Swedish Large-Scale Historical Maps as Sources for Archaeological Research: -Examples from Gotlandic Maps from 1693-1705

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Abstract - Historical maps are a vital and often used source in a variety of disciplines and applications in Sweden today. For a decade or two, they have moved into the GIS-community. A large scanning project by Lantmäteriverket will make most of the maps in Sweden available as raster images. In this article some different applications are presented, which goes beyond the traditional use of historical maps in GIS. These brief examples involve data mining, statistics, retrogressive analysis and hypothesis testing.

Introduction

Sweden has an enormous treasure in its vast number of large-scale historical maps archived over a period of 400 years. These maps also contain text descriptions of the mapped features and additional information depending on the mapping purpose. Use of information from historical maps has been a standard procedure for a long time in many domains in Sweden. Since so many populated areas have at least one historical map they are consequently of great importance as sources for historical knowledge of that area. The maps are frequently used in different studies of a variety of problems and also in different planning activities, such as the archaeological phase of preliminary investigations in construction planning and cultural management in both public- and private sectors. They are also used extensively for academic research in archaeology, geography, history, linguistics, and other disciplines. Examples of research areas are ecology, linguistics, agricultural development, ownership, spatial distribution of historical phenomena, etc.

The Swedish National Land Survey Agency has for some years had a very large and ambitious project, scanning all the historical maps in their archives (Lantmäteriverket -Historiska kartor för alla 2006). This means that hundreds of thousands (if not more than a million) historical maps will be accessible on the internet as raster images for anyone to download for a fee. This will even further boost the use of historical maps in GIS- and database applications. A method developed by the Department of Human Geography at Stockholm University in the 80’s was concerned with rectifying and transforming historical maps onto transparent plastic films. This method has long been used in comparative studies with contemporary maps (Cserhalmi 1997, Frisk 2000). It can be seen as an analogue overlay analysis, which is a standard technique in GIS analysis today. The introduction of GIS and other digital means has not fostered the development of new types of analysis and innovative approaches in the degree that could be expected. The maps have continued to be used more or less in the same manner. The full potential of the maps has never been used and all the text information has, so far, not been digitalised.

There are a multitude of smaller projects dealing with digitalisation of historical maps that are very narrow in their scope. They are set up for a restricted purpose and do not go beyond handling a few maps. The database modelling process is normally very limited and also poorly documented. Two projects have been dealing with historical maps in a more all-embracing fashion. They are Nationalutgåva av de äldre geometriska kartorna project (National Edition of the Older Geometrical Cadastres) at The National Archives of Sweden (Riksarkivet 2006) and the Digitala Historiska Kartor, DHK (Digital Historical Maps) at The National Board of Antiquities of Sweden (Frisk 2000). The former project only deals with the maps from the first phase of Swedish large-scale mapping between 1633 and 1655 and is poorly documented, with the focus on the text descriptions. The text descriptions of these first Swedish large-scale maps were very brief. The other major project, Digitala Historiska Kartor (DHK) at The National Board of Antiquities of Sweden, is well documented with a series of preliminary reports and one final publication with a conceptual model (Frisk 2000). The focus of the DHK-project was the general information, which can be found in any Swedish large scale historical map. The analyses also focused on how the maps are used in the cultural heritage sector and mainly treat the information used in this sector. Our own project, The GM1700, is a pilot project with the objective of showing how advanced conceptual analysis and database modelling can benefit research and other usage of historical maps in GIS, mainly in the humanities.
The GM1700 database model aims on capturing all important information found on both the map- and in the text-portion, in a way never done before. The assumed users of the developed database are researchers of history, archaeology, human geography, and adjacent disciplines, while the purpose is to be able to create database views and queries based on their research questions at hand. For most researchers in the humanities and social sciences, access to the unadulterated source is vital. This project is an attempt to make these maps available and manageable in a way that can be trusted by researchers in these disciplines, thus reducing, or even eliminating, the need to go to the source itself for most of the problems formulated. This makes it vital to keep the original structure of the information. To do this there is a need for a broad perspective and a data oriented view of the maps and the text descriptions. For a deeper and more technical description of the system, see Svedjemo & Jungert (2005) and Svedjemo & Jungert (2006).

The Gotlandic maps made between 1693 and 1705 were chosen because they are quite unique with their rich text content and also because a private researcher, Jacob Ronsten, has typed out all the handwritten text into word-processing files. These maps will henceforth be referred to as the GM1700 maps. Furthermore the maps are also unique because they cover an entire province; the island of Gotland. The original purpose of the mapping was taxation and to gain knowledge about Gotland. The maps were made at the scale of 1:8,000 in the manner described in the instructions for the surveyors of the time. The map and text parts are linked by a code marking system, as seen in Figure 1.

Figure 1. Part of a map and text description from the GM1700 map series. The arrows show the linking of the map and text descriptions via the code marking system.

**Swedish Large-scale Mapping**

In Sweden, domestic mapmaking dates back to the late 16th and early 17th centuries. Both small- and large-scale map productions have been quite extensive in various time-periods. Large-scale mapping is often called *geometrical* mapping and the large-scale is called *geographical* mapping. The real beginning of domestic small-scale map production can be traced to 1628 and this year can also been seen as the starting date for the Swedish National Ordnance survey.
The main purpose for beginning the mapping was to gain insight of the resources of the realm. Sweden was expanding and rapidly developing in economical, political, scientific and cultural senses, but there was a lack of knowledge about the realm and there were no good maps available. The instructions for the mapping also demonstrate an ambition to reform farming to produce higher yields and help the peasants in different matters (Örback 1990, Tollin 1991).

What we now identify as the first phase of the geometrical mapping of Sweden’s countryside was between the 1630’s and 1650’s. Several thousand of villages and solitary farms were mapped (Örback 1990). These maps together with the text descriptions were bound in large books, or cadastres. They are called *Äldre geometriska jordeböcker* (Older geometrical cadastres). During this time-period no mapping was conducted by Lantmäteriverket in the provinces on the eastern and southern shores of the Baltic Sea. During the 1650’s and for some decades to come, the efforts of mapping Sweden were concentrated on small-scale geographical map production. The idea from the beginning was to use the geometrical maps as concept maps in the geographical map production (Bratt 1958).

The next phase in the geometrical mapping of villages and farms started in the 1670’s and had several goals. Sweden had been successful in the wars of the 1640’s and 50’s and large areas were incorporated into the realm. King Karl XI’s reduction of the nobles’ land entailed that many villages and farms came under the Crown. Fiscal reasons were also prominent with the mapping as the basis for setting taxes. These maps are often bound into books, but they also exist as loose maps. Skåne, Blekinge, Gotland and other incorporated parts were, to a large extent, mapped during this period.

Not all of Sweden was mapped during these first two phases. The maps are sporadically spread over the country and not all villages and farms in the mapped parishes have geometrical maps from these first periods, but most of Sweden was covered, as seen in Figure 2. The mapping by Lantmäteriverket was mainly conducted on freeholder’s farms and on the tenant farmers of crown-land. Some maps only cover vicarages, etc. The nobility land was normally not mapped. In the cases where a village had mixed forms of ownership, the nobility’s farms were most often missing on the maps. In some cases, the nobility had their estates mapped themselves, but not in conjunction with the mapping by Lantmäteriverket (Tollin 1991, Sporrong 1990).

Lagging behind England, Holland and other European countries, Sweden got its first modern act of redistribution of land, *Storskiftesförordningen* in 1749. This was the start of a series of land reforms. They were initiated by the fact that the land of each farm had been scattered in many small land parcels in the infields during the centuries, thus making farming very inefficient. Together with *hytväget* – an act stating that all the farmers in a village had to synchronise and agree on how to work the land - the situation became untenable. There was no room for new techniques and improvements of the agricultural sector (Dannfelt 1928). The reforms aimed at aggregating the number of land parcels each farm had into fewer and larger parcels. In 1807 a new act of redistribution of land was established, *Enskiftesförordningen*. The act was modified in 1827 with the establishment of *Laga*
skiftesförordningen. Under this act, the farmers’ land would be gathered in two or three land parcels (Örback 1990). This was, with amendments, in force until 1972. Most of Sweden’s farms were affected by these acts and therefore mapped, but some regions were unaffected and thus lacked maps. The act of Laga skifte had a huge effect, not only on farming, but on the whole Swedish countryside and also social effects. The old medieval villages were split up and replaced by solitary farms (Gadd 2000). The modern rectilinear landscape, with the straight roads and square fields we see today, started to take form. Parallel to the redistribution of farmland, mapping was conducted in the vast forests in the northern Sweden. There was a need to establish the boundaries between the Crown’s forests and the privately owned forests. This process was called Avvittring (separation). In these Avvittringskartor (separation maps), the forests are mapped and described well, but the infields are just briefly mapped. There are also many maps of mines, towns and other features. There also exist special maps of ancient remains (Jansson 1993).

The results of the mapping conducted during several centuries are kept in various archives today. The most important sources of geometrical maps are Lantmäteriverket’s central archive in Gävle and the archives in the local offices throughout the country. For most of the period, the surveyors had to make copies and renovations of the maps and send them to the central body in Stockholm (Lantmäteriverket moved to Gävle in the 1970’s). The original field map was kept at the local office. The central archive today contains more than 200-300 000 maps and the local archives probably more. Other major archives are Riksarkivet (The National Archives) and Krigsarkivet (The Military Archives). There are also many Swedish maps abroad covering lost territories. Those maps were often surrendered in peace treaties. In Russia there are about 20 000 Swedish maps and there are many in Germany as well.

**Ancient Remains in Historical Maps**

When the maps were created, the landscape was full of visible ancient remains, many more than are seen today. The need to remove them was often not as necessary as it is today. Most of the destruction of archaeological monuments came with the urbanisation and expansion of the cities and the increased transport both on rail and roads which meant large building projects. Agricultural machinery requires large and straight fields which mean that the small fields with many impediments, both natural and man-made, vanished.

Ancient remains are often depicted on historical maps, either intentionally or unintentionally. In the latter case the ancient remains often show up as impediments in fields and meadows. In a redistribution map from 1878 the land surveyor mapped fossilised field systems dating from 500 BC without knowing it. Due to the purpose of the map, redistribution of land, the mapping was very careful and accurate in soil quality assessment. The fields are depicted on the maps as regular patterns of different soil quality, which is the result of the farming techniques of the time (Lindquist 1974). It is not unusual that the surveyor intentionally depicted ancient remains. In fact since 1643 the instruction for how the maps should be made contain a paragraph about the depiction of ancient remains (Styffe 1856). Examples are the biggest Bronze Age mound on Gotland, Ugggarde roir, which is depicted on the oldest map of the area and also on a redistribution map from 1876 (Lantmäteriverket Visby, Rone socken). Sometimes there are also long descriptions of the mapped ancient remain, like in the hillfort Torsburgen on Gotland. On the map, parts of the myths and legends surrounding the hillfort are noted (Akt 2 Kräklingbo). Many surveyors during the centuries had a keen interest in remains from the past and depicted them on the maps. There even exist many special maps over more prominent areas with ancient remains (Tollin 1991, Jansson 1993). This is of course a very important source for archaeological research and is regularly used.

**Analysis of historical maps**

The usage of historical maps in GIS has in many ways been a continuation of how maps were used without the help of computers. With the introduction of GIS, it is mainly the tools that have changed, not the analysis or research questions in any higher degree. It is mainly overall landscape and land use that is studied, with the help of a limited amount of information from the maps. It is mostly the land use information, which is easy accessible in colours on the maps. The less accessible text part is seldom used. Analyses are very much based on map overlays to compare different features over time. Together with other types of spatial data they are used for visual interpretation. As an example the landscape analysis of Holm parish in Uppland, Sweden, can be mentioned. In this study, historical maps and archaeological sites are used as the main sources for landscape analysis and used in a GIS system, together with other sources (Larsson 2002). In The DHK publication, *Digitala historiska kartor*
– Tillämpningar i GIS för kulturmiljövården (Rentzog et al. 2002) a series of example applications are presented, which give a fairly good overview of how historical maps are used in different kinds of landscape analyses in GIS-system. Examples are given on how to use data from historical maps to visualize the impact of different activities, e.g. building a new road, to the historical continuity of the landscape. These types of studies are of great value and are often used in the pilot study phase of major building and planning processes, but do not go much beyond the traditional usage of historical maps. In the examples given in Rentzog et al. (2002), the maps are often visualised in 2-D or 3-D, where the map or reconstructed land use is draped over a digital elevation
model (DEM). The examples in (Rentzog et al. 2002) cover much on how historical maps are used in cultural resource management and also point to some extended use.

In the following section we will give some examples of how we have used the information from the Gotlandic maps GM1700. Some of these examples go beyond the normal usage of historical maps in GIS. We have a firm belief that usage of GIS by researchers in the humanities will increase in all kinds of problem solving and reasoning concerning spatial dimensions.

**Locating Abandoned Farmsteads**

The geometrical cadastres from the 17th and 18th century depict the situation and features in Swedish villages or farms, which had bearing on the contemporary society and administration. The state of affairs shown in the maps was the result of a long development that goes far back in time. With proper analysis of the maps, together with other data, the situation in the area can be traced back in time to the medieval/Viking age or even further back. This kind of analysis is called *retrogressive analysis*, which is a firmly rooted tradition in Swedish and European historical geography. The organization of the cultural landscape that can be seen in the geometrical cadastres has its roots in a time period long before the creation of the maps and could be traced back perhaps as far as two thousand years (Riddersporre 1995). Dan Carlsson uses the GM1700-maps as the main source in a retrogressive analysis concerning the agricultural- and settlement development on Gotland during the Iron Age. In his thesis, he argues that the organisation and structure of the Gotlandic farms we see today was established during the older Iron Age (Carlsson 1979).

The older and younger cadastres are the most suited maps for these kinds of studies. This is of course because they are the oldest depiction of the cultural landscape, but also because later maps are made with the purpose of redistributing land and thus show two time horizons; the state of affairs before the redistribution of the land and the state after it. These two can sometimes be hard to separate in the maps (Riddersporre 1995). The cadastres are, on the other hand created primarily to depict the current state of affairs. In a retrogressive analysis both the map itself and the text part are important ingredients. As examples, the study conducted in GIS by Fabech & Ringtved (2001) can be mentioned. They used historical maps and other methods to recreate the prehistoric landscape and land use in the Bjerringbro/Hvorslev area in Denmark. With the proper retrogressive analysis, historical maps can be used for studies of phenomenon and processes with a much wider time frame than just the creation date of the map.

How a farmstead’s land parcels are scattered and spatially distributed can also be important clues to the history and age of a farmstead (Carlsson 1979). Together with other factors like soil type, land parcel names and ancient remains, the patterns of scattered land parcels can reveal the places of ancient farmsteads. As an example, the variables can be used in the following fashion: *Soil type*: A high degree of mould in a field indicates intensive farming during a long period. This is normally done in the fields closest to the farmstead lot. *Land parcel names*: One very important feature of historical maps is all the names they contain. Nearly all land parcels have names and these names can reveal a lot of the feature’s history. Most of these names are lost today. Parcel names can indicate disappeared farmsteads. *Ancient remains*: many different ancient remains are indicators for old settlement and farming. These facts and parameters are well known and factors like the ones listed are often used in retrogressive studies, such as Carlsson (1979) and Riddersporre (1995).

To graphically display the location of each farms land parcel, techniques based on SQL and GIS-functions can be used. The result is very easy to interpret and the visual power is vast, as shown in fig 4. The parameters of interest in this example are: ancient remains of Iron Age settlements, names of land parcels indicating old farmstead names and fields with mould that lay far from 18th farmsteads in “remote” areas where many different farmsteads own land. In Figure 4, the ownership is visualised with the arrows from each farm to it is land parcels. In the marked ovals we can see areas, with the names “Fylleqvie” and “Huusarfwa”, which can be old farm names, and are interesting for further investigation concerning abandoned farmsteads. These abandoned farms’ infields have been requisitioned by the neighbouring farmsteads, probably due to desertion for some reason.

**Reconstructing Road Networks**

Roads, tracks and waterways are obvious features to all societies and therefore essential for historical studies. The geometrical cadastres were also intended to be the basis for geographical maps over larger areas. The idea
was to put all the village/farm maps together on smaller scale for regional maps. These maps were to depict the situation of villages, towns, main roads, lakes, etc. in a region (Bratt 1958). The roads are of central importance and the main road network is often well depicted in geometrical cadastres. This makes these maps quite suitable for studying older roads. There are some problems, however. First the hierarchy of different symbols can make it difficult to see the exact stretch of a road. Secondly, the surveyors do not have the same view of which road to depict. A road depicted in a map by one surveyor can suddenly disappear in the adjacent map made by another surveyor. A third problem is that all roads use the same symbol, so it is impossible to distinguish the size or importance of a road.

Figure 4. Maps showing areas which can contain sites of ancient, abandoned farms.
In a study by Huttu and Svedjemo (2007) concerning the older road networks around Roma kungsgård, a state demesne, large scale historical maps were used as one of the main sources. The purpose of the study was to show the changes in the road network between different time periods. Roma is considered by most scholars to be the place of the main court (thing) on Gotland, Gutna altingi, from at least the Viking Age and onwards. This was the body for the common governing and administration of justice for all of Gotland. From 1164 a very important Cistercians Monastery, S:ta Maria de Gutnalia (Roma kungsgård in Figure 5 and Roma 46 in Figure 6), owning land on Gotland, Öland and in present day Estonia. From the reformation in the 1530’s onwards it was first a Danish state demesne and, since the Swedish conquest of Gotland in 1645, a Swedish one. In modern times there has been a military airfield in the area and there is now a cultural centre in the old buildings and the land is cultivated by a tenant farmer. The area around Roma is very fertile and can best be described as fully cultivated and thus has been heavily disturbed archaeologically.

The starting point for the research was a narrow section of a bog separating the two farms Uppenbys and Kulstäde observed on a map from 1699. These two farms once belonged to the monastery of Roma and we believe there was a need to uphold communication with the monastery and this narrow part of the bog would have been an ideal place to cross it. The map was rectified and aligned with the Swedish national grid in GIS. The ancient remains database (FMIS), was overlaid and showed some Iron Age house foundations and fossil roads in the area, but not passing the bog. After field investigations we found traces that could be a stone pavement on one side of the bog (#3 in Figure 6). These pavements can be found where a road passes waterlogged areas. On the other side of the bog we found a gorge (#4 in Figure 6). We also talked with the owner of the farm, who helped his father to clear new fields in the area when he was young. He has an ardent interest in history and archaeology and told us that they had removed what he believed to be an old road and Iron Age house foundations. With this information we were able to reconstruct the extension of an old road across the bog. We could not date it and could not say if it existed already in the Iron Age, connecting the house foundations on both sides of the bog, or if it was constructed during the monastery period as a route between the Kulstäde farm and the monastery complex. A picture stone from the Iron Age (Roma 64 in Figure 6) indicates that the road is older than the monastery and probably can be dated to the Iron Age.

These first results inspired us to do a larger study, which covered a wider geographical area. The methodology was the same; with the starting point in the old cadastres, a retrogressive analysis was performed. Three time periods were chosen; 18th century, the monastery period (1164-1530) and the Iron Age (AD 200-1150).
With retrogressive analysis of the many large-scale historical maps that exist over the area and other sources like ancient remains, stray finds, and different theories about settlement patterns on Gotland, the authors could reconstruct the road network in a plausible way. Some of the roads found on the old cadastres are not present today and some have an altered usage, e.g. an old main road, which today is used as a local road. Old roads may still be present, but stretches of the roads are altered. Old roads found on the maps and ancient roads together with other ancient remains like grave fields, picture stones and settlements, can be used to reconstruct old road networks. Studies has shown that graves and grave fields and picture stones have high correlation to roads (Huttu & Svedjemo 2007).

The Christianisation of Gotland

Sven-Olof Lindquist (1981) has conducted reasoning around the formation of parishes and the introduction of Christianity on Gotland. This is made from a chorological point of view, which is very well suited for performing in GIS-systems. In 1981, he had no access to GIS-systems, so all calculations had to be mad by hand in paper maps. This took very long time, even when only a sample of parishes were selected (31 of 92). In 2001 Lindquist, together with the author, reanalysed some of the calculations in GIS (Lindqvist 2001). This time it was made for the entire island, 92 parishes, since data were available in digital format for the entire island. The calculations and creation of the resulting maps now only took a few hours to produce.
The main research question was to give a plausible answer to the debated issue of whether the formation of the parishes was a prolonged process, which some scholars advocate, or if it was a quite rapid process, which Lindquist believes. A secondary question was who took the initiative to erect the parish churches and decide where it should be placed. Was it a single man (a great man) or a joint decision of farmers who were all peers? The GIS analysis focused on the second question. The data used in the analysis was the position of the farmstead buildings in 1700 and the parish borders of that time. The usage of the farmstead lots from 1700 for a process that took place 700 years earlier was motivated by a retrogressive analysis. The hypothesis was that the physical location of the church was a joint decision by the farmers and it was placed as “fair” as possible, which means that it should have a central location in relation to all of the farmsteads. The first analysis was to compare the extension of the parishes around the churches, to the “optimal” one. The optimal extension was defined as the thiessen polygon around the church. The location of the farmsteads was then compared to the optimal parish and the actual parish it belonged to. Only around 8 % of the farmsteads lay closer to another church than the church to which they belonged, which points towards strengthening the hypothesis (Figure 7a). If natural obstructions like bogs, etc. were to be taken into account, the number would probably decrease. As a further test of the hypothesis, the distance between the church and the point of minimum transport distance from the farmsteads was compared. The rationale for this is as follows: If the distance is short, it points to the fact that the positioning of the church is “fair”, and all farmers had a say in the decision. If the distance is long, it is interpreted as the decision around the placing of the church is not made in consensus. In the GIS-system the point of transport minimum was calculated as the centre of gravity, by taking the mean position along the X- and Y axis of all the farmsteads in each parish. The distance between this point and the church was calculated. This distance was then visualised with a circle, with the distance as radius, around each parish, as shown in Figure 7b.

The results strengthen the hypothesis further. The parishes that have long distances are all known to be anomalous and there were known explanations for these anomalies.

**Figure 7a.** The dark areas are the difference between the optimal parishes, represented by thiessen polygons around the churches and the existing parishes.  

**Figure 7b.** The distance between the centre of gravity of the farmsteads and the church in each parish.

**Statistics and Calculations**

Statistical calculations and other quantitative methods have a long tradition in studies of past times with historical maps as source material, often combined with other sources. These calculations have, in the past, been very tedious. With a system like ours, they will be rapid and precise. Calculations can easily be made, both from tabular data from the text part and also from the geometrical properties of the mapped features on the map itself. A good example of a classical study of this kind is made by Hannerberg (1971) in which data from historical
maps are used in calculations of yield, consumption, etc. in the agricultural societies of the past to depict the development over a longer period. There are numerous examples of these kinds of studies.

Calculations and statistics will perhaps not give the answers to most problems formulated in the humanities, but it often makes a very good starting point and can help with the interpretation of many problems. It can be used to describe and give a good overview of a situation or state of affairs, which is a necessary foundation when reasoning about a problem. In a GIS system, it can also be presented in a graphically powerful way and displayed in the map. Here we will show some examples of how calculations and statistics can be used in the system presented.

**Location of Iron-age Settlements**

The need and demand for the ways to predict and understand the reasons for the location of various archaeological sites is great, both for Cultural Resource Management (CRM) and for academic research in archaeology. A predictive model attempts to predict where archaeological sites or features are located, by looking for tendencies and patterns observed in a region or by theory and notions of the distribution of sites or features (Kvamme 1990). An example is a large Danish project called “Foranderlige landskaber” (Ringtved 2002) in which different techniques for predictive modelling were tested to identify archaeological sensitive areas. It was based on the methods developed and tested in another project (Ejstrud 2003).

![Figure 8](image.png)

The information used in the models is composed of two parts, the dependent and the independent variables. The dependent variables are the archaeological sites or features whose distribution is sought. The independent variable is the characteristics recorded at each site. These characteristics can be divided in four major themes, according to Kvamme (1990): Environmental variables, cultural and social factors, positional characteristic and radiometric characteristics. With the basis in retrogressive analysis, historical maps can be used in predictive modelling. The information from historical maps is a social factor, used in the same way as other ancient remains. In the agricultural district areas around Roma in the centre of Gotland there are relatively few ancient remains recorded in the national database of ancient remains (FMIS). The general belief is that there have been many
ancient remains, but the modern farming has wiped out most of the visible traces of past. With predictive modelling it can be possible to find the areas where it is most likely that some of these ancient remains once lay.

In Gotland there are several researchers who have noticed that there is a correlation between “Kämpegravar”, which are Iron Age house foundations with dating to approximately AD 200-600 and the land use found in GM1700 maps. The meadows and farmstead lots from the GM1700, and other variables were used in a predictive model to verify this theory and also try to predict areas where these house foundations had been located (Svedjemo 2005). The model performed very well with a high significance. Even if the areas picked out by the model are too large to be really useful in field archaeology, predictive modelling techniques can be very useful in finding patterns in data and also in finding archaeologically “sensitive” areas, with a higher likelihood to inhabit different types of ancient remains than others. Historical maps can be a very good source for variables, according to the methods in retrogressive analysis.

**Figure 9.** Map over Fröjel parish showing each of the parish scattersness indices as a circle.

**Distances**

Distances were of great importance for many reasons in the old agricultural society (Carlsson 1979). The farmstead building lot was generally placed near the fields, which were of highest economic value and also most vulnerable. Distances were also costly for transportation and time reasons; the greater the distances between the land parcels, the more time had to be spent on transportation. Distances are not only important in studies concerning the contemporary society at the time of the creation of the maps, but also play a vital role in many other analyses. As an example of a study that would have been greatly helped by our system (in our opinion), is Östergren’s (1989) work concerning Viking Age silver hoards. In this study, distances between different features found in the GM1700 and the find locations of silver hoards is of paramount importance for the analysis. Using GIS, these distances are very easy to calculate with standard techniques.

As mentioned above, the scatteredness of a farmstead land parcels can reveal something of the age and older phases in the farmsteads history. It is hard to pinpoint exactly how this works, but generally a more scattered farm has been subjected to more changes in its history, thus indicating a longer history. Examples include inheritance.
of other farms, strategic marriage, a moved building lot or the requisitioning of abandoned farm land parcels, as shown above. As a tool to visualize this scatteredness in statistical terms we have created an index, which shows how far the farm is situated between different percentages of its land. The index is defined by for each farm summing the land parcel acreage and finding the median (i.e. the distance that separates the 50 % remotest areas of the farm's land). The median of these values is set at 100; thus values above or below 100 indicate a higher or lower degree of scatteredness. These calculations can, of course, also be done at other breakpoints, like quartiles (25 %, 50%, and 75 %) and others. The resulting numbers can then be visualized in different ways.

Discussions and Future Work

Swedish large-scale historical maps are a unique source for many types of historical analyses. It is not only used in historical research, but also in ecology, archaeology, geography, linguistics etc. They are also used in a very high degree in non-research, for example in CRM, social- and physical planning at all levels, etc. Prior projects concerning the digitalisation of historical maps have drawbacks in various ways, affecting the usefulness of the digitised maps, for purposes other than the original scope of the project. The project Digitala Historiska Kartor (DHK) (Frisk 2000) at Riksantikvarieämbetet had too general of an approach, not addressing all the map- or generation specific information found on different maps. It only handled the general information, found on any historical map. The project Nationalutgåva av de äldre geometriska kartorna at Riksarkivet (Riksarkivet 2006) mostly addressed the text part of the maps, leaving the map itself more or less unprocessed.

In our work the semantic analysis is made with the aim of capturing all concepts in each map series. To model all information on all types of maps, a very data-oriented view is needed. This approach leads to a model that is very map-dependent, not like the DHK-model, which is very general. With this approach we do not lose any (or at least very little) information from the maps in the modelling process. Of course both the modelling of a domain model of this kind and populating the resulting database, takes longer compared to using a more general model. We believe that in the long run it will save time, since different scholars and agencies do not have to redo the process for their specific problem.

Most often when using historical maps in GIS, the GIS has been merely a tool to display the maps as “they are” and does not try to reveal or display any nested or hidden information. The analytic and statistical capabilities of modern GIS packages have seldom been used. In this paper we have presented some examples of usage of historical maps in which we take advantage of more of these capabilities. The graphical and display capabilities of GIS is also an essential part of our examples, but we have focused on using them to highlight and display the more deeply nested knowledge only visible after the information has been processed and analysed.

Some of these analyses are only possible to carry out if one has a domain model like ours that picks up the map-specific information and handles both the map and the text part. As an example, we used the notations about the owners and how they acquired the farm. Due to the lack of scanned maps, we could not fully demonstrate the analyses that can be performed. We only had access to scanned maps from one parish, Fröjel. Much of the map-specific information, present in other parts of the island, was not present here. Among these are the very interesting notations about disputes of land and co-ownership. With the full database these questions could be analysed. Interesting questions would be: Are there any special distributions of the farms and land disputed or co-owned? Can any characteristics of the farms involved be spotted? One working hypothesis could be that the disputed or co-owned land is land once belonging to now (around the year 1700) abandoned farms. Also the notations of what commodities the farmers used to pay taxes would be interesting to analyse, to see the spatial distribution.

With our model, essentially every piece of information from historical maps can be digitised and stored in a database. This will enable us to search for novel, and yet unknown patterns and correlations with advanced data mining techniques to gain new knowledge from the maps. One example was given around predictive modelling for Iron Age settlements in which information from the GM1700 was used. In our example logistic regression analysis was used, but other data mining techniques can probably be used for a great variety of problems and theories. This is, however, a largely undiscovered field of research and further research is needed to explore all the possibilities.

Historical maps are often used in retrogressive studies. In these analyses the depicted state of affairs found in the maps are traced back in time to reveal the situation several hundred, or even thousands of years prior the creation of the maps. As an example we executed a fairly elementary, but very powerful, graphical analysis that revealed
the location of abandoned farmsteads. In some areas the maps reveal very unusual situations, like in the parish of När. Farms from many surrounding parishes own land by the coast at a place called Hammaren. We believe that a method like the one presented here could help clarify and reveal the true nature of this situation and would probably be a good starting point for a deeper analysis. There are probably several more locations, not so obvious, that can be found with this method.

We hope that we with this paper have given some relevant examples about how a GIS database, based on a proper conceptual model of historical maps, can be used in a variety of different applications and problems. The examples we have given do, not of course, correspond to a comprehensive set of analyses. This field is largely an undiscovered area of research and we hope many others will follow in our steps and try to reveal more deeply nested knowledge from historical maps using advanced data processing.

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