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PSEUDO 3D MAPS IN TOURISM

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Abstract: This paper presents some of the findings from a master thesis with the title 'The Third Dimension in Tourism Maps – Comparing Different Geometric Projections Used for Pseudo 3D Maps'. It gives an introduction into why pseudo 3D maps are used and which methods are available to produce such maps. The question posed in the case study was which pseudo 3D map projection is the most appropriate for use in tourism maps.

Keywords: Pseudo 3D maps, 3D maps, projections, orthographic oblique

PSEUDO-3D-KARTEN IM TOURISMUS

Zusammenfassung: Dieser Beitrag präsentiert einige Aspekte einer Masterarbeit mit dem Titel „Die Dritte Dimension in Tourismuskarten – Ein Vergleich von verschiedenen geometrischen Projektionen zur Erstellung von Pseudo-3D-Karten", deren Kernaufgabe es war, die für Tourismuskarten am besten geeignete Pseudo-3D-Projektion zu finden. Neben einer Einführung in die Verwendung von Pseudo-3D-Karten werden verschiedene Methoden beschrieben.

Schlüsselwörter: Pseudo-3D-Karten, 3D-Karten, Projektionen, orthographisch oblique

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1 WHY 3D?

The starting point for the thesis was to produce a pseudo 3D map of the Bezirk Perg (part of Upper Austria). By trying to decide which projection to use it became clear that no research had been conducted to see which of them was most suitable for map use tasks important in tourism maps.

Three dimensional cartographic representations have always been fascinating for people because of their similarity to real landscapes. The following citations illustrate advantages of 3D representations, especially for less experienced map readers:

"It is a larger cognitive effort to get a spatial impression from a two-dimensional map than to interpret this information from a three-dimensional depiction" (Buchroithner & Knust 2013, p. 1).

"Many cartographers think that inexperienced map users more easily understand 3D maps because they present the landscape in a realistic manner and mimic what people see while on a trail" (Schobesberger 2007, p. 2).

Frequently the term 3D map is used when speaking about pseudo 3D maps, these being three dimensional representations on a flat medium. Therefore, it can be assumed that the statements given above hold true for pseudo 3D maps as well.

Pseudo 3D maps have long been used for different applications and gained popularity through hand painted panoramas by artists such as H. C. Berann. But the making of those maps has always been very time consuming, which contributed to them not being widely used. Through the development of specialised 3D software over the last decade it is now possible to produce such maps in much less time, which has led to more interest in 3D maps. Most research on the topic is focused on interactive pseudo 3D cartography (such as the terrain feature in Google Earth), while static pseudo 3D maps have been somewhat neglected. Nevertheless, they represent a valid field of research, especially in the area of tourism, where a computer or internet connection on a mobile phone is not always readily available.

When it comes to pseudo 3D maps, several projections and settings can be applied that influence the depiction of a region. Some papers, by authors such as Patterson (2005), Haeberling (2003 & 2005), Jenny & Patterson (2007), among others, deal with what settings should be used for pseudo 3D map projections. Mostly, different settings for certain parameters are examined and evaluated, but not much empirical research exists on how users perceive those parameters.

2 AIM OF THE STUDY

The question posed in the study was which pseudo 3D map projection is most suitable for use in tourism maps. In other words, it dealt with how map users, either consciously or subconsciously, perceive the projections and whether the users were successful in performing a number of map use tasks. More specifically the research question was: How do different geometric pseudo 3D projections influence user perception regarding terrain interpretation, distance and height measurement as well as general orientation.

The thesis tried to, and succeeded in identifying the appropriate projection for a pseudo 3D map for tourism purposes in general and more specifically for the use case and terrain examined. This was achieved by providing an in depth description of various pseudo 3D projections, of which some of them were put to the test in a user survey to see if their geometric characteristics are perceived by the map users.

3 MAP USE TASKS

Considering what the final map will be used for, some map reading tasks were deemed more important than others. As most potential map users would be tourists, getting a general impression of the area as well as identifying sights and where they are located in relation to the position of the user (distance, difference in altitude) were crucial.

Board (1978) classified map use tasks by assigning them to the groups of navigation, measurement and visualisation. The following map reading tasks were taken from his classification as they were deemed the most important in tourism maps:

1. Describing the area and being able to get a general impression of the terrain.
2. Comparing, whether it be the height, distance or position of different points (sights).
3. Estimating the height and distance of points (sights), seeing as exact measurement is often not possible on pseudo 3D maps.
4. Identifying and locating one's own position on the map, as well as finding points of interest or routes on the map.
5. Orienting the map.

Overall, the map created had the objective to provide the user with the ability to accomplish the tasks listed above, while tasks such as interpolating, measuring, discriminating, delimiting and generalising were somewhat neglected.

The survey that was conducted as part of the thesis tried to answer the question whether, and how well, different pseudo 3D maps let the map user execute those tasks.

> **PSEUDO 3D MAP**
>
> According to the Lexikon Kartographie & Geomatik (2001) maps that give the user a three-dimensional impression when visualised on a flat medium (screen, paper) are referred to as pseudo 3D maps.

4 PSEUDO 3D METHODS

The underlying question of pseudo 3D maps is, and always has been, how to show height on maps as well as the ground plan view. In topographic maps this is achieved by contour lines and spot heights, which is something that can be used with three-dimensional projections as well. But contours alone do not depict an area three-dimensionally. Other methods that are mainly used in ground plan maps but can be used for pseudo 3D maps as well are hachuring, hypsometric tints and shaded relief.

For the purpose of this study the methods that are used solely to create pseudo 3D maps were split into traditional methods and ones that use geometric projections.

Traditional methods are the first form of pseudo 3D maps and have been in use for some time. Examples include planimetric maps with added 3D objects (a method that is particularly popular for city maps), hill signs (stylised drawings of hills, such as in Tolkiens (1954) map of Middle Earth), the landform maps by Erwin Raisz (1957) and (painted) panorama maps by artists such as H. C. Berann or Hatsusaburo Yoshida. Panorama maps have the considerable advantage of the artist being able to show exactly what he wants in the way he wants. The disadvantage being that they are extremely time-consuming to create and cannot be adapted once finished.

The other group of methods described in the thesis is one that uses geometric projections. A projection is defined as "the transformation of points and lines in one plane onto another plane by connecting corresponding points on the two planes" (Weisstein 2014). The connecting lines are called projectors and originate from a single point, the centre of projection. If the centre of projection is at infinity, the projectors are parallel and produce a parallel projection. If it is finite, they produce a perspective projection (Carlbom & Paciorek 1978, p. 465). These are both planar geometric projections, whereas in Cartography cylindrical and conic projections (i.e. Mercator, Lambert, etc.) are often used. Pseudo 3D map projections differ from them in the choice of projection plane and its position in relation to the area in question.

Other options of using geometric projections include the progressive projection (where the terrain can be artificially curved), fisheye projections, panoramic strip maps and circle ring projections. All of them are often used for tourism maps.

For a historic overview of how the planar projections used for pseudo 3D maps were developed refer to Carlbom & Paciorek (1978, p. 467 ff.) and Krikke (2000).

Taken from geometry, where these projections have long been used to draw three-dimensional representations of objects, they can also be applied to landscapes, as each point on a map has an x-, y- and z-coordinate. The development of specialised computer software has made it possible to create maps using those projections without spending hours at a drawing board.

The choice of the projection and its settings is very important, as it has implications on horizontal and/or vertical displacement of points. Each of them has advantages and disadvantages, and one method may not be useful for all use-cases. The question is whether map users recognise the shortcomings of the projections and how they handle them.

5 MOST SUITABLE PROJECTION

The projections that were tested by means of a survey as part of the thesis were a two-dimensional map as reference point, a perspective projection, an orthographic oblique projection and a plan oblique projection. The testing was done in German via an online survey that was completed by 107 respondents with 66 of them males and 41 females. The age ranged from 16 to 76 years and the survey included people very familiar with the area as well as people who had never been to the area (see Figure 1).

For each of the four projections (in the above order) participants were faced with the same examples, with tasks regarding terrain interpretation, altitude and distance estimation as well as tasks concerning the cardinal directions. Figure 2 shows one of the examples from the survey where the participants were asked to describe the

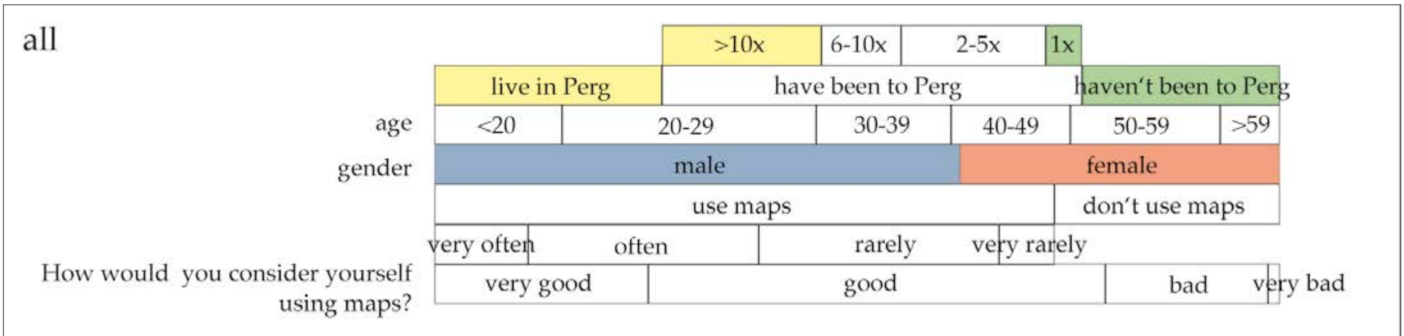
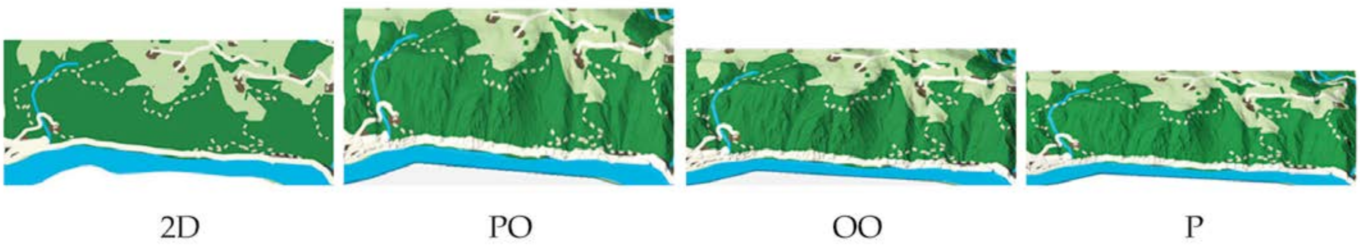


Figure 1: Characteristics of sample population



Q7	No.	%
flat	34	31.776
hilly	31	28.972
steep	37	34.579
can't tell	5	4.673
total	107	100.000

Q38	No.	%
flat	7	6.542
hilly	26	24.299
steep	74	69.159
total	107	100.000

Q69	No.	%
flat	5	4.673
hilly	19	17.757
steep	83	77.570
total	107	100.000

Q100	No.	%
flat	7	6.542
hilly	19	17.757
steep	81	75.701
total	107	100.000

Figure 2: Example of survey questions with corresponding results

area shown. In order to help the participants an overview map was provided for each question where the area that was shown to them was marked and the east-west and north-south extent of the whole study area was stated. For the two-dimensional examples a 'can't tell'-option was always included as the map does not provide any information on altitude. Respondents, however, rarely used it.

The projection that performed best was the orthographic oblique projection, which is another term for an orthographic axonometric projection. The name refers to the projectors orthographically intersecting the oblique projection plane (see Figure 3). It can be trimetric, dimetric or isometric. Whether there are two or three angles and foreshortening ratios is determined by the angle of the projectors. The foreshortening of the y-axis (north-south) and z-axis (altitude) can be seen in Figure 3 as well. Values along the x-axis (east-west) are not foreshortened because the projection plane lies parallel to this axis. In the figure it can be clearly seen that the foreshortening is greater if the projection plane cuts the axis at a shallower angle. For example, the projection plane using 15° cuts the y-axis with an angle of 75°. This results in the 100 mm being foreshortened to 26 mm (-74%), while the 10 mm of the vertical feature are still 9.7 mm (-3%). It has to be mentioned that the measurements in Figure 3 are rounded, so the percentages are not completely exact.

The plan oblique projection is different in that the projectors do not intersect the projection plane at a right angle (as seen in Figure 4). The advantage of this method is that it results in a planimetrically correct map as long as there is no difference in altitude in the area depicted. Even if there is, the general shape of the area is still better preserved than in other projections.

Using a projection plane with an angle of 45° for an orthographic oblique projection means that it cuts the y- and z-axis at 45°, which results in two equal foreshortening ratios along those axes. This was one of the reasons this angle was chosen for the map that was created. Even though the map user might not be aware of this it should make it easier to discern heights and differences as they are equally foreshortened, especially since the foreshortening ratio along the x-axis (east-west) is 0. Figure 5 illustrates how the orthographic oblique projection affects horizontal and vertical features as well as slopes that are tilted towards the projection plane and away from it, when an angle of 45° is used. The table next to the drawing lists the lengths of the features 'in reality' and on the orthographic oblique projection, as well as the foreshortening ratio for the horizontal and vertical features.

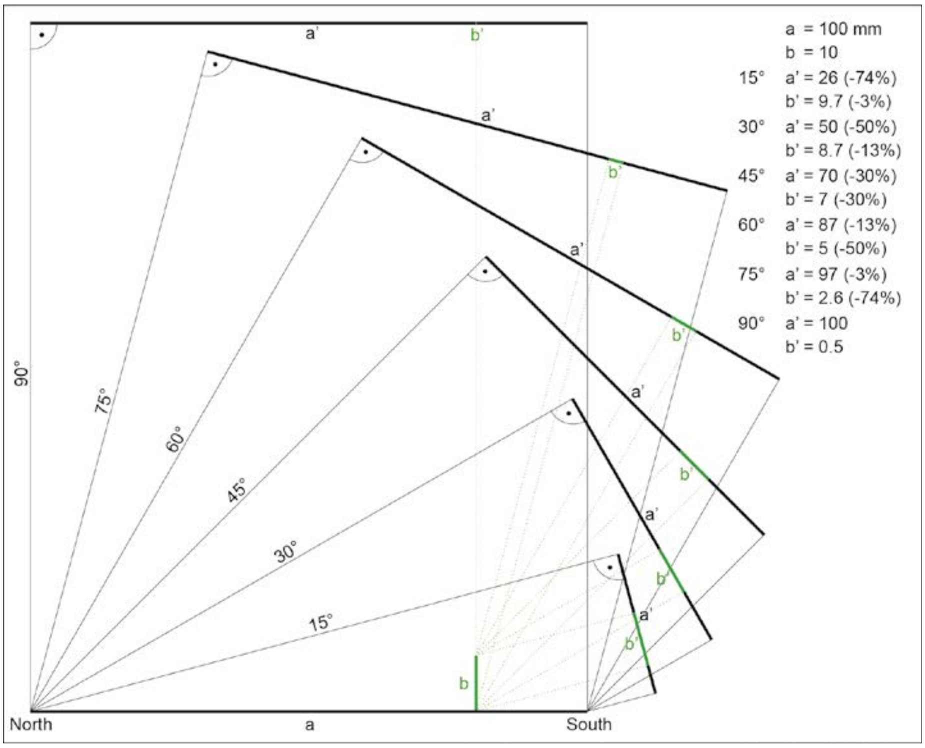


Figure 3: *Foreshortening for different angles using an orthographic oblique projection*

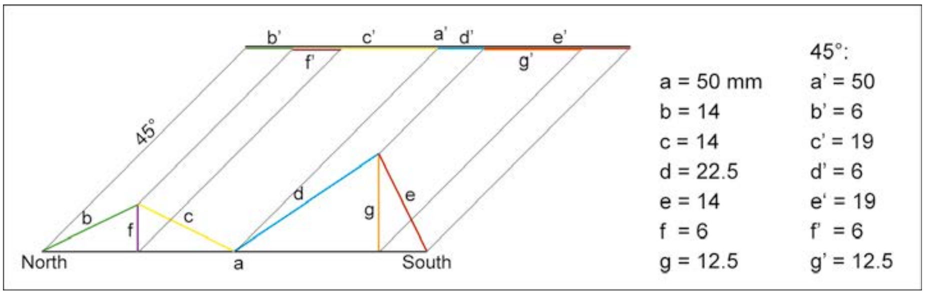


Figure 4: *Example of a plan oblique projection using 45°*

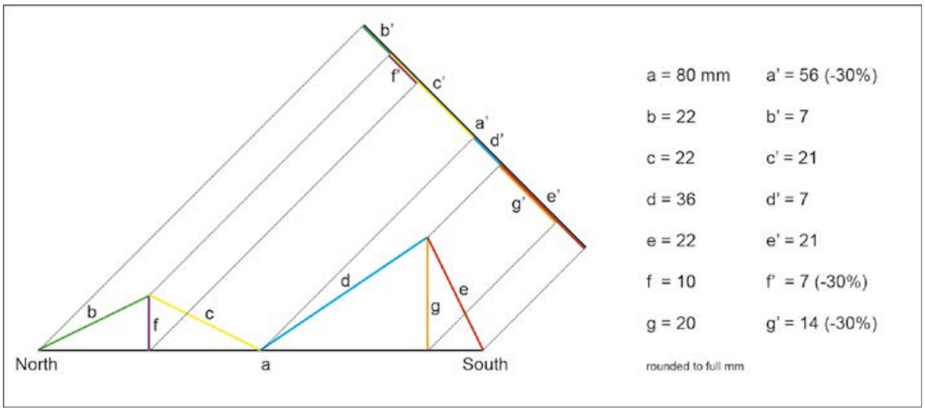


Figure 5: *Example of an orthographic oblique projection using 45°*

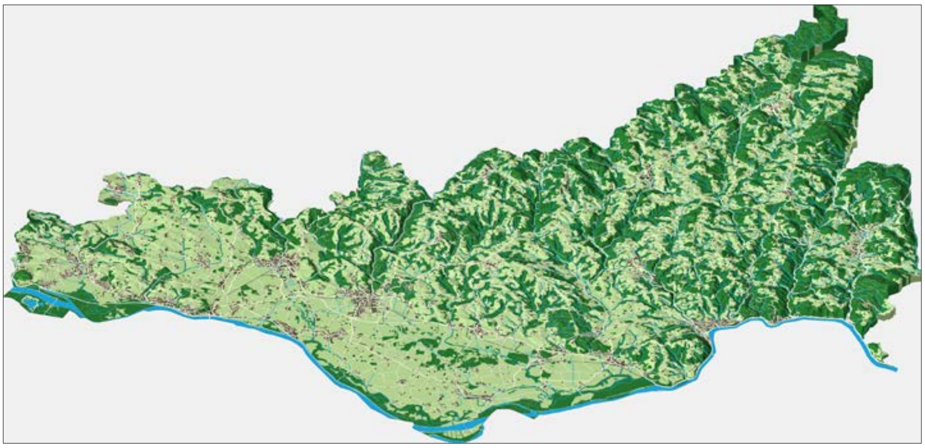


Figure 6: *Orthographic oblique map of the Bezirk Perg at 45° (without labels and additional information)*

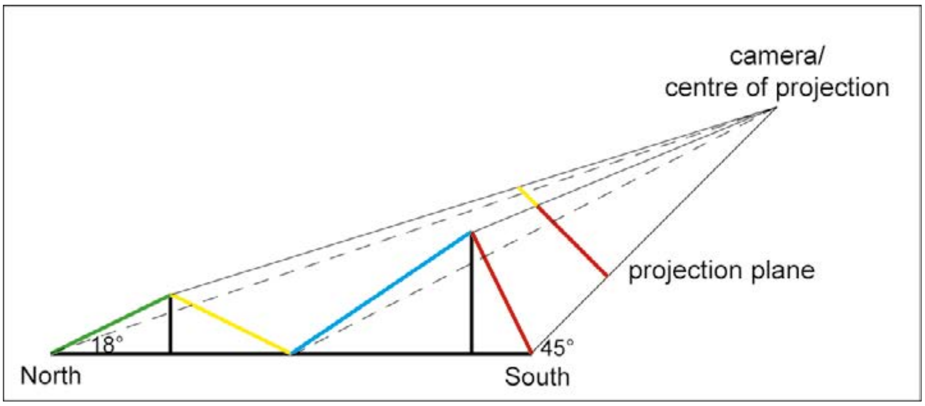


Figure 7: *Occlusion of the slopes facing away from the viewer (green and blue lines)*

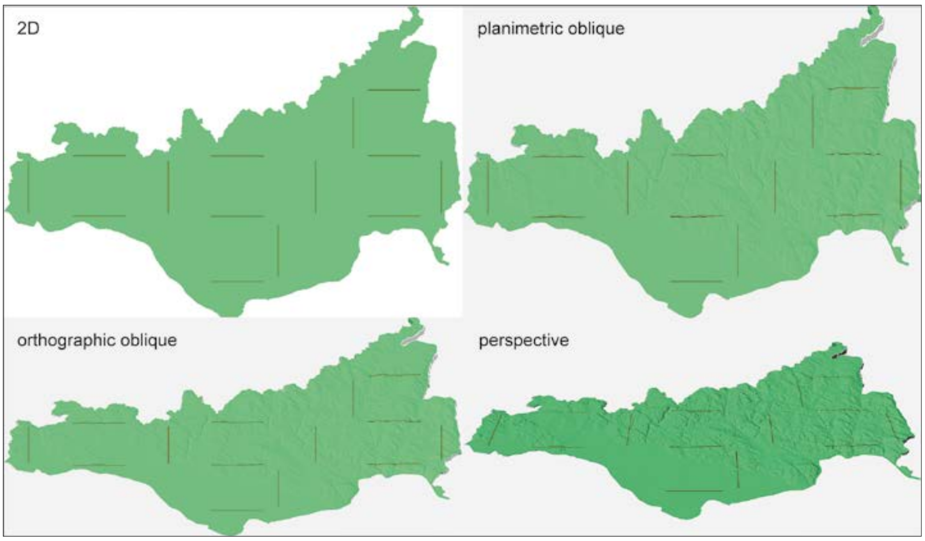


Figure 8: *5 km lines shown in the four projections examined*

Other reasons to use an angle of 45° were that it provided the best spatial impression while still somewhat retaining the shape of the area and that the same angle had also been deemed most suitable for the other two projections examined. The map that was created using this method can be seen in Figure 6.

6 PROBLEMS WITH PSEUDO 3D MAPS

There are various issues that arise when producing pseudo 3D maps, which is why such maps are not that popular and widespread used. Firstly, obtaining adequate data is sometimes still difficult and rather expensive, as for smaller areas a very high resolution DEM is needed. For some areas OpenStreetMap data might be sufficient but in this case it was not consistent so the buildings, as well as various other layers, could not be included. But the bigger problems – the ones that exclude pseudo 3D maps from being used for exact measurement and navigation – are, that by showing the side of features some parts become occluded, that the scale can change drastically on a map and that features can be foreshortened and displaced.

Occlusion is the problem of one feature blocking the view of another feature. It is an inevitable problem in pseudo 3D maps. In general, a three-dimensional view cannot be achieved by showing all sides of features. If it is necessary for the use case to show all sides of an area, more than one view should be considered. Since slopes facing away from the viewing direction often become occluded in pseudo 3D maps, it is important to choose the viewing direction carefully.

Another important factor that influences occlusion is the viewing angle. As a basic principle, the occlusion becomes greater, the more acute the viewing angle is. This effect is particularly prevalent in the perspective projection as Figure 7 shows.

The scale change throughout the map is an important issue in pseudo 3D maps as it influences the distance measurement and to a lesser extent the height measurement. The plan oblique projection is somewhat of an exception in this case as it preserves the scale in both x- and y-axes, and if a viewing angle of 45° is used, also for the z-axis. Orthographic oblique projections generally have three different scales, one for each axes. Again, a map using a viewing angle of 45° is an exception, as it has only two – one for the x-axis and one for the y- and z-axes. Figure 8 illustrates the scale change for the projections examined by using lines of equal length. Of the projections examined as part of the thesis, the one with the biggest problem of changing scales is the perspective projection. In a central perspective projection the scale differs depending on the distance from the centre of projection (view point). There is no constant scale in a perspective map.

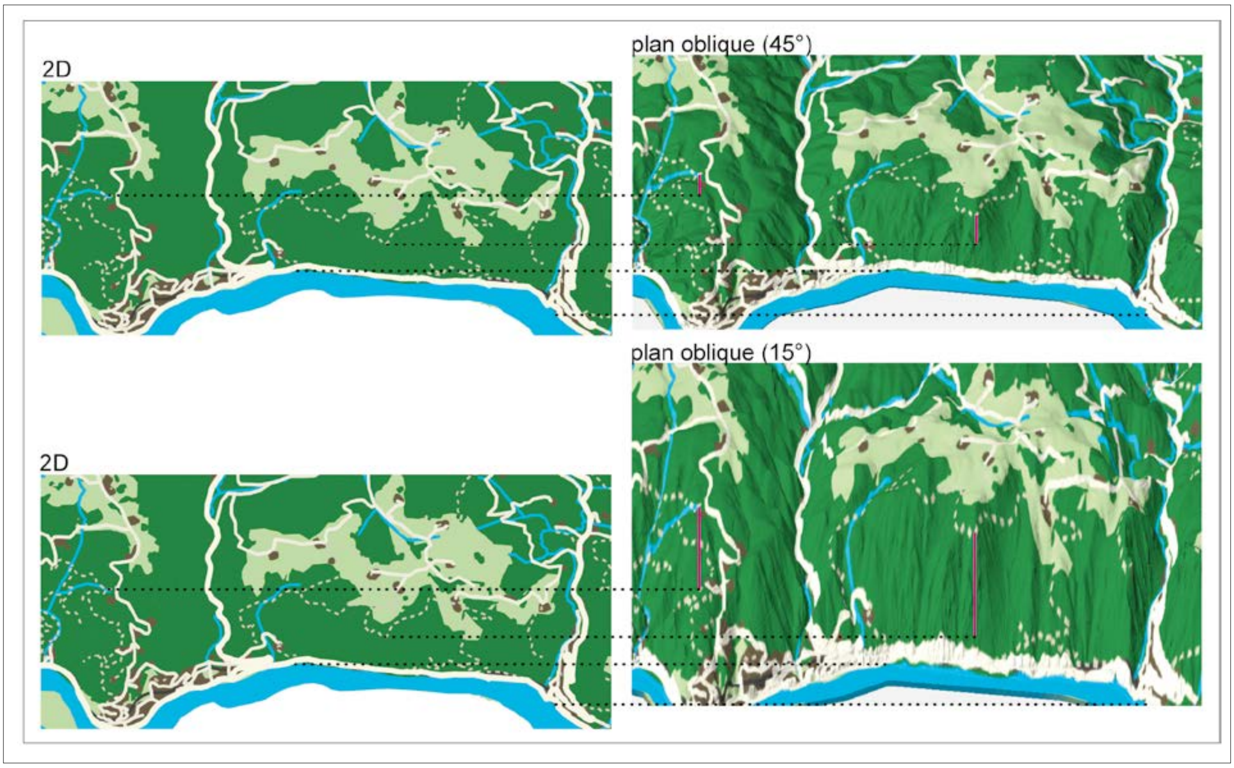


Figure 9: The displacement of points in a plan oblique map using two different viewing angles

task	2D	PO	OO	P
terrain interpretation	--	+	++	++
comparing points regarding their altitude	--	+	+	++
estimating altitude differences	--	+	++	+
estimating distances	++	+	+	+
general orientation - cardinal directions	++	-	-	--

Figure 10: Suitability of projections for different map use tasks (PO = plan oblique projection, OO = orthographic oblique projection, P = perspective projection)

Another issue with the scale is how to communicate the differing scales to map users, especially to non-experienced map users, as people might not read a text box added to the map or they might not be interested in the geometry of the map. In the final map this was done with two scale bars – one for east-west and one for north-south.

The accuracy of a map most importantly concerns two topics – the planimetric displacement caused by introducing a side-/front-view and the foreshortening caused by the scale change. The planimetric displacement is, apart from the occlusion, the biggest problem in plan oblique projections. An example of this can be seen in Figure 9 which shows how the viewing angle influences the magnitude of the displacement. The displacement of vertical features in orthographic oblique maps is decreased by the foreshortening of the z-axis. The foreshortening in this projection, however, introduces displacement along the y-axis as well, which is not the case for plan oblique maps. In perspective maps the displacement is not only the case for features of different heights but for features on the same elevation as well, which is caused by the centre of projection being finite and parallel lines converging. This effect goes hand in hand with the foreshortening of features in perspective maps and is an important factor in giving the map user a three-dimensional impression of an area.

7 OUTLOOK

For the use case in this study and the survey conducted the orthographic oblique projection performed best in comparison to a perspective projection, a plan oblique projection and a 2D map.

How the projections were rated for the map use tasks described can be seen in Figure 10.

In order to find out whether the orthographic oblique projection is generally better suited than the plan oblique and perspective projections, the survey has to be replicated for other areas with a different terrain. However, for a terrain that is similar to that of the Bezirk Perg, it can be assumed that using an orthographic oblique map, with the settings used in this thesis, will give map users a better understanding of an area than the other projections. A lot of the parameters (viewing direction, viewing angle, focal length in the perspective projection, as well as the map design itself) set in the map-making process of this study can be adjusted to tailor maps to the needs of the map user, and each parameter influences the perception a user has of a map, making it important to conduct further tests. Generally speaking, the choice of map projection depends on the use case and the map use tasks which are important for the use case.

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