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Identifying surviving landmarks on historical maps

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Summary

Historical maps can provide valuable information for different disciplines. In this way maps are used more and more as data sources to detect spatial and temporal changes. But maps do have their limitations mostly because older land-surveying and map-making techniques were different from what we use nowadays. We should consider this when dealing with maps as data sources. Are the sources reliable enough to be taken as bases to determine changes over time? Or, are they merely pictorial representations without geographical or spatial foundation? The reliability of historical maps is studied in the research "Measuring the historical city" as part of the NWO research program Paper and virtual cities.

By studying the education of mapmakers and land surveyors and by comparing various maps we try to understand how maps were made and to assess their reliability. We approach the reliability of the spatial context by measuring the accuracy of the maps by comparing historical maps with modern data. To enable such comparisons we consider differences between sources that are the results of real temporal changes and differences due to the techniques used to produce maps. This must result in a method that objectively describes how to interpret and compare features on historical maps with the same (and sometimes no longer existing) elements on reliable modern maps.

On the basis of a case study of the Dutch town Zwolle we try to visualize difficulties and constraints resulting from these comparisons. We explore in detail aspects such as 3D effects and the correspondence between features from map-to-map by looking at the differences in: depiction of features, content of the map, and stages of the mapmaking process. Our hypothesis is that a correct interpretation of features depicted on historical maps in the end will reduce the number of errors we might make in processing and therefore lead to a more reliable use of digital maps.

Introduction

How do digital urban reconstructions relate to the original or to the contemporary situation? To answer this research question, formulated at the start of the project Paper and Virtual Cities in 2003 (Universities of Groningen and Maastricht), we need to study visualizations of the past. Based on historical maps depicting contemporary situations in mainly 17th century Dutch cities, this project aims to create a matrix that represents the reliability of these maps. Such a matrix can help the user to see

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whether a map is accurate enough to be used as a primary source in research or design. Unfortunately there exists neither a good standard to measure the accuracy of historical maps, nor is it fully clear what the results of standardized tests (like calculations of the root mean square error) mean in relation to the map. In the project two main types of reliability are considered: historical evidence and technical accuracy. This paper focuses on the later one.

The aim of the sub-project *Measuring the Historical City* is to find out the accuracy with which measurements were taken by surveyors from that period, and the precision with which they were mapped. By measuring this we might define how confident the user can be when using the map as a source for research or design. The best way to find out how accurate these maps are is by comparing them to modern cartographical products. To do so we must study the techniques used in land surveying and mapmaking from that period. An important step in this study is to recognize errors, distortions and differences in historical maps and understand why they occur. We can do so by trying to find patterns and relationships between errors and feature representations, and use these to assess accuracy.

The dataset that was used for a number of examples in this paper consists of a set of six maps of the city of Zwolle from different mapmakers and from different periods. A modern digital base map, provided by local authorities, was used as a reference, and the cadastral map 1832 is used as an intermediate between the modern and old cartography.

The methodological approach covers different stages including data acquisition, data processing, integration, analysis and evaluation. In the phase of the data processing historical and modern maps are compared in detail by using techniques of geo-processing and spatial analysis. In this way it is possible to detect and quantify differences in the representations of cities. In order to recognize the differences we need to determine how features (or areas) on the map correspond to objects in the city at the time the map was made. We assume there is something like "mapping priorities": elements depicted with higher priority will reflect also higher accuracy than those with lower priority.

A complete study of accuracy starts with a comparison of the old data with real data. In our approach we do so by analyzing measurements taken from historical maps and comparing them with their homologues in the cadastral map 1832. A number of aspects need to be considered: Firstly, that accuracy can vary from one feature to another even within the same map; secondly, features can be depicted differently in different maps; and thirdly features can be depicted with different priorities for different mapmakers. These and other issues will be explained in more detail in the following sections.

Historical Context

In the original application for our project we noted: "Errors in interpolations can be diminished by establishing the original measure points of the land surveyor and by using these for the coordinates". The main problem is that these points are almost never known. In just a few cases we know the original sketches or a visual display of measured angles by the surveyor. Examples of this can be found in the sketches from Daniel van Breen (c.1599-1665) as he used them to create the birds-eye perspective of Beverwijk.[1] The second example is the drawings of the measured values as they were created by

[1] Daniel van Breen (c.1599-1665); Jaap van Venetien (1974).

Johannes van den Corput for his famous map of the German town of Duisburg (1566)[2]. But for many other maps this kind of data is not available, and we can only guess what points the surveyor could have used in order to create the map. Fortunately we can get some help from another type of source: the materials used for the education of the surveyors and military engineers.

In 1600 the first school for military engineers and surveyors started at Leiden University. This school was founded by the Dutch Prince Maurice of Nassau, and his advisor Simon Stevin wrote the teaching program. Since the engineers were taught the basics of mathematics, land surveying and map making in Dutch, it was called the "Duytsche Mathematique". The books that were used at these colleges are practical in nature, being a sort of step-by-step manual of how to design fortification works and how to survey. There are several of these treatises, and one of the aims of the project is to see whether we can find those points in a map that were used by the surveyor. The main question is: How can we find the original measuring points, based on both the maps that were created, as well as on the texts in the treatises?

From the texts in 17th century books on surveying, and a number of engravings, we know that there were several types of instruments used during the surveying process. One of the instruments that is described in such detail is the Dutch circle, an instrument created by the Dutch surveyor Jan Pietersz. Dou. In 1620 he published a short manual on the use of the instrument, i.e., describing the use of the circle (Dou 1620). With the instrument it is possible to measure angles in relation to a fixed baseline. From a high point, for example a church tower, the angles towards other points can be measured, and if repeated from a second position the two sets of measurements can be combined into a triangulation (Figure 1). Dou, together with his colleague Johan Sems, had already indicated in an earlier publication that early instruments, like the quadrant lacked sufficient accuracy when it came to measuring angles over 90 degrees. This might be due to a lack of experience (Pouls 2004: 20). Nevertheless, Dou wanted to create an instrument that would enable the surveyor to measure angles over 90-degrees: the Dutch circle.

One of the major improvements in the accuracy of the measurements that came with the circle was related to the size of the instrument. With a radius of 30 centimeters and with a graduation on the outer circle the instrument maker was able to subdivide every degree into six parts.[3] This 10-minute subdivision will be about the accuracy of many of the angles taken until the 19th century. However another problem should be taken in account when analyzing the accuracy of the measurements taken. On many church towers the surveyor must have moved his instruments at least three times in order to measure a full circle, mainly because of the steeple on the tower. Milz, in his analysis of the Corputius sketches, already showed that the cartographer used six different positions on the tower of the Salvator church, and that the angles taken were all within the range of 90 degrees (a clear indication of the use of the quadrant).[4] Based on all the measurements Milz concludes that there is a 2 percent divergence in the total of angles measured and the maximum subdivision is a quarter degree.

[2] J. Milz (1996:227-250)

[3] Pouls (2004), p.41. The circle kept in the museum of the Groningen University has a similar lay-out.

[4] Milz (1996), p.242, abb.8.

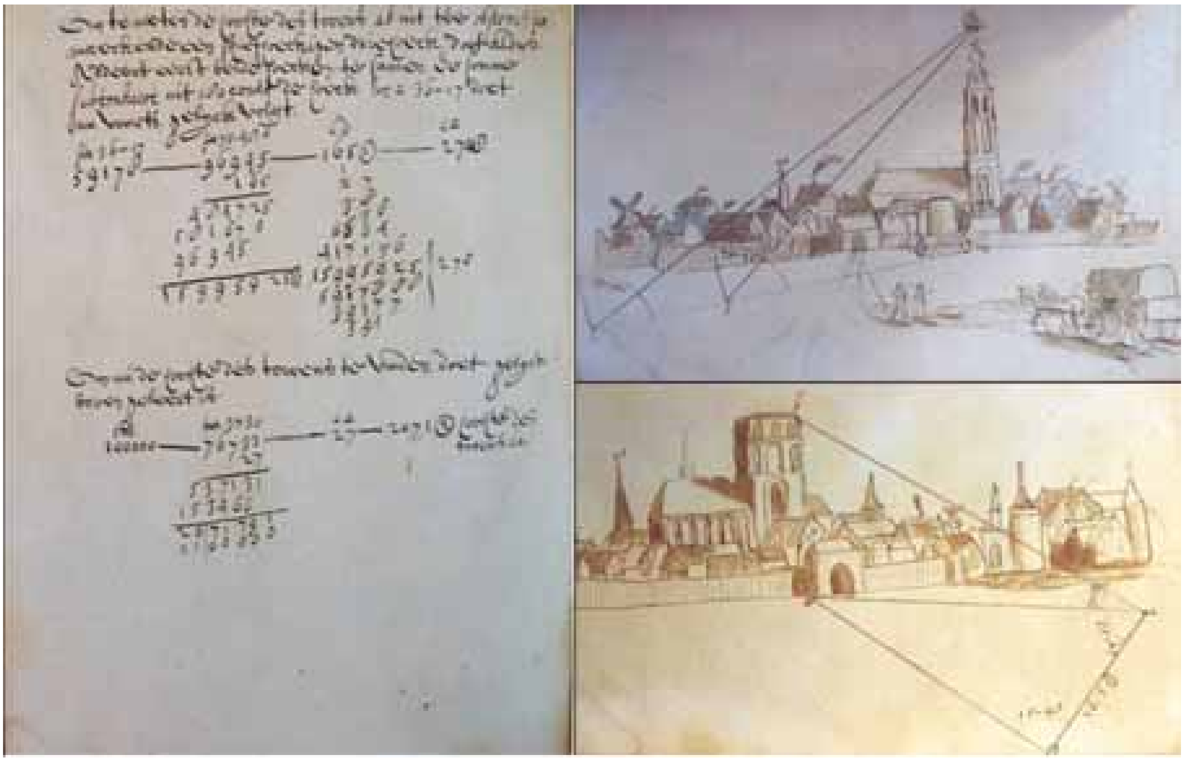

Figure 1. The measuring of angles and distances by using high spots (towers) in Zwolle.
(From the manuscript Geometria Zwolle[5], Historisch Centrum Overijssel).

With these short notes of 17th century land surveyors on the precision of these two instruments in mind we can have a look of the map itself. Which are the points that the cartographer has used in taking the angles? Translated into modern GIS-terminology this question relates to the choice of Ground Control Points (GCPs').

Comparing historical and modern cartographical sources

In order to find common features between current and old situations in the depiction of a city it is essential to compare both representations. However, finding this kind of spatial relation between old and modern sources might turn out to be a very delicate, perhaps even often subjective process. In order to reduce the subjectivity in the interpretations of features one should have a good look at the historical context of the source. A correct understanding of features in historical maps will help to refine the process of finding points that might be chosen as GCP's during the geo-referencing process. However before we can start this search of points we first need to solve a number of problems.
The main goal of the visual comparison of different maps is to find out which points are good references to be used as GCPs in geo-referencing of the data and as a basis for comparisons. However this all depends on differences in both the function of the map, as well as in the style in which these features are represented. Obviously, the gate building on an orthogonal map will look very different on a

[5] Nicolaum ten Have, Geometria ofte meetconst, gedicteert doer Nicolaum ten Have, conrectorem schola Zwollana, Manuscript 1641, Zwolle, Historisch Centrum Overijssel.

birds-eye perspective, although both features might be mapped with the same precision and at the base of the same measurements. Such a difference in style might not lead us to exclude these points, but it demands a careful reading of the map. This is what we referred to above as: "priority of feature depiction".

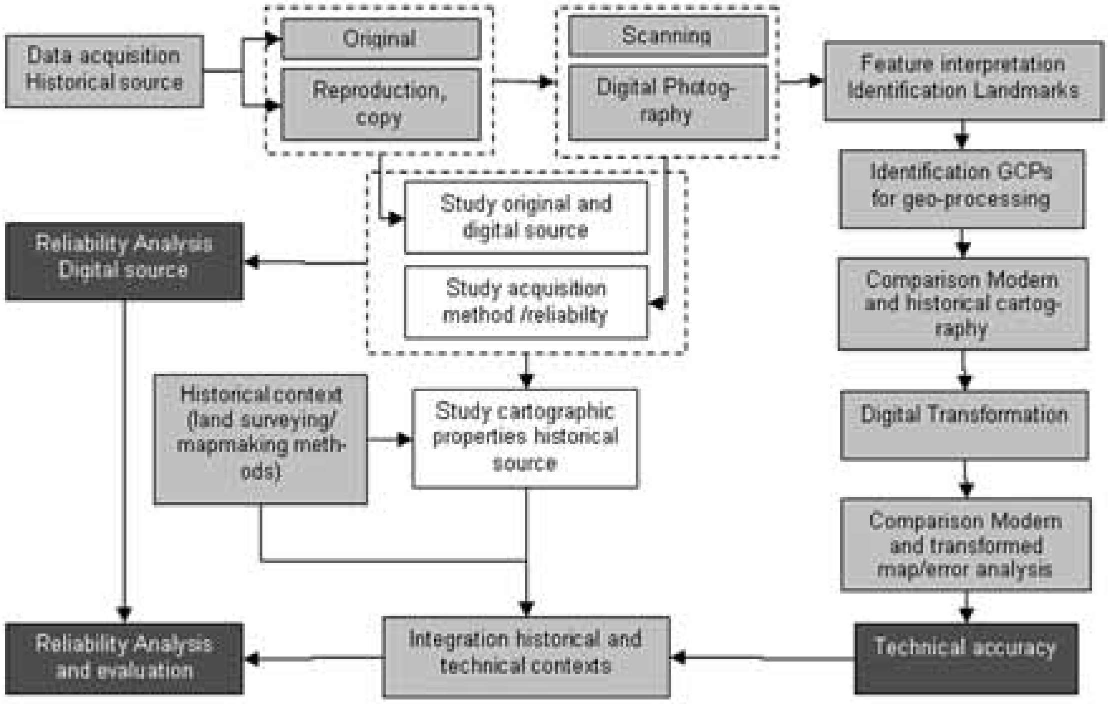

Figure 2. Schematic representation of the methodological process.

In a pilot study on the maps of Zwolle different experiments have been conducted using high-quality digital scans.[6] The method as it is represented in the diagram (figure 2), is as follows: Firstly we acquire the data in digital format by rasterizing the paper map. In many of the cases this is done by using a digital camera. The second step is to identify points on the map that can be used in the process of rectification as Ground Control Points (GCPs'). Several carefully chosen control points are located on the digital image. Each of these points refers to the homologous point on a reference map, in this case the 1832 cadastral plan, but we should keep in mind that errors might be introduced during this process. After the identification of useful Ground Control Points we move to a next important step: the comparison of historical maps with the cadastral map, a comparison on which the assessment of errors in representations and technical accuracy are based. In order to find out about these errors we make some linear transformations to the map just by applying a number of simple operations like scaling, translation and rotation. These comparisons will help us to identify drastic changes occurring in the map in respect to the same comparisons made by using more complex transformations (like

[6] The researchers are aware that processing of digitations inevitably introduces its own distortions, which could in principle affect the reliability of the study but are confident that contemporary digitization techniques ensure sufficient fidelity so as not to influence the results.

affine or different orders polynomial transformations). In the next step a geo-referencing of the map is carried out using the control points set in the second step. In order to check on the rectification in the fourth step the rectified historical map is compared with the reference map (in this case the cadastral plan of 1832) by comparing several common points on both maps and how their positions differ. In this step the whole process of rectification is analyzed. The data from this analysis is the basis for measuring the technical accuracy. Parallel steps are carried out in order to study the historical context and to verify the quality of the digital source materials used for the research. Results of this analysis will be integrated with the technical accuracy for the final analysis and reliability assessment: the reliability matrix that is to be one of the main goals of the total project. In the following parts we will focus on the problems that appear in the choice of the best points to be used as GCP's and the results of the study.

To define the points that can be used in the second and fourth step we need first to identify common objects in the old and modern townscape. This implies the interpretation of features map-by-map. One of the problems is that due to the diversity in the drawings from one map to the other features are not, or not exactly, depicted in the same way on each of the maps. For example there is a difference between the 2D and the 3D depiction of features in a map.

In many 17th century maps of cities we find many types of depiction of the townscape (Figure 3). According to the typology of Koeman[7] we can distinguish four main types of maps, where some of them have sub-categories. If we look in detail at the set of maps we are studying, we recognize characteristics of a plan with buildings in oblique (parallel) projection "in which each of the buildings is represented by using the same angle in respect to the map surface".[8] This is especially clear in the maps of Priorato (1673)[9], Blaeu (1649)[10] and DHSlide (1739)[11]. In these maps we see buildings depicted as 3-D objects. Although the map is created using an orthogonal projection, special objects like buildings, city walls, churches, and so on, are depicted using oblique parallel projection. The other 3 maps, DH68[12], DH68A[13] and G35II[14], are to be categorized as plans.

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[7] Koeman (1985: 110-111).

[8] ibidem

[9] *Svvol*, Priorato (1673), Leiden University Library, Collectie Bodel Nijenhuis (COLLBN) P 44 N 137 (original) and Zwolle (copy), Collectie Historisch Centrum Overijssel. The Netherlands. Scanned from copy (reproduction). Listed in this paper as "Priorato".

[10] *Swolla*, Blaeu [c.1649] COLLBN P 44 N 126 (original) and Zwolle (reproduction). Scanning from copy (reproduction). Listed in this paper as "Blaeu".

[11] *Plan der Stad Zwoll, gelegen aan de Revier de Veght, met hun fortificatie en Situation*, (1739) ARA4 OPV Z66 Nationaal Archief, The Hague, Min. Oorlog. Archief Genie, Plans van Vestingen 16eeuw-1800, The Netherlands. Scanned from slide. Listed in this paper as "DHSlide".

[12] *Plan der Stad Zwol*, ARA4 OPV Z68 (1739). Nationaal Archief, The Hague Den Haag, Nationaal Archief, Min. Oorlog. Archief Genie, Plans van Vestingen 16eeuw-1800, The Netherlands. Scanned from print copy A4. Listed in this paper as "DH68".

[13] *Plattegrond van de stad Zwol,* ARA4 OPV Z68A 1739 (1750), Nationaal Archief, Min. Oorlog. Archief Genie, Plans van Vestingen 16eeuw-1800, The Hague, The Netherlands. Scanned from print copy A4. Listed in this paper as "DH68A".

[14] *Plan van Zwol en werken aan den Yssel boven stuk*. Genie ST. G35 II., Nationaal Archief, The Hague Den Haag, Nationaal Archief, Min. Oorlog. Archief Genie, Plans van Vestingen 16eeuw-1800 and Historisch Centrum

Figure 3. These maps show different representation of the same city (Zwolle, The Netherlands).
a. Blaeu [c.1649] b. Mattaheus Merian (1621)[15] c. Guicciardini (1582)[16] and d. ARA 4.OPV Z64 (1765,1775)[17].

We need to keep these differences in projection in mind when choosing the locations of these buildings on historical maps as reference points on the digital ones. Is the location of these buildings accurate enough to be used as spatial reference? Is the accuracy constant within one building? Because of the 3D effects, we can expect a variety in the accuracy of spots within the same building with implications for its use as reference. Koeman already mentions in his text a number of examples where the cartographer “played” with the direction of the lines towards the vanishing point, or where he notes that the orientation of a part of the church of Delft has been altered.[18] Koeman, at this point, even

Overijssel, Zwolle Collectie Historisch Centrum Overijssel (reproduction). Leiden University Library, Collectie Bodel Nijenhuis (COLLBN) (original). The Netherlands. Scanned from copy (reproduction). Listed in this paper as “G35”.

[15] COLLBN Port 44 N 129[1]

[16] COLLBN Port 44 N 123[1]

[17] Plattegrond van de vestingingwerken, ARA 4.OPV Z64 (1765,1775) [3]

[18] Ibidem 6

mentions the case of Zwolle where the map of Braun and Hogenberg would have looked better if the direction of the map had changed with 45 degrees.
In order to visually compare common objects in maps made by different mapmakers, a visual analysis needs to be performed at the level of detail in the depiction of bastions, buildings and other features of the urban fabric that preferably do not change much overtime. This analysis can help us understand the representation and facilitate the identification of common details between maps. One of the issues in this analysis is in the study of the profiles of bastions. In the research drawings of the profiles of some of the bastions found on the maps of Zwolle have been created (Figure 4a, b). These profiles show the level of detail we can visualize for many of the bastions in the different maps. This type of drawing enables us to interpret the lines and other details and differences in the depictions of bastions on the map.

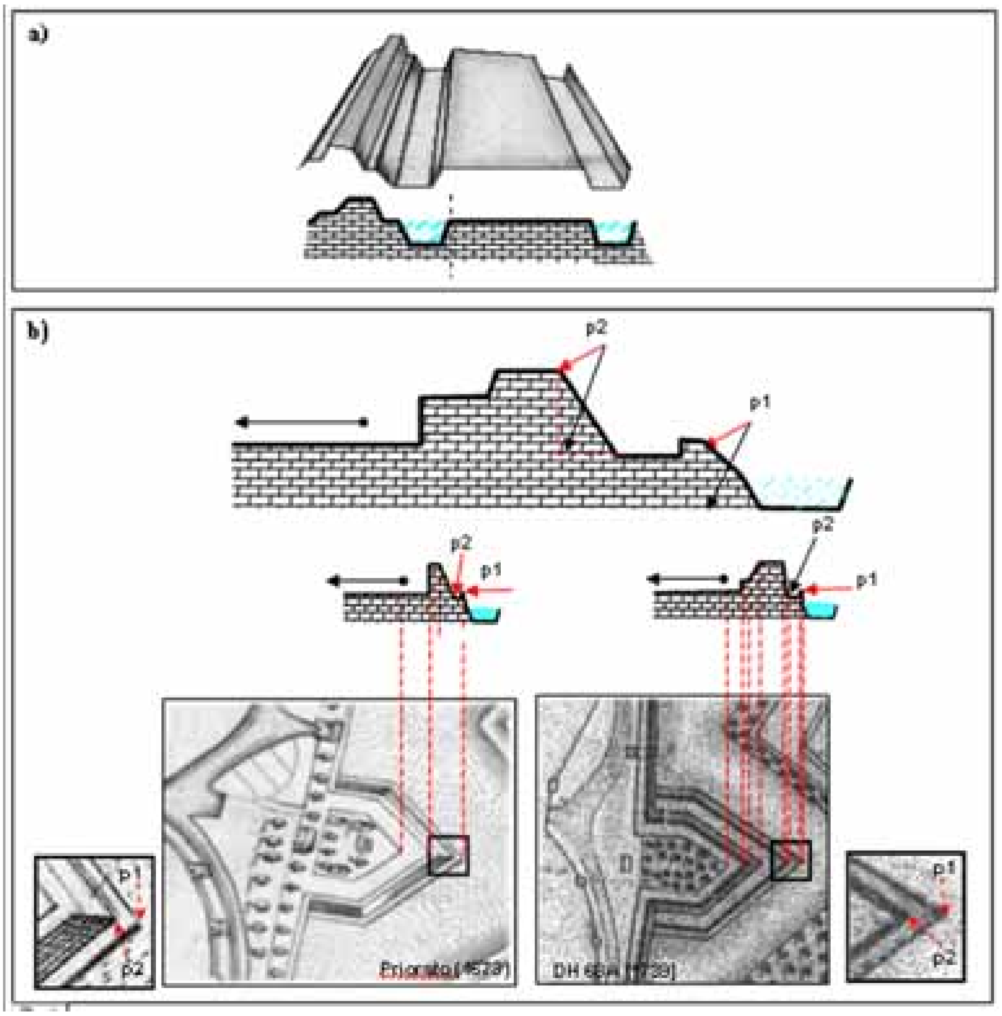

Figure 4. Profiles used for choosing common points in the historical maps of Zwolle a. Detail of a profile as on map ARA 4.OPV Z65 (1672)[19]. b. Detail of a bastion's profile (above) and interpretation of the profiles of the bastions depicted on the maps of Priorato (1673) and DH68A (1739) (below). The corresponding points are indicated by dotted lines.

[19]*Plattegrond van een verschanste legerplaats buiten de Diezerpoort (met doorsnede),* Nationaal Archief [3], ARA4 OPV Z65 (1672)

Profiles are especially useful for recognizing objects that are representing three-dimensional objects. If we refer to what we know from the surveyors' treatises we can say a number of things about what they would like to show on a map. What we also can say is that seen from the high viewpoint within the town (e.g. the church tower) they would probably map the highest contour line of the point of the bulwark. From this point any military engineer or surveyor could, with the help of several guidelines, reproduce the full line of defenses since this was one of the main issues in the education. In this way it is possible for the mapmaker to map the contours of the city. Of course not all fortification works were as regular as they were in the many analyses of the treatises, but even during their education the surveyors were trained to design the irregular city. So what we often see is that the inner point of a bulwark is given and the slope of the earthworks is hatched. But even recognizing this we can run into problems when comparing two different maps, as for example the third bastion in the maps of Priorato (1673) and DH68A (1739). The first map is a plan with objects represented obliquely while the second is an orthogonal plan. When we try to reconstruct the profile of the bastion based on Priorato the form will be correct with a wall and a covered road outside the wall. Doing the same thing with DH68A would lead to a confusing situation since what we see (and probably interpret) as hatched slopes are just the horizontal heights of the wall and the covered road. As mentioned before, these are the constraints that complicate the selection of features, the identification of common points, and which therefore hinder the choice of the location of strategic points for geo-processing of historical maps. Another problem arrives when not all features on a map are depicted. For example when we study 17th century fortification plans of cities we will notice that on many of these the emphasis is on the walls and bastions. In many of these plans the street pattern has been drawn in a much vagues way, or is even missing. In and of itself this should not be a problem since the fortification works, being the main subject of the map, are generally drawn with a much precision. Unfortunately in many Dutch cities we cannot use the fortification works directly as ground control points. Therefore we use the earliest cadastral plan of 1832 as an intermediate for the choice of the GCP's.

The Cadastral map 1832 as intermediate

The 1832 cadastral plans are in many cases the most reliable and earliest plans that depict the lay-out of the city in detail.[20] For this reason they are used by many urban historians as the basis for their research. In 1829, after a number of earlier attempts, surveyors set out to measure the city plot-by-plot. The main reason for this detailed survey was that the results were used for determining the amount of the taxes to be paid for a certain piece of land. Every parcel of land was stipulated by an official arrest, and since money was involved it was done with the greatest precision. Another reason to use the first cadastral plan as an intermediate is that its depiction of the city most of the time comes closest to the situation of the centuries before. This mainly has to do with the fact that, unlike the situation in many other countries, the industrial revolution in the Netherlands, with its enormous impact on the townscape, had already taken place in the 17th century.[21] While the lay-out of French and English cities often changed completely in the late 18th and early 19th century, the urban fabric of most

[20] Koster (2001: 124)

[21] De Vries and Van der Woude (1995); Koster (2001).

Dutch cities remained more or less the same until the mid- 19th century. So there is much resemblance between the situation recorded in the 1832 cadastral plan and the one, let us say in maps of the 1650's. The major change in Dutch townscape takes place after the late 1870's with the dismantling of the defense works caused by the new law on the fortifications that passed in April 1874.

Unfortunately in this investigation we cannot use the cadastral plans for all features that one would like to take as reference points. This mainly has to do with the function of the map as a tax register. The cadastral plan is mainly a map indicating the surface area and boundaries of plots for which the owners had to pay taxes. However since the large defense systems around the city were state-property, they are not listed. The reason is obvious: the state did not have to pay tax over these areas. Unfortunately many fortification works around cities were owned by the Ministry of Defense until 1874. Therefore they were not mapped in detail, that is to say only the contours are shown. In finding points that can be used for comparison between a historical map and the cadastral plan this means that the fortification works cannot be used in many cases, or at least that other points are needed to do an accurate registration. But in many other aspects the cadastral map can be considered very accurate, for example on the position of buildings. Corners of building blocks can be found on many maps and specific features such as alleyways between buildings often got mapped in historical city maps. It is mainly for this kind of features that the cadastral plan is a perfect map to use as a reference and an intermediate.[22]

But the cadastral plan also needs to be geo-referenced. In order to do this, the modern cadastre could be used, but since a number of years ago the Netherlands have been very accurately surveyed with the "Grootschalige Basiskaart (GBK)" the large-scale base map.[23] This digital vector map covers the whole of the Netherlands and is kept up-to-date by local governments. In 2003 the local planning authorities of Zwolle offered us access to parts of this vector data, on the basis of which it was possible to carry-out the registration of the earlier data (as well the cadastral plan, as well as the 17th century maps) with great precision. But there is a huge gap between 1832 and 2003; not only in years, but also as result of the transformations of the urban landscape that have taken place in the last two centuries (Figure 5). Many of the boundaries shown on the cadastral plan do not exist on the base map and vice-versa. In many of the city centers more radical changes took place: slum clearance, parking space, and renovation were the keywords of city planners in the 1970s and 1980s. So even when the plot boundaries on the maps look the same we still need to check if they actually are the same. Historical research can help in this process, but also comparisons with aerial photographs taken on different moments in time. Due to the accuracy of the surveying techniques used by the makers of the 1832 cadastral plans we can, based on a limited number of points, make a good registration.

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[22] Over the period 2001-2003 all the cadastral plans of the Netherlands dating 1832 have been digitized in a large project sponsored by the Dutch government. The results can be found at: http://www.dewoonomgeving.nl

[23] http://www.gbkn.nl/

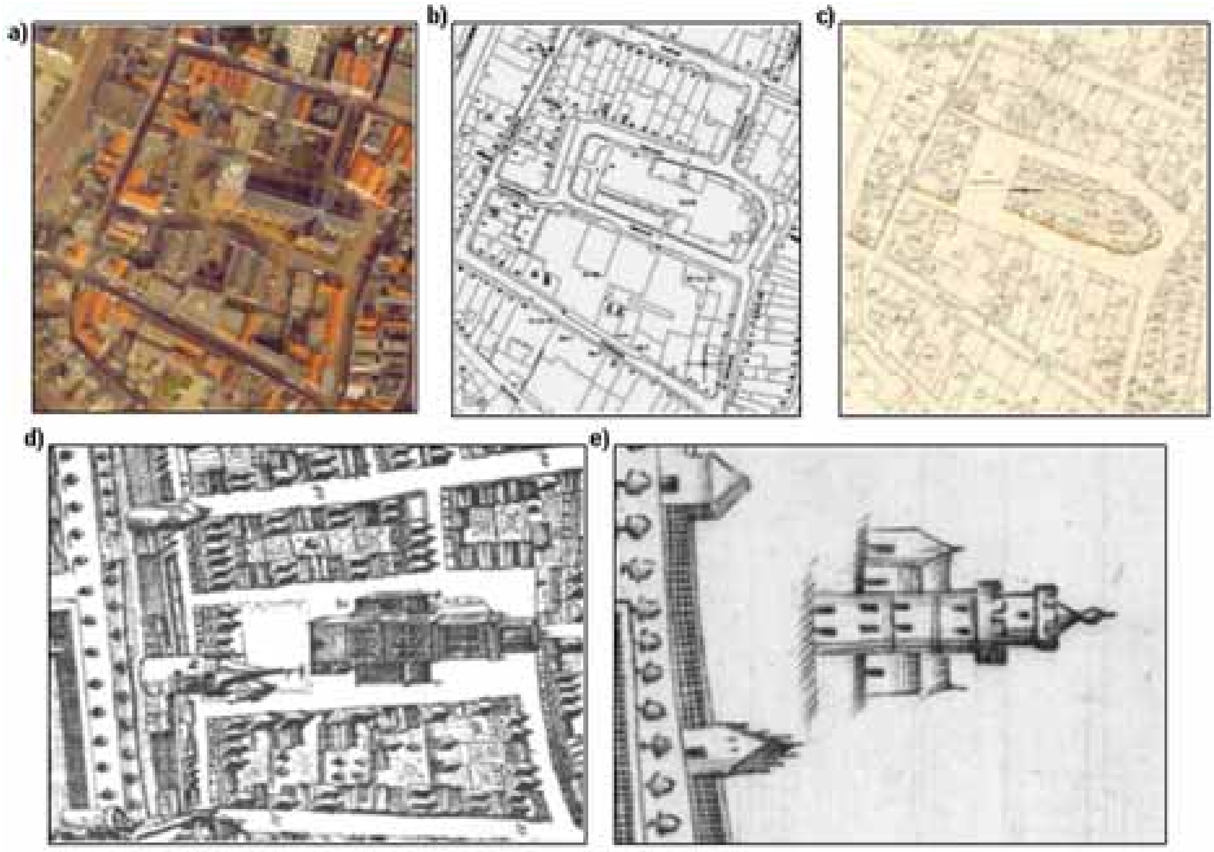

Figure 5. Views of “De Kruis” church and surroundings from different modern and old sources, case study of Zwolle city (Netherlands). a) Aerial photograph 1994, b) GBKN 2004 (Gemeente Zwolle), c) Cadastral map 1832, d) Blaeu [ca. 1649] e) Priorato (1673).

Limitations and constraints in the identification of landmarks

Based on the six maps of the pilot study of Zwolle the following examples can be given that are related to the problem of identifying useable landmarks in historical maps. As stated before, three-dimensional effects are noticed in the maps of Priorato, Blaeu and DHSlide. These effects are also recognizable in some minor details in the other three maps. Together with the 3D effects we can also see the complexity in the depiction of buildings especially along the city wall (Figure 6). The same complexity in the drawing is also shown in the figures 7b, d, e, where it becomes difficult to find a spot that gives a precise location of the buildings. In the cases of maps with buildings drawn in perspective, the intersection of the buildings with the canal has been chosen to locate common points. In the two-dimensional maps, several points can be selected. In finding the location of a common point in the building (e.g. of the figure 7e), we selected the point by drawing a line perpendicular to the wall and intersecting it with the circular shape used to depict the building.

Buildings drawn in three dimensions are not only affected by their heights but also by the oblique parallel projection. How should we choose the best position of a reference point in such an object? As in the earlier case of differences between maps, here we have to deal also with the differences in drawing techniques. The level of detail of features varies from map to map creating a new constraint in the interpretation of features. Here we show an example of three different depictions of the same bridge located in the north part of the city (figure 7f). If we look at the different maps we can see that many points on the bridge might be chosen as common points. In the three-dimensional drawing (figure 7f on the right) we can easily locate a spot on the northwest edge of the bridge, but in the other drawing this spot is not easy identifiable. In this case it becomes important to also consider the technique used by the mapmakers to draw bridges on maps. We can choose between lower and higher spots or an intersection of where the bridge starts. However, it is difficult to tell which would be the better location.

In some cases the same detail has different representations from one map to another. This aspect becomes important when it suggests a real change in the building. Such a change can be found in maps from different moments in time, but can also vary between maps from the same period. But such a difference can also be caused by a difference in techniques of drawing or it may be the result of different stages in the mapmaking process. The latter we find when comparing the map DH68 with the earlier version (DH68A). As shown in figure 7c the detail on the right intersects the wall but the same detail on the left side does not. This difference is about 3 meters which can make a difference when locating GCPs or quantifying differences between common points. Figure 7d shows another example where the features not only differ in the fact we compare three-dimensional and two-dimensional representations but also because of differences in how details are drawn. The common point refers to the intersection of the wall with a building (red arrow, figure 7d) which is not present in the 2D representation in the map DH68 (1739).

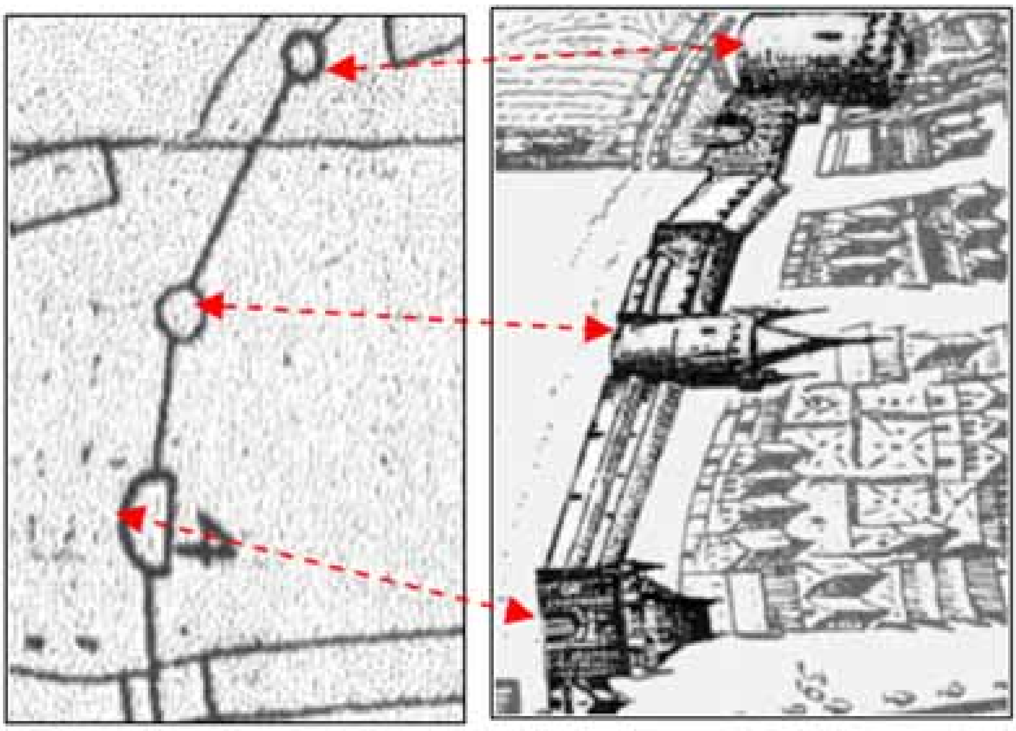

Figure 6. This figure shows an example of the complexity in the 3D depiction of the walled area in the map of Blaeu [c. 1649] (right) versus the simplicity of the 2Dimensional drawing in the map DH68A(1739) (left).

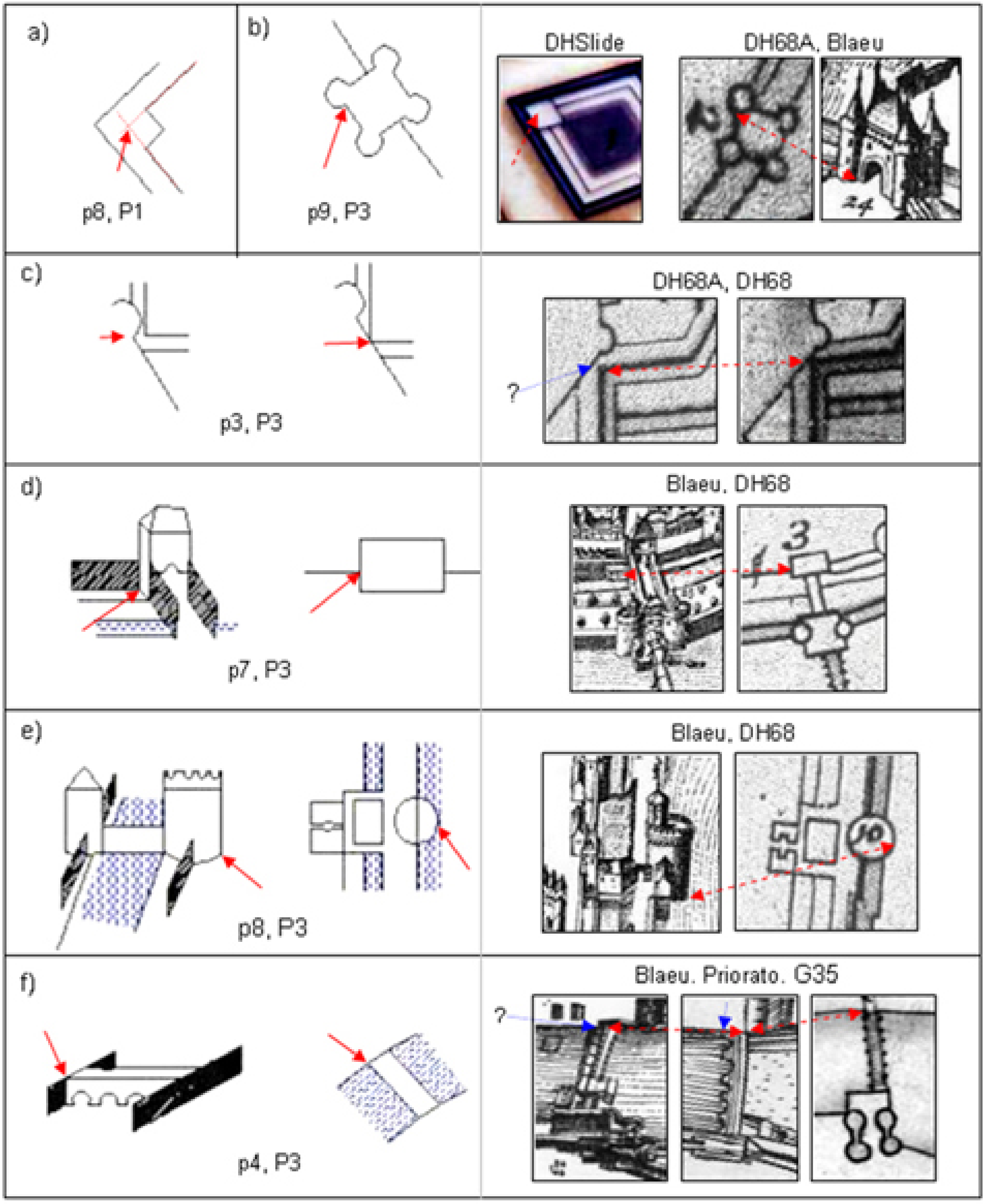

Figure 7. Examples of common points indicated with red arrows. These show the effect of the perspective view on these points. Blue arrows refer to other possible points locations.

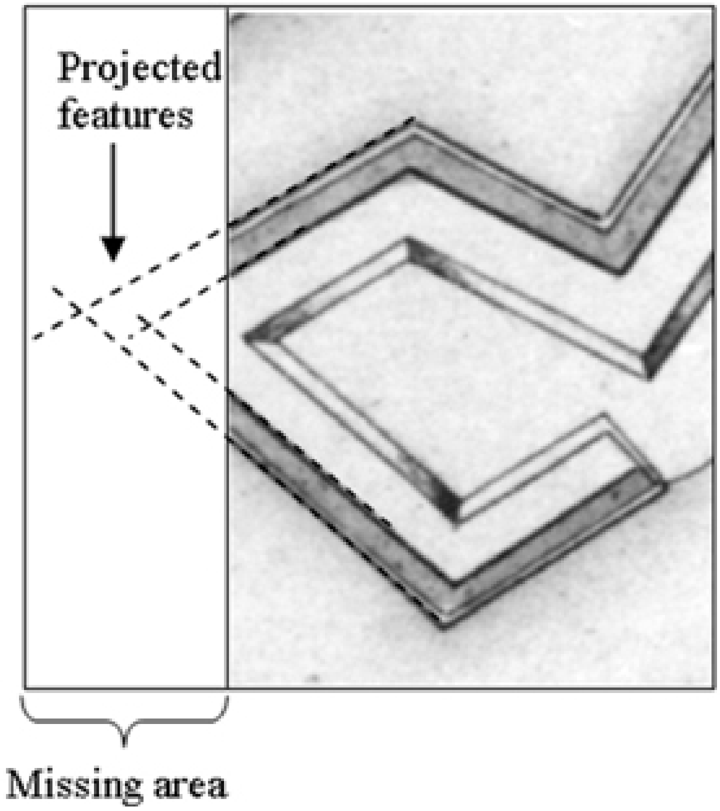

Figure 8. Bastion 8, map G35. This is an example of the case when parts of a bastion are missing due to the acquisition of the map. Here during the scanning process part of the map is cut off. The projected lines on the missed area (left) show how the shape of the bastion is reconstructed.

Some features are not drawn on the map but still it is possible to locate the common point by extending other lines in the map (Figure 7a). This applies to cases where the shapes of the features have been drawn slightly differently from how they were drawn in other historical maps. In many of these cases it is still possible to reconstruct its shape (e.g. when square angles in corners are drawn as rounded corners). Here we assume that the difference is not due to any real change in the shape of the object but is the result of a different drawing technique. This can be shown in some of the bastions in the map DHSlide (1739), and others in the map G35 where the shapes of the corners of the bastions are different. This technique of using construction lines is used also in the cases where parts of the bastion are missing due to the acquisition (Figure 8, bastion 8, map G35) or the conservation of the map.

Final Remarks

The main conclusion of this project is that surveyors and mapmakers in 17th century could map with very high precision. Firstly this has to do with their training. The newly founded surveying schools, from the early 17th century on provided a group of practitioners that were trained as well in theory as they were in practice. Secondly, the intellectual climate changed in the late 16th century, as it did a century earlier in Italy. The main causes of the new atmosphere were new treatises on planning and surveying written and new instruments such as the Dutch circle which had been developed. The basis for these new inventions is in mathematics, but once the theory is given into the hands of the practitioners, it is applied to the field of the mapmaker.

But the high precision of the map does not yet help in finding common points between maps that can be used to geo-rectify the map. As shown in this paper the choice of good and reliable ground control points can be problematic. For example, if we compare two maps, the first made using oblique parallel projection and the second one using orthogonal projection, we cannot trace back all features to one location. As it was shown in the example of what point to choose when mapping a bastion we can see that differences in the drawing techniques that are due to the different ways of depicting the slope of the wall in oblique or orthogonal projection might confuse the reading of the map. The main issue here is that we need to know about the historical conventions of how to draw since it was part of the education of the mapmaker.

This last issue is an important one that can help us in identifying the right common points between maps. We need to know about the basics of mapping from the 17th century. If we can reconstruct the historical process of design, measurement, mapmaking, and the (re-) use of a map we can better select our common points. As a result of this, well-chosen reference points for the geo-rectification process will help us in getting better knowledge on the technical reliability, one of the main goals of the project Paper and Virtual Cities.

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