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3D MODELING OF ARCHITECTURAL STRUCTURE BY PHOTOGRAMMETRY METHOD - A CASE STUDY „ĆELE KULA“IN NIŠ

Abstract: *Photogrammetry has a large use in different areas. One of them is architectural practice. Photogrammetry is one of the suitable methods for production of models of existing objects through photography. It represents collecting specific data from photography which is two dimensional, in other to get three dimensional model of object (3D). Models can be done for different purposes. This paper shows the whole procedure of making a model of "Ćele-kula", which represents cultural and historical heritage, in order to promote tourism in Niš. The three dimensional model is constructed in software "Sketch Up" as a part of the project "3D Niš".*

Keywords: *photogrammetry, photography, 3D models*

1. INTRODUCTION

Three dimensional images are two dimensional medium, which can provide precise information about special structure [1]. According to that statement they can contribute to our understanding of space as it is and help to determine relationships between the elements in it.

Photogrammetry has a big part in everyday life of a modern man. That term is firstly used by W. Jordan in 1876. [2] Unlike photogrammetric shooting methods, in different circumstances, a number of very significant photographs make by the ordinary photographic cameras, without pre-established plan. The possibility of using those shots as a material for modeling can be priceless. The scientific discipline that uses photography as the main source of modeling objects is photogrammetry. With this technic we can collect all specific data that we need for modeling the objects with only photography. The information is structured based on the specification of objects and demands of investors, but also storing in digital format [3].

Photogrammetry represents "art, science, and technology of receiving information about objects and environment in the process of filming, measuring and interpreting photography's and models electromagnetic radiations objects and other phenomena" (American Society of Photogrammetry 1980).

The advantages of photogrammetry are using the affordable software packets such as „Sketch Up“, „AutoCAD“ for making models, the wide range of using models because of their small memory. For modeling, as mentioned, are necessary only their photos as documentation. Furthermore the diversity of types of documentation, such as: photo, graphic, numeric and of course descriptive documentation [4]. Usage goes that far that it can contribute for virtual reality presentation [5]. The disadvantages of this method are first of all, the amount of time that is needed to collect all the data (photos) for modeling the objects, it is crucial to know the technic which photogrammetry represents as well as the software for modeling. Models are detailed representations of the actual objects, more so simplified version which is realistic view and thus can be used as a very suitable web presentation.

The new photogrammetric technology is used in the practice around 20-25 years. In the next 25 years It will share the market with the newest technologies to come [6].

2. APLICATION FIELD

The technologies for collecting the spatial data are:

- The classic measurement on the field;
- GPS;
- Photogrammetry;
- Laser scanning ;
- Radar scanning;
- Remote detection [7].

Other advantages of the photogrammetry in compared to the other methods of collecting the special data are:

• It does not require a lot of work on field.
• It covers very large areas.
• The measurement can be easily repeated if necessary.
• It is suitable for collecting data from undetected and dangerous areas.
• Diverse areas of usage (cartography, medicine, forensics, archeology...) [7].

The area of implementation of photogrammetry according to specification of used technology:

- Topographic and thematic cartography (analog and digital vector maps, photo maps) - All the conditions of cartography maps are from 1:500 to 1:250000. The basic method of filming data is satellite or aerial photogrammetry [8].
- Cartography usage (cartographic example) - It is used only as an aerial photogrammetry method. The downside represents the need for photo signalization of property`s boundary, as also filming in the early spring. Conditions of filming are in the range from 1:4500 to 1:12000.
- GIS (making geocoded databases) Geo-information systems.
- Production of DFM-a (Digital field model DFM).
- Geodesy, Cadaster and Cartography.
- Production of 3D models of the cities [9].
- Civil engineering and Hydraulics. Topographic maps, montage of elements, monitoring of workload [10].

- Architecture (recording of exterior and interior, reconstruction of facades, protection of historical and cultural monuments).
- Archeology (making plans and models of sites, drawings and models also of new discovered items).
- Spatial planning and ecology (providing groundwork, analysis).
- Astronomy (mapping stars).
- Industry and mechanical engineering (control of product's quality, montage) [11].

3. THE MAIN PRINCIPLES OF PHOTOGRAMMETRY

Photogrammetry represents a measuring technic that implies camerawork which provides us with measures, shapes, and position of the analyzed objects (Fig. 1).

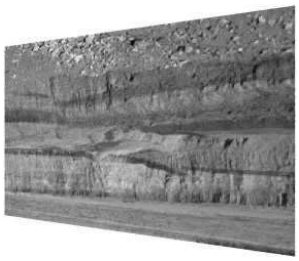

Fig. 1 The example of 2D representation of the points on the flat surface, with two coordinates.

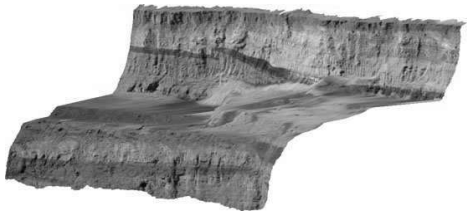

Fig. 2 The real position, 3D view, of the surface in space with three coordinates.

Location of any of the points from the picture can be represented with only two coordinates: (x, y). The photos are two-dimensional. Location of any point can be defined by three coordinates: (x, y, z), geography wheat, height and longitude. The real world is three-dimensional (Fig. 2) [12].

Photogrammetry is science of using 2D photographs for precise measuring in 3D space. In order for that to be possible it is necessary to do a reconstruction and recognition of lost information that have been lost in the process of filming [7].

3.1. Problem to define the positions of points in space

It is very crucial to determine the exact position of the point in location in order to have the most possible precise model of object.

Problem: With one photograph, recorded from the central point, it is not possible to automatically determine the accurate position of the point (A_T) in space, because the position of ray of light, which falls onto one pixel of our photo, can come from any point that belongs to exact direction of that ray (Fig. 3).

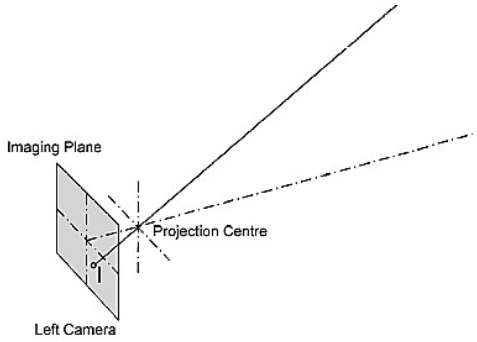

Fig. 3 The way that ray of light falls onto the picture.

Solution: adding one more photo, that is taken from some other location that will provide us with the intersection of those two rays which will determine the 3D location of the common point (Fig. 4) [7].

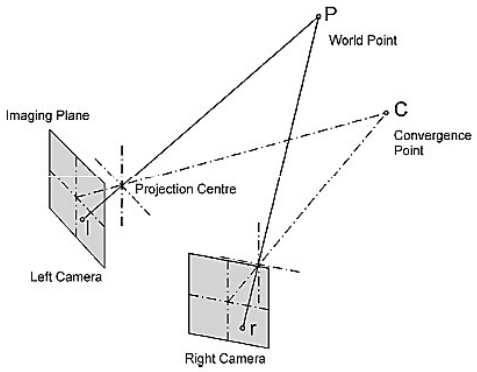

Fig. 4 Two photos taken on two different locations.

The two photos that are taken from two different locations, but on the same field, represent stereo pair. Stereo pair is a pair of shots exposed from a different angle of camera on which are, more or less, the same content of the filed, made on the photo (Fig 4).

Stereo field represents the common area for both photos (Fig 5).

Stereoscopic effect is a special observation of filmed area in all three dimensions with the correct order of depth.

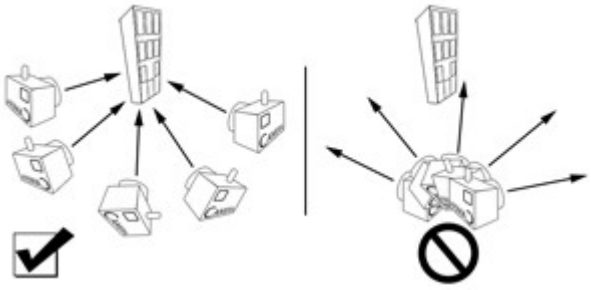

Fig. 5 Representation of stereo field and stereo match – left, Representation of shots without stereo field – right [13].

If the object is photographed from two different positions, the line between two projection centers is called “the basis”.

4. CASE STUDY – ĆELE-KULA IN NIŠ

The main goal of using photogrammetric method in this research is getting a model of cultural and historical object “Ćele-kula”. Considering that the model is constructed in the real dimensions, we were able to get the exact measures and shape of object without any work in site. In this research, it is used only one photo of the object and the characteristics of the dimensions. The complete model is placed on „Google Earth“, and represents the extension of the project „3D Niš“, whose goal was forming models of objects which have historical and cultural heritage of the city. In that way we were able to upgrade the tourism, save or make technical data of the objects and use it for other research. To this day the 150 models have been uploaded. In this way it is possible to preserve data of the objects to help the future reconstructions, and also better web presentation of the city in the way that modern technology personates in the world. Models of existing objects can be useful during representation of the future projects in the location of Niš. They can be taken from the web and be incorporated in environment of the presentation and improve its realistic impression.

Fig. 6 Photos taken from the site.

In order to make a model of the object, as photogrammetry implies, we must collect all the data that we need, that is, to take photos of the object. In this case, the photos are made around the whole object (Fig. 6). In this way, we have access to all the facades and changes in its shape. It is not necessary to use all the taken photos, only those ones we think are crucial. The rest are helpful for a better on site of the final and more realistic look of the model.

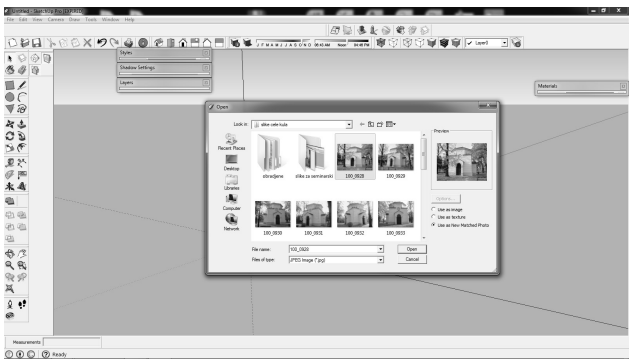

Fig. 7 Import of the photo.

From these photos we can remark that object Ćele-kula has four completely same facades, which was the benefit during process of modeling. Therefore the most suitable photo has been chosen for modeling of one side of the object. That was photo (Fig.7). Before beginning of the modeling it is necessary to import the chosen photo into the program that we use for photogrammetry, in this case it is “Sketch Up”, by following this steps.
Open the “Sketch up”, and go into „File-import“, than pick a photo, check that photo is imported as a „Use as New Matched Photo“ and click “Open”. When that is done, the picture is represented like this in the program. (Fig. 8).

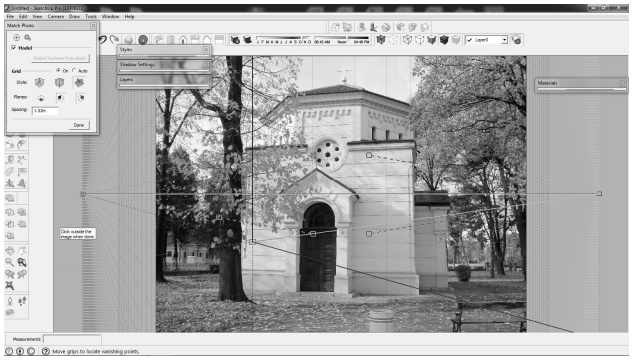

Fig. 8 The look of imported photo.

Lines that we see represent the vanishing points of orthogonal directions a, b and c (Na, Nb, Nc) in that way that green color is direction b, red direction a and blue direction c.

They can be moved and adjust by clicking on the lines or by moving their point. In order to make as precise vanishing points as possible, we should strive to adjust the same vanishing points to be as far as possible. We can crosscheck the adjustments as we move the line of the vanishing point c and see if it matches with the verticals on the picture (Fig. 9).

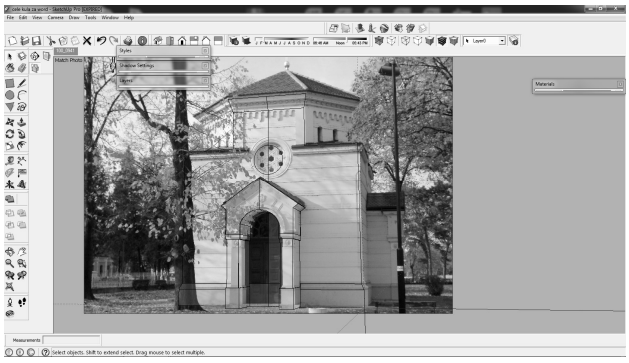

Fig. 9 Matched photo with the orthogonal directions a, b and c.

When we are finished with the adjustments of the orthogonal directions a, b and c, we can click with the right mouse button “Done” and start the production of the shape of object in the “Sketch Up” (Fig. 10).

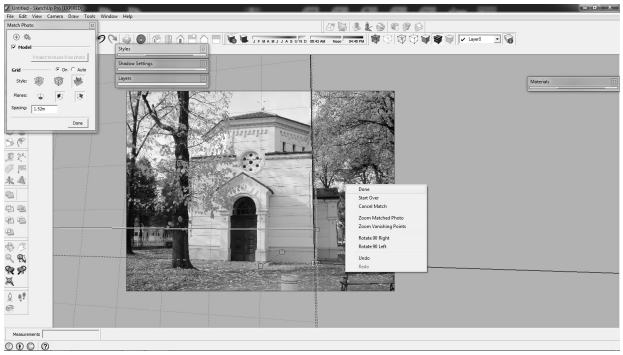

Fig. 10 Confirming the position of the photo.

On this object the biggest plane of the façade's wall it has been noticed, and it was enough to draw one half of it, because of its symmetry. Than the part with the columns and canopy, in front of the main plane of facade was modeled, with all details on the foothill, columns and its capital (Fig. 11). Doors, wall and the circle remained at the same plane. The crossing from wall to roof has a wreath which is modeled with all its details in the profile.

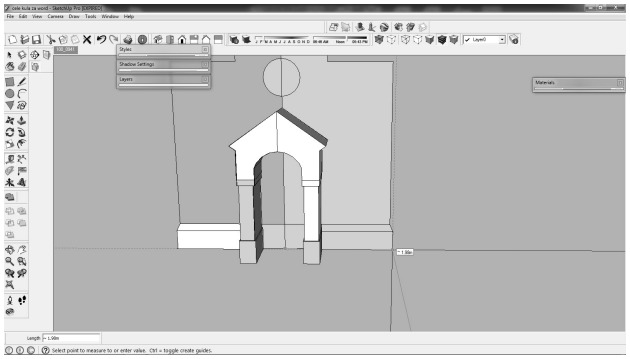

Fig. 11 Modeling of one main facade.

Using the symmetry of the object the right side was mirrored and the one facade was completed. After finishing that facade, the roof of the object has been modeled (Fig. 12).

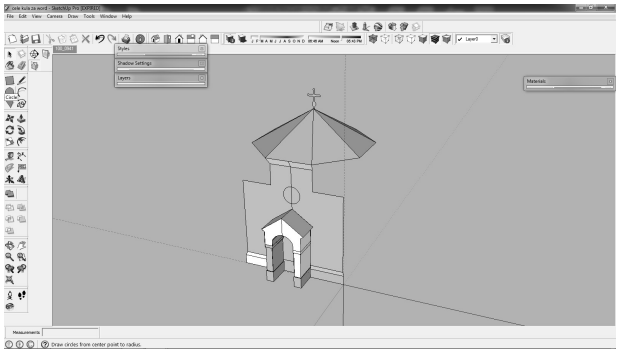

Fig. 12 Finished model of one facade and roof.

That was the hardest part, because it was not able to see the entire construction of the roof on all photos. The length and height of one roof plane is collected from one of the photos, and there are eight. The rest of the roof is completed with recognition of its geometry. The roof is one straight eight sided pyramid, from which we know the length of the side and high. Pyramid is placed onto the eight sided prism.

The next step was adding the material on the modeled façade as well as arranging the main façade plane and roof, in order to use them for the rest of the model later because they are identical.

The first way for adding the material to the surface is to match modeled surface to its façade on the photo and by clicking command „Project photo" on the selected surface we pick up the material. In this case only that selected surface will have this material from the photo. However, that is not the suitable way for adding material to all the existing surfaces, such as in case of the door, which are a little re-entrant (Fig. 13).

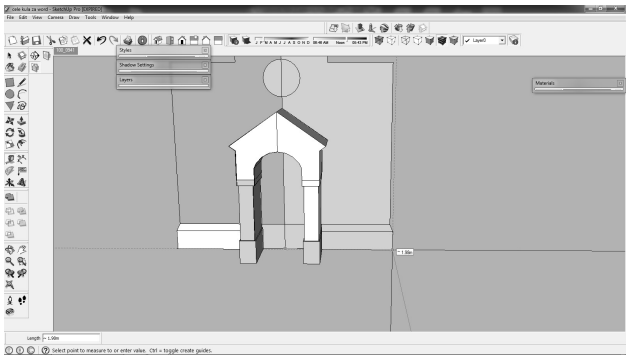

Fig. 13 Materialization of the door.

The second way of adding infliction of material is to choose it from the material library „In Model" from the program Sketch up. In this way the materialization of the door was made, only on one half and then copied and mirrored to get the whole (Fig. 14).

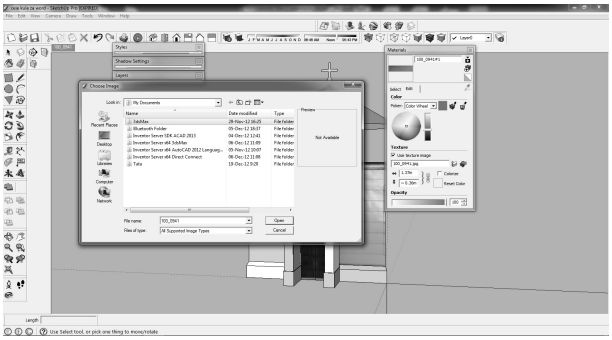

Fig. 14 Assigning materials to the model.

What is crucial for this technic of materialization is that all of the selected materials that we choose from the photos are in the library "In Model" of the program that we are modeling in. We can always adjust the material to the surface, if we fell need to, in the program for processing pictures "Photo shop". When that's settled, we can add the right material to the surface by selecting „Window/Materials/In Model/Edit/Browse" (Fig. 15).

In this paper the materialization was completed with the help of both ways. The first way is used for adding material to the main facades, and the second one for details on the object (doors, circle window, roof). The

material can be used directly from the photos, but it is usually necessary to clean up them from the surrounding element such as: trees, bench, people, etc. Because of that, the photos for materialization should be chosen wisely in order to have as less additional work as possible.

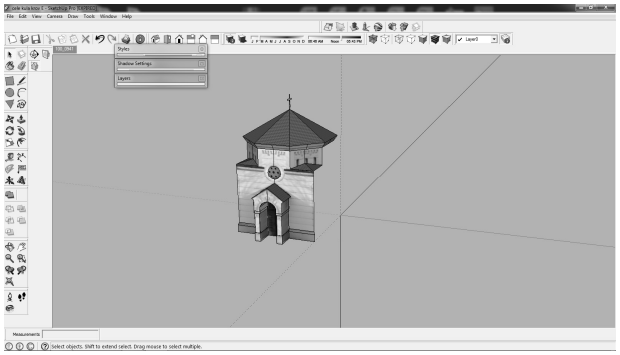

Fig. 15 The complete component of the object.

Considering that the object is symmetrical, it was necessary to finish materialization of one whole façade (Fig. 16).

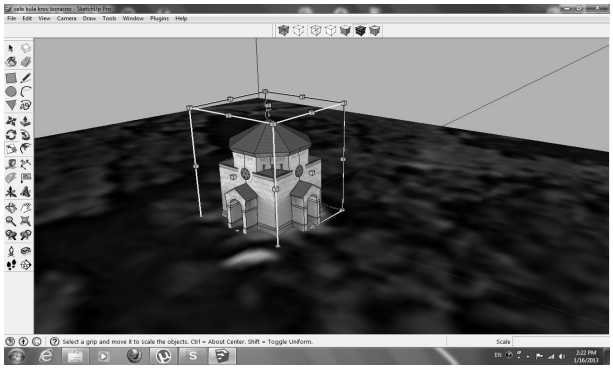

Fig. 16 Placing model to its location on the Google Earth.

In order to make a component of that one piece, and manipulation easier while modeling, we select the modeled piece and go „Make Component” from the program Sketch Up. By rotating and copying components four times for 90 ° we get the existing model of Ćele-kula.

Moreover, to get the model in its natural size, which is not paid attention at the beginning of the production, ‘we used its position in map of the „Google Earth” and matched the size of the basis of 3D model with basis on the map, using the option „scale”. It is important to know the objects exact location and to place it to its 2D map’s shot (Fig. 17).

When production is finished it is now important to get from the model it`s real dimensions, which can be seen from its basic projection. The model is placed in characteristic views, front and top, in this program. This views are imported into as „DWG“ in program AutoCAD where we can measure it.

In this case we have two characteristic views front and top, because as mentioned, the object is symmetrical, so the others views are the same.

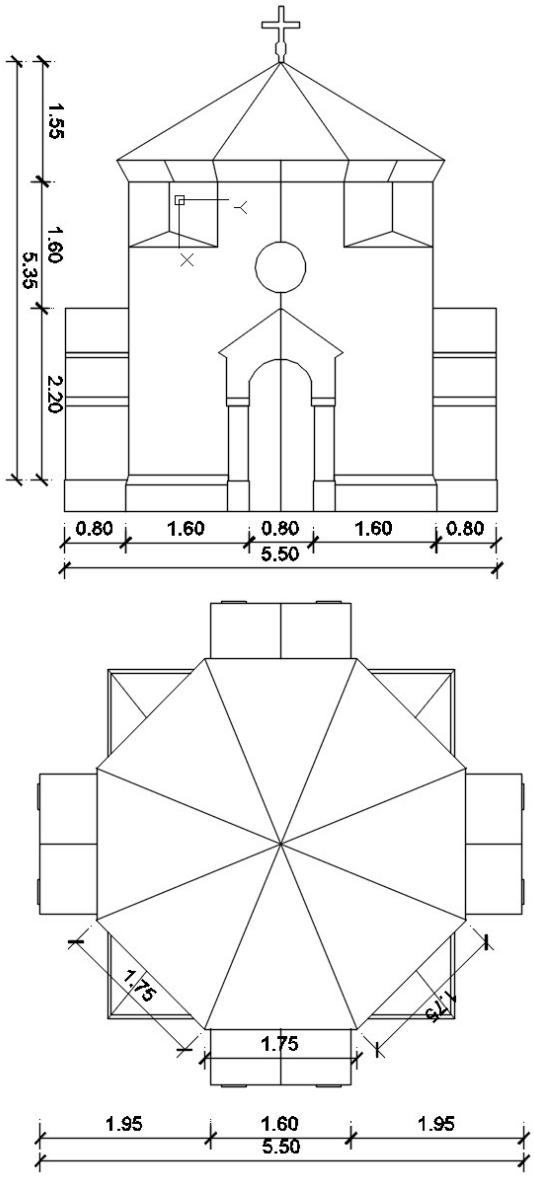

Fig. 17 Orthogonal view with real dimensions complete.

5. CONCLUSION

Photogrammetry as method in architecture serves for better analysis and documentation of the objects. The classic way of it, represents going into the site and measuring all the crucial dimensions. Sometimes the detail on the object is unavailable to reach physically, and it becomes impossible to measure it in the classic way.

Moreover the time that we spend collecting data on site is much longer and harder than when we are doing it through photography. Because of this reasons the photogrammetry is recommended for the production of the models of architectural objects. In this research the production and materialization of historical and cultural object “Ćele-kula” has been shown in details in the program “Sketch Up”. Based on the 3D model the all

characteristic dimensions are taken from the main views, front and top. This type of procedure takes much less time so it represents more productive way in compared with the classic one. For the modeling it has been used only one photo, thanks to symmetry and simplicity of the geometry of the real object. During the work there can be some issues, but it is crucial to search the simplest solution for them.

Problems can be inadequate photos, complex geometry of the object and small number of “clean” surfaces that can be used for the materialization. This method of 3D modeling also is more approachable and affordable than the classic one.

Great number of advantages in comparison to the other technics of collecting the data of objects: it demands less work on the site, it covers large field areas; it is easy to repeat measuring if necessary, it is suitable for undetected areas, wide range of use.

All the reasons that are listed above, are the justification why this method is the most recommended for analyze and documentation of the architectural objects.

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