex objects into a system allows to think about other new applications that are not available in 2D systems. But the complexity provided to the 3D system by this supplementary dimension is so large that we need to define new structures for the data. A great problem when we work in 3-D is the acquisition of data and their structuration.

To perform this very efficiently we need a lot of new tools for data acquisition, data structuring and data representation (Figure 8).

A software package TIPHON, for digital photogrammetry allows to acquire data in vector mode. A CAD engine like Microstation makes it possible to complete the reconstruction of the 3-D objects.

New tools for data structuring, topology decomposition and thematic description by using a database are implemented.

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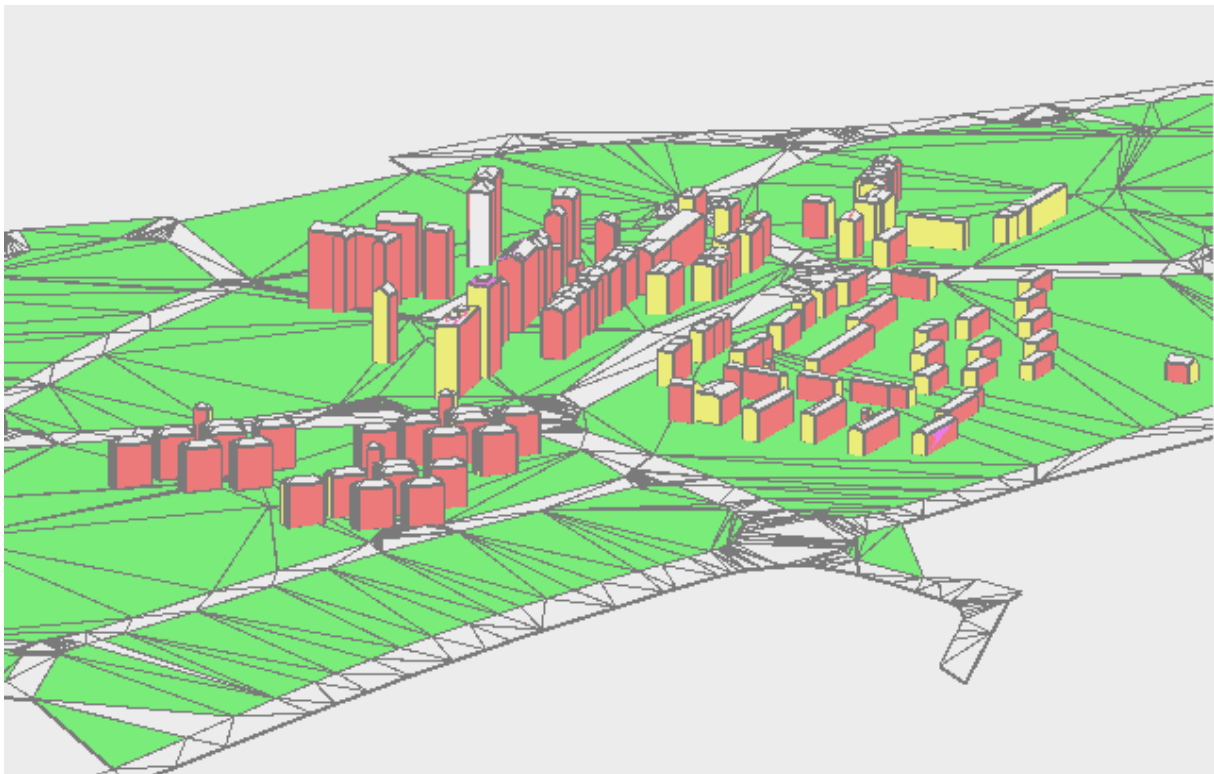


Figure 8: Part of testfield and DTM