UVM SYSTEMS

Building restitution rules for usage in City**GRID**®

Guidelines for photogrammetric line restitution from aerial stereo images

Content

1. An introduction

1.1 Aim of the restitution

The aim of the restitution process is the generation of a city model. To achieve a correct impression of a building model, it is important to focus on the restitution of typical building characteristics. These are:

- Orthogonal angles
- Vertical building edges
- Symmetry of the building
- Symmetry of the roof structure: for example, regular arranged roof-details (chimneys, dormers) and the correct orientation of those roof-details to the main roof.

Within the realms of measurement precision these issues need to be addressed as accurately as possible.

1.2 Special requirements: integration with building footprints

City**GRID**® is able to use the structure lines derived from aerial restitution in conjunction with any footprint information that maybe held to construct a roof protrusion. This may include for example, cadastral, ALK, or some other data source. This ensures that the building model will fit official building outlines.

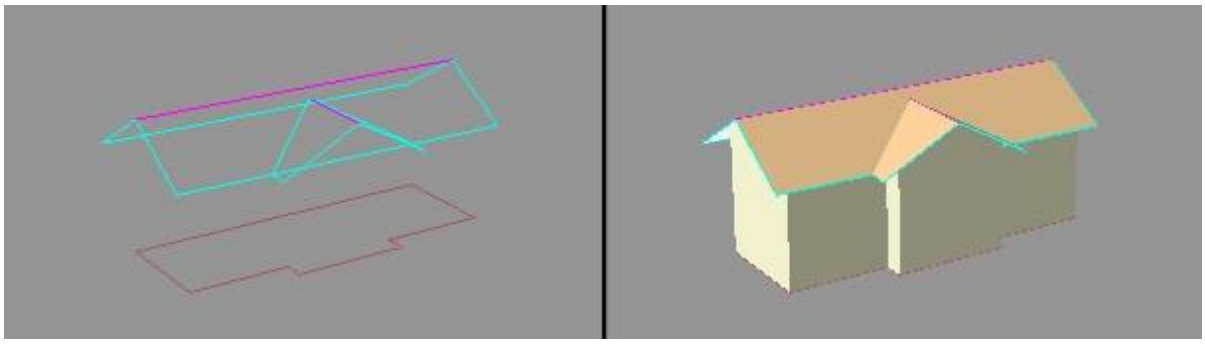


Figure 1.1: shows the photogrammetric restitution and the building footprint on the left hand side and the final model with the roof protrusion calculated automatically on the right hand side.

If a protrusion is to be generated, the measured eave line must be restituted either completely outside the footprint, or at least identical to it. Those buildings that can't conform to this requirement within the measurement accuracy, should to be marked and reported to the ordering customer.

2. Organisation and structure of data

2.1 Lines to be measured

For a building to be modelled, it is necessary to capture all the defining structure lines of the main roof. These are:

1. Outer eave line
2. Ridge line
3. General roof line
4. Upper break edge
5. Lower break edge
6. Courtyard eave line

The structure lines of roof details (LOD3) like chimneys, dormer windows are measured in the same way.

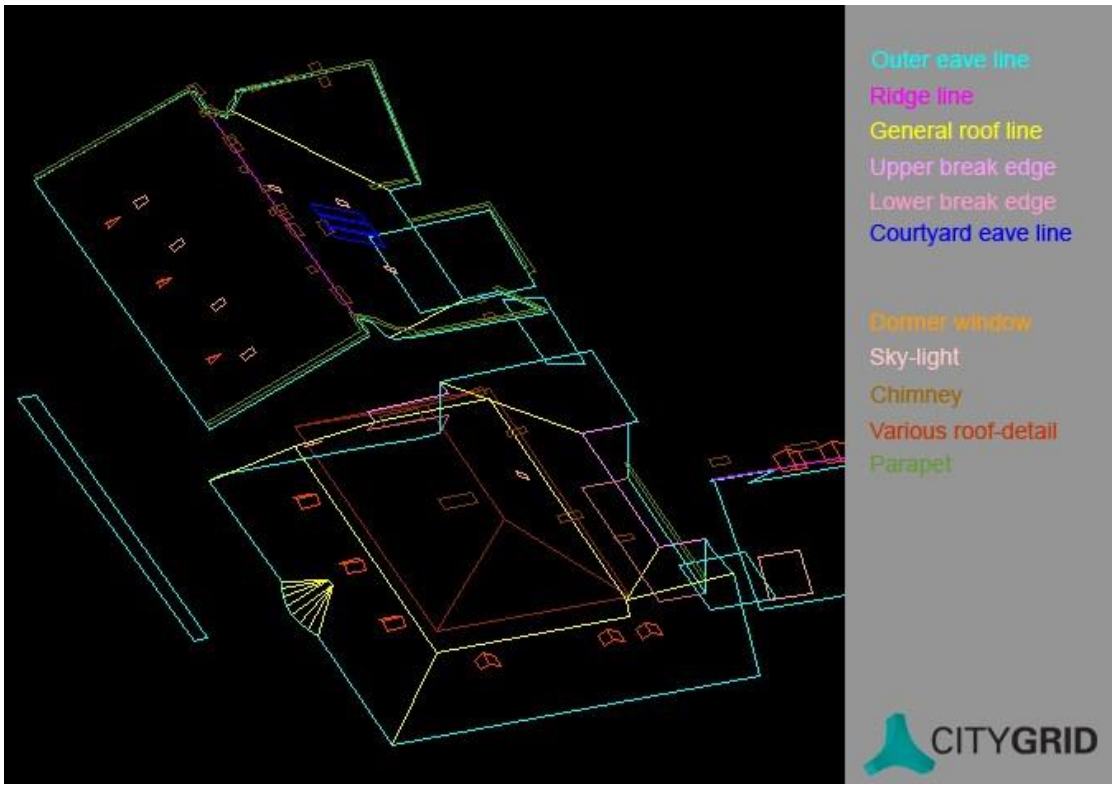


Figure 2.1: Image of roof structure lines

2.2 Definition of buildings

A single building, or an important part of building is to be defined by a single closed 3D polygon (AutoCAD: 3D polyline) depicting the outer eave line. In general it is recommended to compose an entire building from a set of simple building parts. This strategy significantly speeds up later modelling steps.

If there is additional footprint data available, it is necessary to keep in mind that several outer polygons may cover a single footprint. However **a single outer eave line can not contain more than one building footprint.**

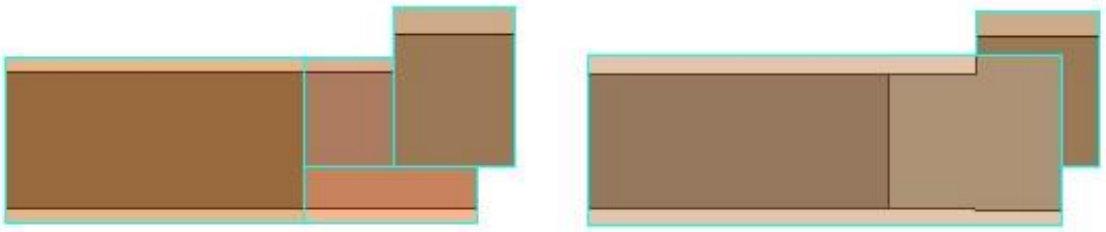


Figure 2.2: Two potential examples of a group of buildings (polygons) and their associated foot-print information. The cyan line indicates the outer-eve line. The image on the left is correct while the image on the right is incorrect. In order to be correct, the outer eave line can't cross multiple foot-prints (although multiple outer eve lines can be used to within a foot-print). This is expanded in Figure 2.3 below.

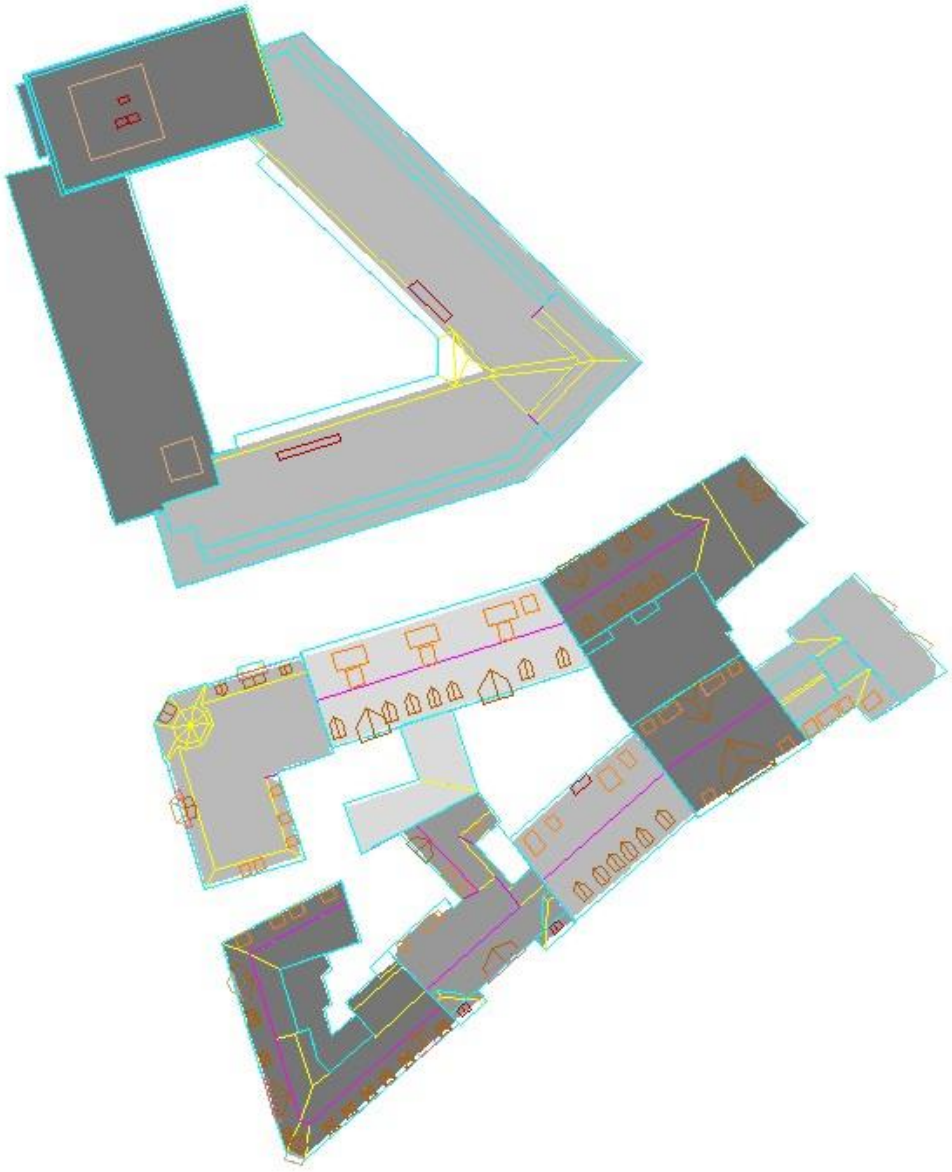


Figure 2.3: *The relationship between the outer eave lines (shown in cyan) and building footprints (shown as grey polygons). In most cases one eave line will cover one footprint. The upper left building shows several eave lines covering one footprint. It can be clearly seen that the eave lines (or a group of them) are identical to the footprint, or exceed the footprint area. The outmost eave line never lay inside the footprint.*

If there is no footprint data available the buildings are divided into smaller parts based on the visible subdivision seen in the aerial imagery. It is strongly recommended to use as simple geometry as possible for the eave lines. The building parts can be combined later during the modelling process. In addition we would recommend separating building parts, where there are vertical changes in the eave line exceeding ~1meter.

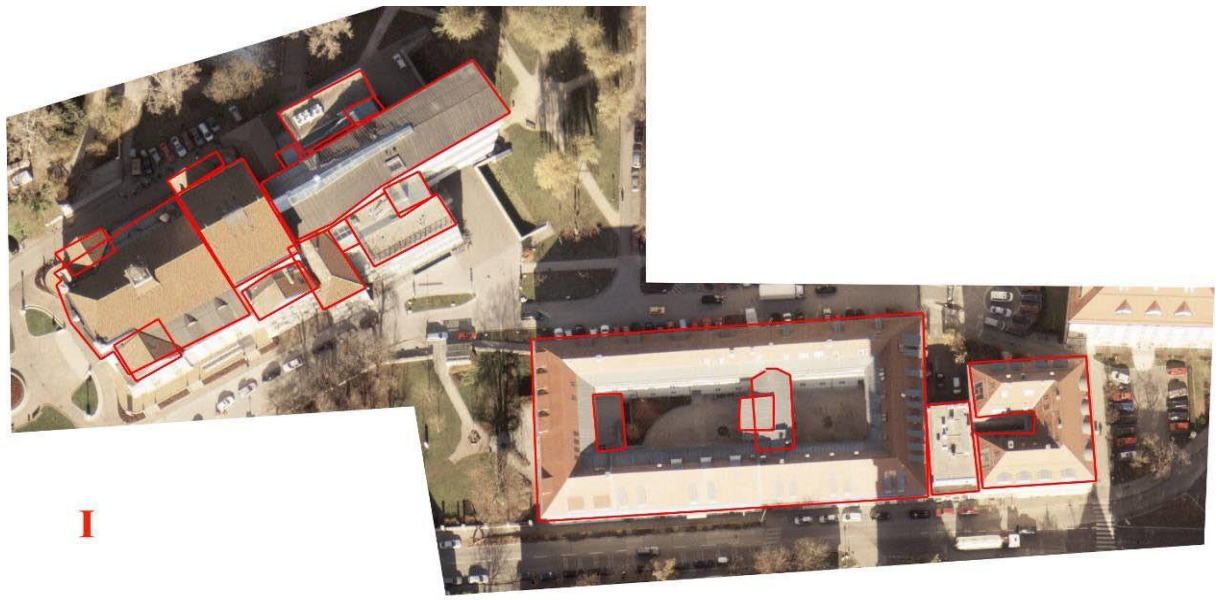


Figure 2.4: *Examples of unit separation. The red lines depict the outer eave line of a building or a part of a building. A set of eave lines contribute to the entire building model. Please note that intersecting eave lines are possible from a geometrical point of view and City**GRID**® is able to handle this, although such models would overlap. Rather than being a restriction of the software, it is a matter for the customer to decide if this is logically acceptable.*

2.3 Organisation of the CAD File:

The layer structure of the CAD file can be defined according the customer's needs, however the following structure is suggested as suitable for the modelling process:

1. outer eave
2. courtyard eave
3. ridge
4. general roof line
5. upper break-edge
6. lower break-edge
7. dormer window
8. sky-light
9. chimney
10. various roof-detail
11. roof terrace
12. upper facade line
13. lower facade line
14. facade line

The layers 12 – 14 cannot be measured by aerial photogrammetry, but can probably sourced from other data sources.

2.4 General drawing instructions:

1. All lines must be of type **3D polyline**.
2. *Outer eave lines* and *courtyard eave line* have to be closed polygons (i.e. with an identical start and end vertices). Using the AutoCAD function 'close' is **NOT** suitable.
3. Objects on the layers *dormer window*, *sky-light*, *chimney*, *various roof-detail* and *parapet* are defined by one closed polygon and can contain additional non-closed structure lines.
4. Use the **snap mode** during construction.
5. Skewed intersections of structure roof lines of various types are **not** allowed.
6. The outer eave line must not consist of several joining polylines (see Figure 5 below). Furthermore this line must not intersect itself as viewed in the AutoCAD top view.

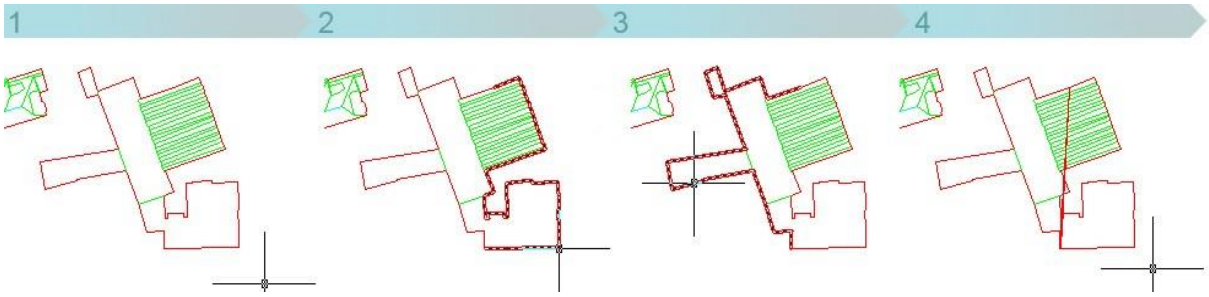


Figure 2.5: S*hows that the outer eave (1) consists of two polylines (2) (3). (4) shows the result of an automatic closing of these two polylines, resulting in two buildings and self-intersecting eave lines.*

7. Break edges define vertical sections of the roof and always come in pairs: an upper break line and a corresponding lower break line. Both break edges are identical in top view and are constructed using 2D snap methods. Both break edges require an identical number of vertices. Only the lower break edge can vary in height.

2.5 Restitution of special objects

2.5.1 Roof terraces:

Roof terraces are defined by a closed polygon stored on layer roof terrace.

2.5.2 Various roof-details

All objects, which can't be assigned to a special layer, should be placed in the layer *various roof-detail*. For example this could be firewalls, elevator installations or air condition boxes.

2.5.3 Dormer windows

Roof details like dormer windows are also described by the same structural lines (eave line, ridge line, general roof line, break edge) as the main roof. Unlike the main roof, these structural lines are all placed on the layer of the object itself and not separated; i.e. all lines describing the dormer windows of a building are placed on the layer 'dormer window'.

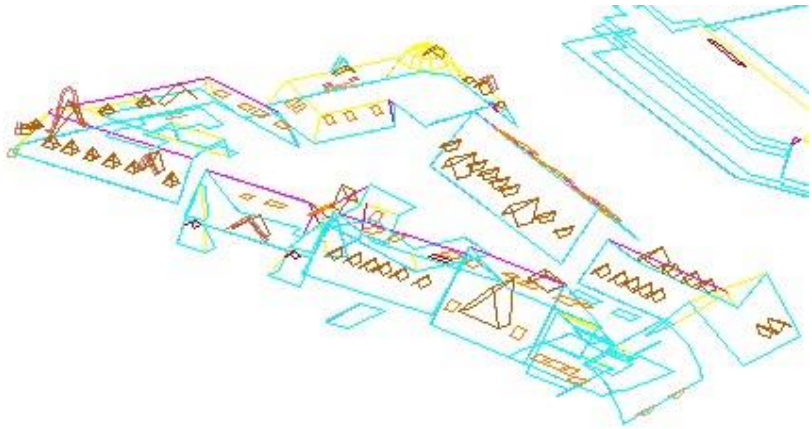
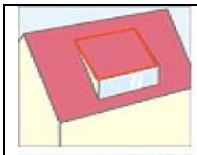


Figure 2.6: shows a typical restitution of roof details. Note the separation of objects according to their layers (dormer windows in brown, sky-lights in orange and parapets in red).

Table 2.1: Depicts the typical structure lines required to model common roof detail objects.

	**mandatory**: closed outer eave polyline
	**mandatory**: closed outer eave polyline, **mandatory**: ridge line
	**mandatory**: closed outer eave polyline, **mandatory**: ridge line, **optional**: general roofline
	**mandatory**: closed outer eave polyline, **mandatory**: general roofline
	**mandatory**: closed outer eave polyline, **mandatory**: general roofline
	**mandatory**: closed outer eave polyline, **mandatory**: ridge line
	**mandatory**: closed outer eave polyline, **mandatory**: general roofline
	**mandatory**: closed outer eave polyline
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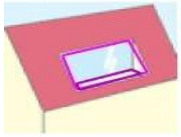
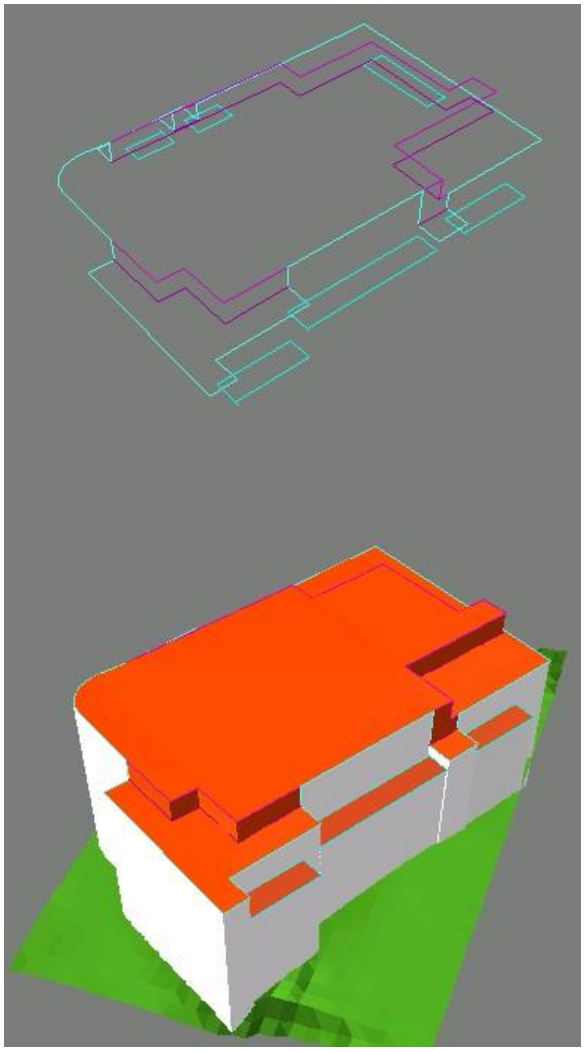
	**mandatory**: upper break edge, **mandatory**: lower break edge.

2.5.4 Flat roof

The below figure shows an example of a flat roof restitution



mandatory: closed outer eave polyline,
optional: general roofline
optional: break edges

Figure 2.7*: Example of a flat roof restitution with upper and lower break lines*

2.5.5 Hidden corners of buildings

Corners of a building which can't be identified properly in the aerial imagery should be constructed from the intersection of the last measurable points of the eave line. This situation can occur when installations, such as solar panels or air-conditioning units, are placed on the roof.

2.5.6 Towers, oriels

Towers, oriels should be regarded as separate objects. To speed up the modelling process it is strongly recommended to treat these elements as separate to the main roof. Any hidden parts of the main roof then have to be constructed.

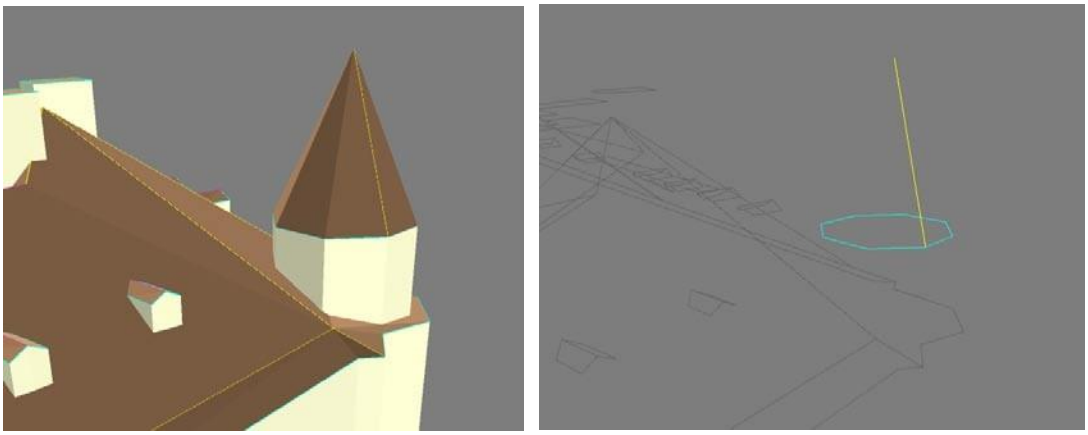


Figure 2.8: *Towers, oriels are either measured as roof-details, or as standalone objects. All defined structure lines (typically outer eave line, general roof line, but also ridge lines and break lines) can be used. If they are treated like stand alone objects, the structure lines have to be separated on the specified layers. But we strongly recommend treating these objects as roof-details, similar to dormer windows.*

3. Demo data

Attached is a demonstration data set (sample_data_engl.dxf). The file is in DXF format.

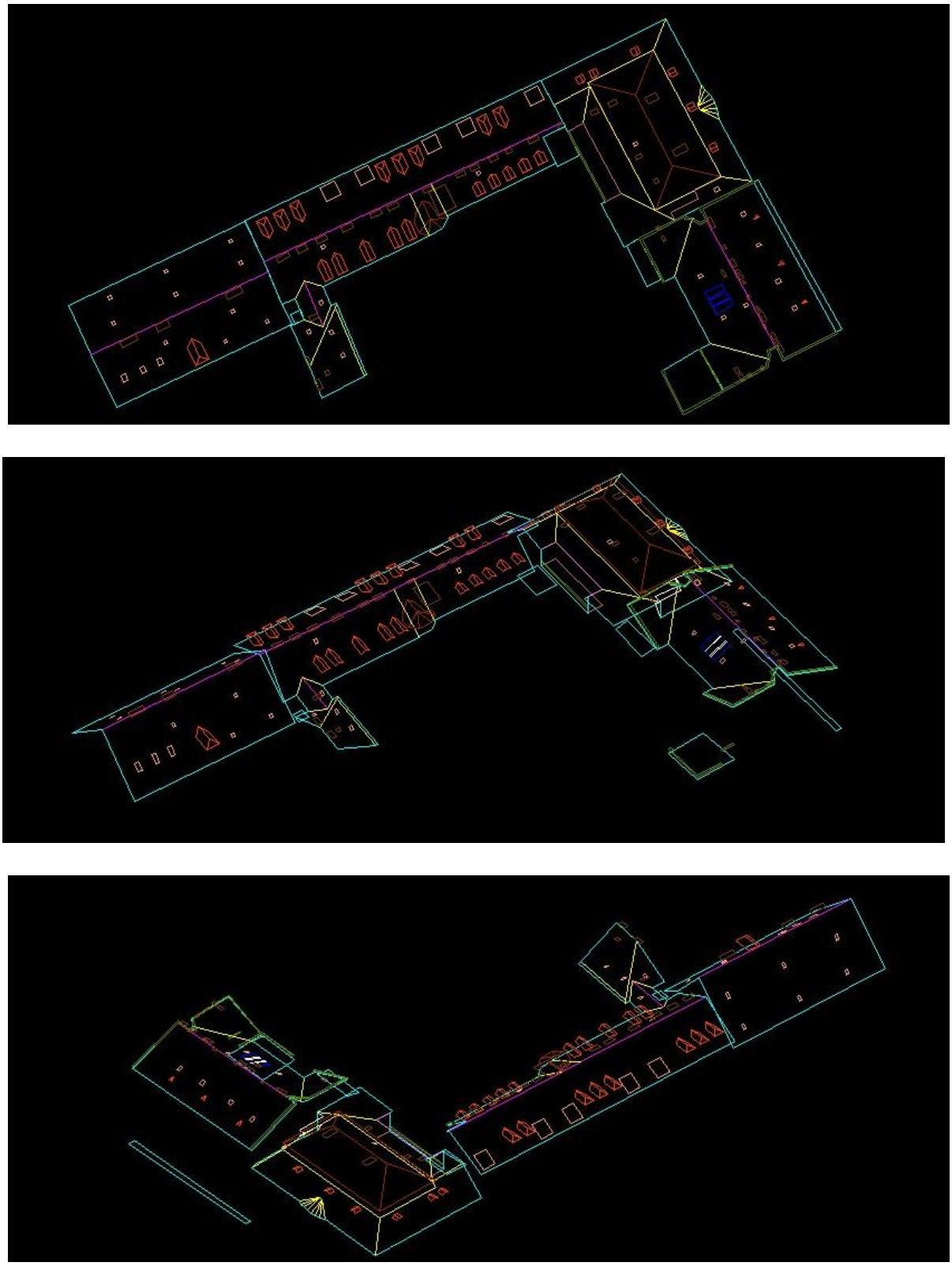


Figure 2.9: *Screen shots of the sample DXF file.*