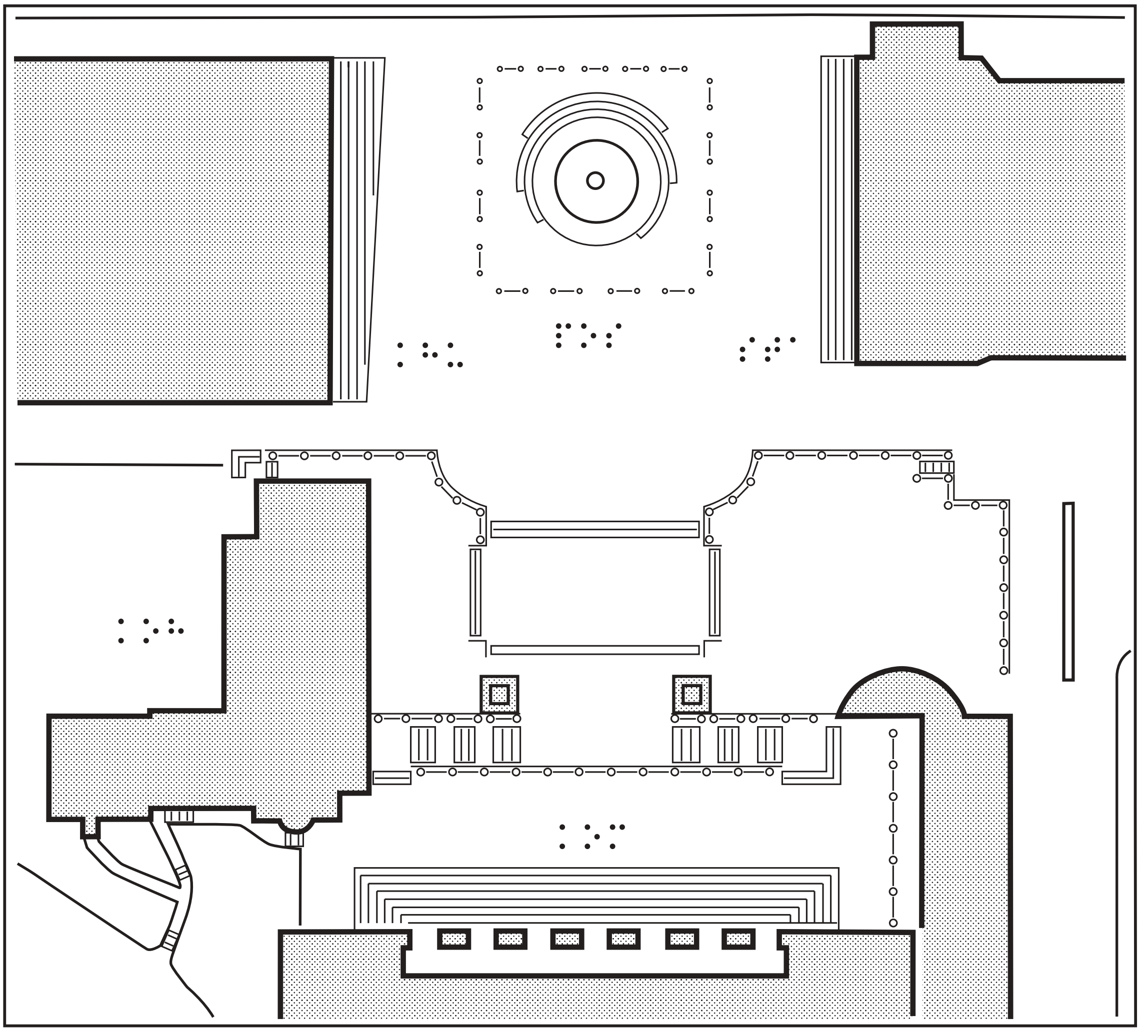
Tactile maps

Guidelines for the production of maps for the visually impaired



by Yvonne Eriksson, Gunnar Jansson and Monica Strucel

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The Swedish Braille Authority

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PREFACE

This booklet, *Tactile maps – Guidelines for the production of maps for the visually impaired*, is based on *A guide to the production of tactile graphics on swellpaper* (1995) which treats basic prerequisites of the production of relief maps and pictures. Readers with no previous experience of the production of tactile material are advised to read this before consulting our booklet.

We have chosen not to include the use of any of the special drawing programmes for map production, but to concentrate on the problem solving process, which is the same whether maps are drawn by hand or by computer.

Tactile maps – Guidelines for the production of maps for the visually impaired is based on our practical and theoretical experience of tactile reading and the problems involved in interpreting tactile information.

Our guidelines are a result of close co-operation between Monica Strucel and myself – Monica Strucel created most of the relief maps in this booklet. Many of our solutions would not have been possible without the knowledge of tactile perception we acquired from Gunnar Jansson and others. Our booklet concludes with a general view of research into this field written by Gunnar Jansson.

Yvonne Eriksson

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INTRODUCTION

The map as a picture

Although our everyday life generally takes place within fairly reduced spatial limits, we often travel farther afield by land, sea or air. To be able to overview and be in control of these transportations, mankind has, since the beginning of history, produced maps as a means of representing graphically the known world. A map generally depicts larger territories, while lesser areas such as buildings or rooms are represented on ground plans. This guide deals with different types of maps and plans.

A map is not simply a representation of a particular region; it enables people to communicate knowledge of places and geographical phenomena to others. The function of the map is thus not limited to that of reproducing mathematically a given area of the world's surface, it also represents territorial conquest and thus political and religious dominance. Most of us look upon the world we live in via the map, that is, a series of land-masses are not regarded as non-political, but as belonging to countries, nations or larger political units. This comes so naturally to us that we do not realize that we in fact look upon our planet from a political perspective.

The map is the most useful (and indeed the only) tool we have at our disposal when we want a rapid, general vision of large geographical areas. We come across maps on a daily basis in the media, whether they are weather maps, maps showing where particular events have occurred, or maps of bus, tram or underground networks. The latter type of map should be distinguished from, for example, road maps or city plans. Maps of urban transport systems are generally limited to schematic outlines of each route, with the different stops along the way clearly indicated. The user is not usually interested in the exact route each line follows; he wants to know which bus, tram or underground line he should take to get to a certain place. The verbal information is thus important, since as a traveller, I need to know which stop or station a particular indication represents. The only way I can find this out is by reading the written information, or "spoken text", found on most public transport maps.

The map is an abstract picture of a specific area, created by conventional symbols (based on agreements). Symbols, however, may vary from map to map. The map gives us a topographic view of a particular area, but also permits us to move about from one place to another. A map may indicate actual or historical political borders. The map has also, of course, less practical uses. When we look at a map, we can wander off into a dream of all the places we would like to visit or recall those places we once saw.

When I was a child in the mid-60s, my parents' dream was to drive (all of us) around Europe in our newly-bought '56 model SAAB with its two-stroke engine – or at least around one of the Nordic countries. My sister and I encouraged them enthusiastically in this idea, and off we all went to the nearest Texaco station to buy a road map of Europe. After studying the map and calculating the distance between Ludvika and our intended destinations, our trip, sad to say, remained a dream to be realized years later in another car.

Approximately ten years later, I worked in an institution for people with mental disabilities. During the day, the residents usually worked at a nearby day centre. One of them was a man who had dedicated his whole life to travelling. In fact, he travelled several times a day. For every day after lunch, before leaving for work, he would get out his road map of Sweden, and when he had decided what trip he was going to take, he looked up the appropriate pages in the map and set off on his travels. This was repeated in the evening when he had finished the day's work. Unlike myself and my family, that man probably never had the chance to visit the places he had so often visited in his imagination, yet he did gain a knowledge of how different towns and cities related to the surrounding countryside; he knew which main roads and European highways he should take to reach a particular city; and as he studied his map, he saw the landscape change from North to South, and the rivers as they flowed to the sea.

The opposite may also be the case. Several years ago, I participated in a conference at the Museum of Modern Art in New York. One of the participants, a colleague and good friend who is blind, had only visited New York once before. As it was summer and the evenings long and warm, we had plenty of time for walks after the conference sessions. We looked at sculptures, noted architectural details and a host of other interesting things. However, my colleague had great difficulty in figuring out where exactly we were on Manhattan. Time and again I attempted to explain the directions and where we were, indicate which street we were on and which building we were standing in front of at that particular moment. The task was practically impossible. How do you explain the topography of Manhattan, its orientation and street system (even when this is on a grid plan in the central part of the island) to someone who lacks visual references of New York and does not have access to a tactile map? It was not until years later, when my friend did have a relief map of central Manhattan and Long Island, that we were able to relive our walks and sort out where our joint adventures had taken place so long ago.

The map as a culture-historical phenomenon

The map plays a decisive role in confirming the existence of an area and in the relationship between different places. But this is true not only for the map. If we have no personal experience of an object, we normally need a picture or a drawing of it, perhaps even a model, if we are to understand what it looks like or how it works. The illustration need not be very elaborate; a simple home-made drawing is usually sufficient when we want to describe an object to another person. A description, together with written information, is usually vital in this type of picture, depending on the quality, the drawing may not be good enough to make us believe that it will work out independently. So just how efficient is a map or picture with no verbal information? I would go so far as to say – not very. In order to interpret a map, I need to know the exact meaning of each symbol. It is not enough to know that blue areas and blue lines represent oceans or lakes and rivers. I need to know *which* oceans or lakes and *which* rivers. At school, many of us had to fill in the names of lakes, oceans, rivers and cities on blank maps in geography exams to prove that we knew where these were located. But that is not equivalent to memorizing each individual geographical feature. When we plan to visit a place or a friend for the first time, someone (perhaps we ourselves) usually draws a rough map of how to get there. At first, the map may be more or less to scale, but as it spreads out, scale is usually abandoned or changes radically to fit the paper. Rough maps of this kind contain what we usually call “points of reference”, that is, representations of characteristic landmarks or other features we should look out for. For example, “turn right at the yellow house”, or “at the traffic lights”. Instructions of this kind, verbal and visual, give us a preunderstanding – a mental map of an unknown area.

The fact that we find it hard to imagine things which are not graphically represented has throughout history led to the creation of maps of places that have never been discovered or do not even exist. When the Ancient Greeks made the first maps, it was not for practical reasons. The first Greek maps were expressions of their need to describe the cosmos, and perhaps more than anything, its inception. In the Middle Ages, maps were drawn of the Garden of Eden, the biblical Paradise, while many editions of Defoe's *Robinson Crusoe* contain a map of the island Crusoe supposedly lived on after being shipwrecked.

Today we take maps for granted as something everyone has access to, but in Sweden maps have been available to the general public only for a short period of time. Only in 1857 maps became public, earlier being an exclusive matter for the military.

Tactile maps – a long history

This desire for a general view of the places we are planning to visit or have visited motivated the early production of relief maps for tactile reading. Written proof exists of the production of maps for visually disabled people towards the end of the 17th century, and the oldest map in existence is probably the one produced for the blind singer and composer, Maria Theresia von Paradis. This map (which is kept in Vienna) is an ordinary printed map, on which borders, rivers and cities are shown in relief. National borders have been embroidered and rivers are indicated by finely-stitched pewter threads, while cities, towns and villages are represented by different-sized buttons.

Various techniques were later developed to permit the reproduction of several copies of tactile maps. Matrices of different materials were made onto which damp, heavyweight paper was pressed to duplicate the maps, producing a relief map with various levels. This technique was developed further and from the beginning of the 20th century, embossed metal printing plates were used.

The modern debate on how to design tactile maps to afford maximum tactile readability has its origins in the 19th century. In 1885, Martin Kunz, headmaster and teacher at the school for the blind in Illzach bei Müllhausen, was commissioned by the European Geographical Society to produce relief maps for teaching the visually disabled in the western world. Kunz, who had been a geography teacher at a boys' grammar school, went on to produce more than 100 000 copies of maps of continents, countries and major towns and cities. To facilitate tactile interpretation, Kunz stressed the importance of making clear distinctions between land and water, longitude and latitude, national borders, rivers and major cities. Apart from his knowledge of geography and cartography, Kunz had vast theoretical and practical knowledge and experience of tactile perception.

The relief maps printed on Martin Kunz's matrices had several levels: a continent or a country would be on one, and above that on a second level indicating national borders, with dots for towns, cities, hills and mountains. When the thermoform technique was introduced in the production of tactile pictures and maps in the 1960s, maps using this technique resembled Kunz's maps in many respects. This technique is based on the production of a matrix which is then covered with a heavy plastic film. Matrix and film are vacuum-pressed, resulting in a relief which coincides exactly with the matrix. This technique also permits the production of multilevel relief maps and pictures.

The most commonly-used technique today is swellpaper, invented in the 1970s. This technique, however, produces one-level relief, which has its advantages and disadvantages. Pictures and maps on swellpaper consist exclusively of lines, dots and surfaces which can be distinguished tactilely. If the symbols are chosen with care, clear differentiation can be made between the various details on the map. The low relief creates a clear outline which is fairly easy to read tactilely, while higher relief gives a less distinct outline shape and may hence be more difficult to interpret. High relief is therefore not always to be preferred to low relief.

Since the 1970s, both swellpaper and thermoform techniques have been the most popular methods, and are often in conjunction. The producers' choice of one or the other technique is generally determined by the wishes of the target group and the number of copies to be made. There are also national variations, that is, in some countries one technique is more popular than the other. In the 1980s and 90s, a number of other techniques were developed, with varying degrees of success. A technique that is gaining in popularity is silk-screen printing, executed using traditional methods, with the difference that, in order to achieve relief, a thicker film is used with a colour which dries quickly under ultraviolet light. The silk-screen method makes it possible to produce durable relief, but this technique is more limited than the swellpaper technique. The widths and textures on a swellpaper picture or map are more varied than on silk-screen prints.

Picture versus verbal information

A description of an object or place may be more or less explicit, and this applies equally to representations of topographical areas or buildings. We can leave out many details on a map or a plan, which is usually the case, and still produce a satisfactory overall picture of the area or building.

Today there are a variety of orientation tools which help people with visual disabilities to know where they are. These tools are described in this guide by Gunnar Jansson. Their function is sometimes confused with that of the map. Knowing where you are with the Geographic Information Systems is not the same as knowing what a particular area looks like. For an overall impression, a relief map is preferable, and this map must be adapted for tactile reading, if the visually disabled reader is to interpret its contents satisfactorily.

FROM VISUAL TO TACTILE MAP

Finding where you are on the map

For the reader to orient himself on the tactile map, the symbols used must be clear and unambiguous. Yet it is hard to define what a distinct symbol, line or surface is. This depends on the technique used and on the interrelation between symbols, lines and surfaces on the map. The points of reference on a map may vary, depending on the type of map. On maps of continents or countries, for example, lines of longitude and latitude are generally indicated, although major cities, lakes and rivers are also excellent landmarks, as well as national borders.

On city maps, we may have difficulty finding the place or street we want unless we know which section of the map to look at. To be able to find the place we want to get to, or to find our way back, a system of co-ordinates marked on the outer edges of the map may be helpful. These co-ordinates can also be used as a measuring line for calculating the distance between two points.

Identifying the characteristic features of the shape

It is difficult to summarise all that is involved in making relief pictures and maps possible for visually handicapped people to read tactilely. Giving advice on the production of tactile maps is likewise tricky. This is because a number of factors must be taken into consideration before producing a tactile map. The most common procedure is to start with an existing map, which is then simplified. The choice of model depends on the type of map we want to produce. The choice of too simple a model can complicate the production of the tactile map, particularly if the map lacks important information which enhances tactile readability. Take the West coast of Norway as an example. On a detailed map of Norway, the coastline forms a long, jagged line with hundreds of indentations which represent the many fjords and small islands. If we work from a simplified map, on the other hand, it is hard to tell which fjords are the longest and should therefore be emphasised on the tactile map so that the reader can readily identify one of Norway’s chief characteristics easily.

Simplifying a shape means stressing its salient features. In the production of tactile maps this means stressing features such a national borders. The problem, however, is to enhance the outline of the country without falsifying it. The reader must be able to find his way on the map without the need for explanatory text for every section, but with the support of a verbal description referring to easily recognizable details on the map. Most people, for example, recognise Italy instantly because it resembles a boot. If we omit the bays, which look like folds or creases, on the western side of the “leg”, both Naples and Corsica would be difficult to locate.

The format of the map

The format of the tactile map depends on readability format, the formats of swellpaper available (A4, A3 and FA44 are standard formats) and machines equipped for thermal treatment. The choice of format depends on several factors; if, for example, the map is part of a braille book, FA44 may be most suitable, as it coincides with the format of this type of book. If we are making a separate atlas or collection of maps, the A3 format can be used (A3 files are available, so maps need not be folded).

The size of the map sheet must to some extent be adapted to the individual map. A long, narrow country like Sweden, for example, obviously requires a lengthwise format, while Poland is best represented horizontally. The size of the format depends, in turn, on how detailed the map will be. If a large format is chosen for the production of a map of a particular country, it is usually possible to include details such as cities, towns, lakes, rivers, roads, etc. For the reader to perceive the country as a whole, however, the first map should have no details, indicating only the shape of the country. Remember that shapes and lines must always allow sufficient space for freedom of movement of the reader’s finger.

The following examples are included to clarify the discussion on how tactile reading can be simplified by emphasising the characteristics of a shape, and on how this relates to map format.

The map of Sweden

Sweden is a relatively large and extended country and it is difficult to produce a satisfactory map of it in a format smaller than A3. Even at this size, only a very general representation of the principal lakes, rivers and cities can be shown. For greater detail, certain areas have to be enlarged on separate maps. These partial enlargements might be of individual provinces, represented separately on a uniform scale, or regions such as Norrland, Svealand and Götaland. If we have to divide the country into smaller units than provinces, it may be helpful to use a grid of the type often found on road maps. Each square is indicated by a combination of figures and letters marked along the top and one side of the map (co-ordinates). As a tactile map requires certain simplifications and displacements, any scale will not be exact. If the map is provided with co-ordinates, the side of the square can be calculated and indicated as an approximate measure of distance. When a section of the map is enlarged, we should indicate clearly which section of the map it represents by stating the appropriate co-ordinates. The grid indicates distance; when one section of the map is enlarged, the relation between the co-ordinates and the area of the map remains constant.

Whichever method we choose to represent a continent, a country or a region in various sections, it is important to be consistent. The division between one section and the next must be sufficiently clear to make the map as a whole easy to use for the reader.

Whenever a visual map is transferred to a tactile map, we encounter fresh problems to which there are no general answers. The purpose of the following example is to introduce a step-by-step problem solving method. Every production of a new tactile map involves two types of problems. The first relates to the production process and the other to the specific requirements of readability made by the reader. To enable the reader to read tactile maps, the producer must start by using maps on a suitable scale with sufficient information for him to make appropriate simplification. It is not unusual to work on more than one model of the same tactile map in order to include the necessary information.

From the whole to details

When a particular country is represented, with no information about bordering countries, it is important to give its latitude and longitude, which are indicated in atlases. Looking at a map of Sweden (figure 1), we note that Sweden extends from approximately 55ºN in the South to 69ºN in the North. We also observe that the coastline forms a curve from about 11ºE in the south to approximately 24ºE in the north. This curve must be distinguishable on the final relief map.

Figure 1: Map of Sweden, Metria, Lantmäteriet.

General map

The larger the map, the more difficult it is to simplify, since the details shown seem important. In this case, it may be better to start with a map in a smaller scale. Tactile reading becomes difficult if, for example, every minute detail of the outline of a national border is reproduced. On the other hand, it is useful to retain certain characteristic features for the sake of reference. At the same time, it is better to go for the general shape of the country.

The long Swedish coastline, with its many bays and islands, should be reproduced as a continuous series of distinct curves and straight lines forming identifiable shapes. A finger following a line, moves quicker and perceives the shape easier, if the line is distinct and clear. The towns, cities and other geographic details we want to emphasise on the map are best indicated by individual markings.

Figures 2–6 represent the simplification process from visual to tactile map *(by Monica Strucel).*

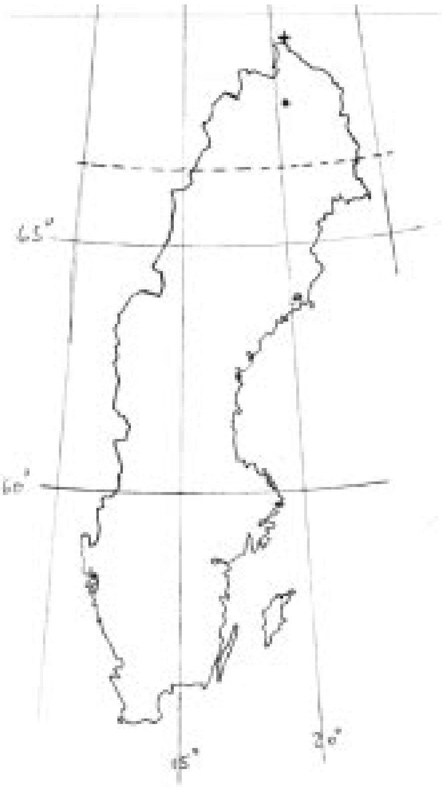
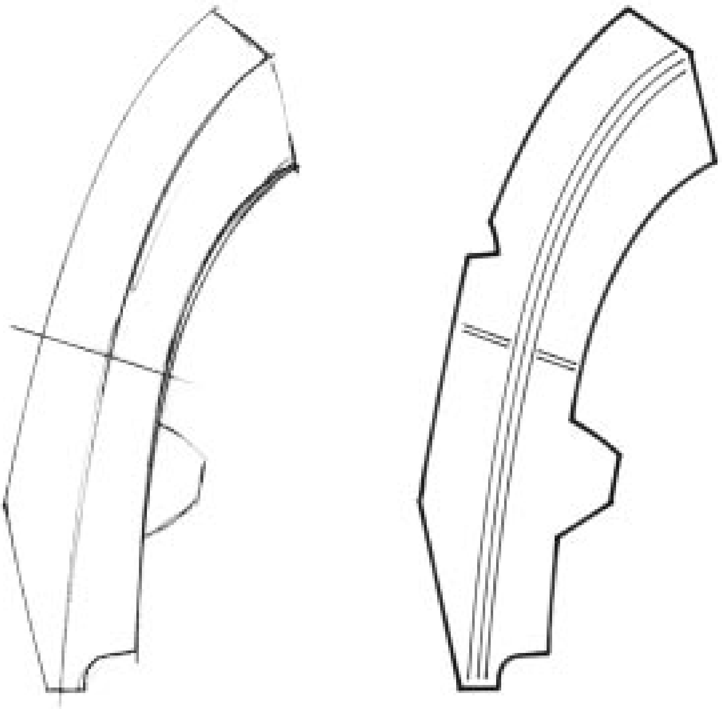


Figure 2: Try to identify the general shape. Sweden is oblong in shape, of uniform breadth, slightly crooked, with a marked convexity on the right hand (Eastern) side.



Figures 3–4: The parallel lines in the middle are there to facilitate tactile perception of long curves. The horizontal line indicates the middle. Another possibility is to rest the finger on the mark on the outline on the left-hand (Jämtland), which is an easy reference for readers.

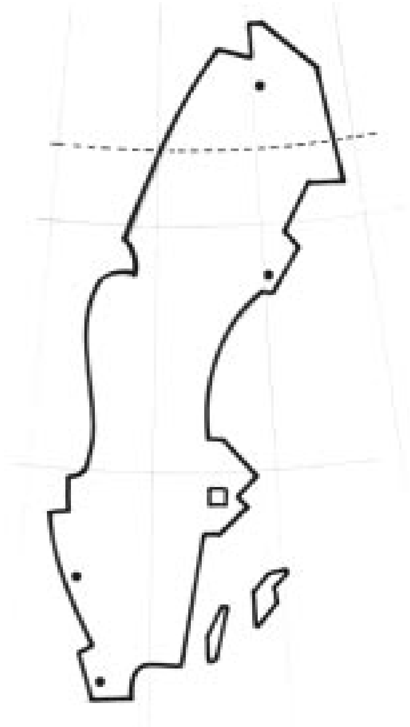
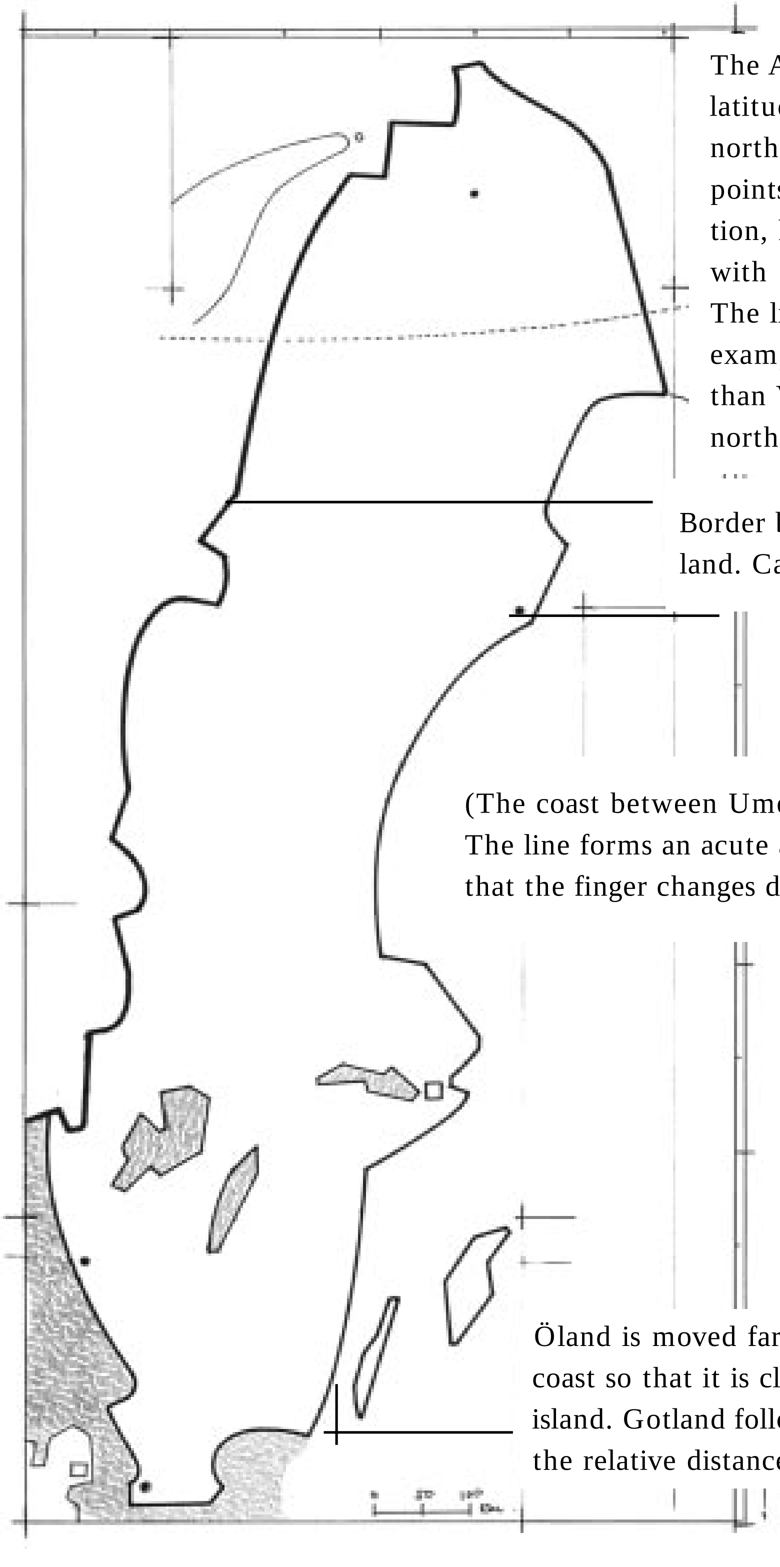


Figure 5: The southern part of Sweden is the most detailed part of the map and limited by clear shapes to the right and left. The location of Stockholm is clearly marked and is a good starting-point. Other points of reference are Gothenburg, Malmö, Umeå and Kiruna, and the Arctic Circle.

Figure 6: On a general map, the shape and location of a country should be clearly represented. Location is given in longitude and latitude.



The Arctic Circle and the lines of latitude situate the reader in the northernmost part of Sweden. These points of reference, plus verbal information, help the reader compare Sweden with other countries.
The lines of longitude show, for example, that Haparanda is farther east than Visby and that Kiruna is directly north of Umeå.

Border between Lappland and Jämtland. Can be compared with Umeå.

(The coast between Umeå and Uppland.)
The line forms an acute angle to ensure that the finger changes direction.

Öland is moved farther away from the coast so that it is clearly perceived as an island. Gotland follows suit, maintaining the relative distance.

Map of Sweden showing provincial borders

To identify the Swedish provinces on a tactile map, at least A3 format should be used, while for the general map in the above example (figure 5) A4 might be more suitable. When a map is transferred to a larger format, certain details have to be adjusted accordingly. On the larger format, for example, it is impossible to maintain the same degree of simplification as on the smaller format. A very simplified border could be misleading in the larger format and should therefore be shown in greater detail. An added benefit of the larger format is the fact that more cities and towns can be added, together with the principal lakes, etc.

Each province in Sweden has a particular extension and shape. Continuous lines and shapes are most suited to a simplified map of the provinces, and particular attention should be given to those provinces which have characteristic shapes (for example, Värmland, Dalarna and Jämtland).

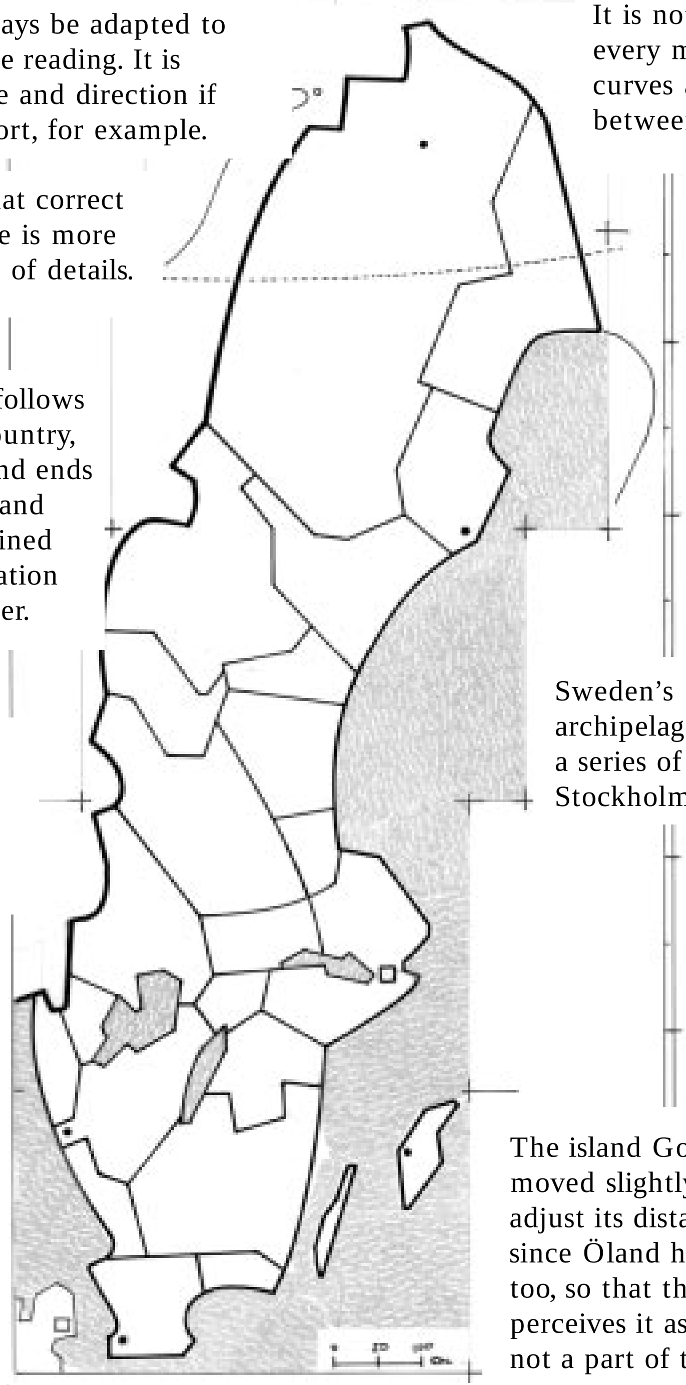
The eastern limits of Dalarna up to the point where the province meets Härjedalen and Medelpad is more or less the geographical centre of Sweden. In the southern parts of Sweden, where there are several small provinces, lakes are useful points of reference. In this case, the outline of each province is reduced to more or less straight lines, which gives slightly angular but more distinct shapes than when these smaller areas are reproduced in greater detail.

In order to draw attention to the shape of the provinces the shapes are emphasised with bold, continuous lines on this map, whose purpose is to inform the reader about the political or administrative subdivisions of the country and their relative sizes. When the reader then goes on to a physical or thematic map of Sweden, he will hopefully carry with him in his head a mental picture of the political map.

This kind of general maps is vital when it comes to interpreting more detailed maps.

Figure 7: Map of Sweden in relief, by Monica Strucel.
The outline of Sweden could have been drawn as an undulating line, but this would have made it more difficult to interpret. Definite curves and shapes which connect with other shapes or straight lines, preferably at a wide angle, help the reader's finger to detect changes of direction more readily.

The outline of the national border can be more pronounced on a larger, more detailed map.



Shapes and lines must always be adapted to the need for space in tactile reading. It is harder to distinguish shape and direction if the lines are extremely short, for example.

We should bear in mind that correct representation of the whole is more important than correctness of details.

The outline of the border follows the curved shape of the country, but it is free from details and ends where Jämtland and Lappland meet, creating a clearly defined shape which makes orientation simpler for the tactile reader.

The characteristic shapes of Dalarna and Värmland make them easy for the reader to locate on the tactile map.

While Sweden's western archipelago can be shown in detail on a map of a larger scale, here it would only make it difficult for the reader to identify individual shapes.

Öresund (the straits separating Denmark and Sweden) has to be shown wider than it really is or the reader's finger will find itself following the outline of Denmark instead of that of Skåne.

It is not necessary to reproduce every minute detail of the curves along the border between Sweden and Finland.

Sweden's eastern archipelago is also limited to a series of continuous lines; Stockholm is indicated.

The island Gotland has been moved slightly farther east to adjust its distance from Öland, since Öland has been moved, too, so that the reader perceives it as an island and not a part of the coast.

Europe – a map of a continent

If we want to know the geographical position of a particular country on the map, it is not enough to indicate its longitude and latitude. We would also want to know what countries border on it, and a map of a continent gives us this kind of information. Here we have chosen to illustrate this point by concentrating on Europe.

Europe is a compact mass of territorial units of varying sizes; each country can be situated in relation to its neighbours. Our problem is how to adjust the map of Europe to the format available to us (A3) without distorting the relative position of each country.

European countries which have no coastline are particularly difficult to locate on the tactile map. They are numerous, they are often small and most do not really have any characteristic features which we can take advantage of on our tactile map. To help tactile readers identify the different countries on the fairly small A3 format, we are forced to displace certain countries on the map. When we move these countries farther north or south, east or west we do not actually change the shape of each country. What we do is creating enough space between them for the reader's fingers to interpret their shape (see figure 8). The purpose of a general map of Europe is to reproduce the "pattern" of countries which enables the reader to find where he is – sufficiently at least to get a general view of Europe.

Figure 8: Relief map of Europe, by Monica Strucel.

The example below (figure 9) is modelled on an existing map of Europe. It measures 32 × 26.5 cm and is divided into squares 6.3 × 6.5 cm (4 × 5 squares). If the full A3 format is used, squares can be 7 × 7 cm in size, which involves no major changes, but does allow us to increase the space between the smallest countries in order to make room for shortened forms of their names in Braille.

In figure 8, we have enlarged the Baltic and the Gulf of Finland. To allow for tactile perception of the straits between Denmark and Sweden (Öresund) and to leave more space for Denmark (and also to prevent the reader from confusing it with Skåne), we have moved Denmark and Germany farther south.

Britain and Iceland have been moved to the left, since we have widened the English Channel to allow for the inclusion of the Channel Islands. Because Britain has been moved, we have to adjust the space between Britain and Ireland (the Irish Sea) accordingly. Similarly, the Adriatic also has to be widened to make it easier to identify.

Once we have created the necessary space on the map, we must join the different countries to whole forms without losing the characteristic shape of each country. In order to do this, we need to have the original visual map in front of us.

Our problem is to design simple shapes without losing sight of the characteristic features of each country. Norway, for example, has an extremely rugged, indented coastline made up of islands and fjords, which cannot be shown on a general map. In this case, the coastline of Norway should be a continuous line, showing only the principal fjords such as the Oslo Fjord, Bokna Fjord and Sogne Fjord. These will have to symbolise the deep inlets along the coast of Norway. Further to the north, Vest Fjord is indicated, as it arises naturally when the Lofoten Islands are accentuated. North of the Lofoten Islands another bay is shown for similar reasons, while yet another fjord is indicated to help identify the North Cape. Straight lines and right angles should be used as far as possible, and all details should be big enough to allow even unexperienced readers to identify them.

Finland has been moved slightly to the east with the widening of the Baltic, and is represented as a simple, solid shape. Russia has been moved along with Europe, as a result of which the White Sea becomes slightly larger than it ought to be according to the scale of this map. This difference, however, is not tactilely discernible. To permit identification of the three Baltic countries, we had to make them slightly bigger. Their shapes have been simplified, but there is still room for the islands of Dagö and Ösel.

It is difficult to show Denmark on a general map because of its many small islands crowded in between Sweden and Jutland. The Öresund Straits have been widened to allow the finger to identify these islands, since they form a quadrilateral whose upper edge is a direct continuation of the “Kullen” area in the western part of Skåne in southern Sweden. This gives the coastline of Kattegatt a straighter appearance. Germany’s Baltic coastline continues in a straight line through Denmark to the North Sea and ends as part of the coastline of the Netherlands, while the English Channel begins in the angle thus formed. With more space between Britain and France, it is simple to adjust their coastlines to make room for the Channel Islands.

France, Spain and Portugal require no major changes except for the straightening of some curves, which does not affect the overall impression. Gibraltar and the Straits of Gibraltar, however, should be clearly identifiable. The Adriatic has been widened; its eastern coastline is irregularly represented, as are the outlines of most of the central and eastern European countries.

If we produce a map of Europe with so many details, we have to separate some countries and then bring them together again, ensuring that the resulting shapes form a pattern that makes each country easy for the tactile reader to identify. I.e., the specific shape of each country should be emphasized and simplified, and the details in border lines should be eliminated.

Figure 9: Outline of relief map of Europe, by Monica Strucel.

Map of the world

A map of the world always implies some form of distortion of the Earth's surface, since a map is by its very nature two-dimensional and discontinuous, unlike a globe of the world, which is three-dimensional and spherical. There are various map projections (that is, ways of representing three-dimensional geographical details on a two-dimensional surface), and when producing a tactile map of the world, we usually look for a projection which is consistent as to area. The projections commonly used are Eckert's, Mollweide's, Hammer's and Goode's projections. When we design a tactile map of the world, although we start with one of those projections, as in the case of the map of Europe, we will have to adapt it to make it suitable for the tactile perception.

The amount of detail on the map of the world depends on the format used, but tactile maps are limited as to format. On a map of the world, the shape of the continents is the most important feature. Other details which help the tactile reader are lines of longitude and latitude, the equator, the polar circles and tropics of Cancer and Capricorn. Lines of longitude and latitude make it easier to compare the flat map with the spherical globe.

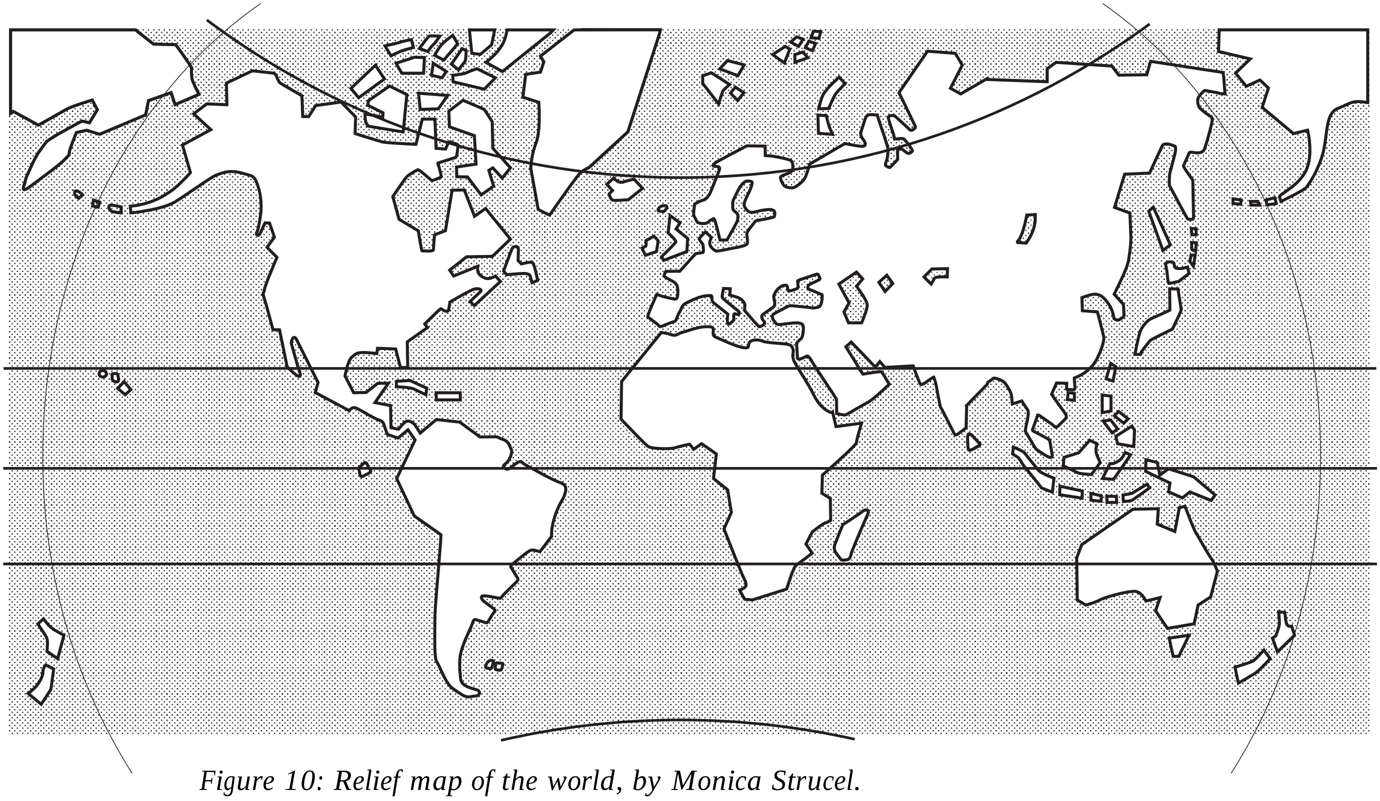


Figure 10: Relief map of the world, by Monica Strucel.

Tourist maps

Holiday trips to other countries are increasingly common and the demand for maps for visually impaired tourists is growing. Maps in guide books and travel brochures are often misleading as their purpose is to give little more than a sketchy image of a particular region or country. The people who write guide books assume, as do travel agents, that the traveller possesses more detailed maps of his own. For the sighted this is not a problem, but the visually impaired tourist rarely has access to tactile maps. For this reason, when maps for the visually impaired tourist are being made, it is not enough to transfer a map in a guide book or a travel brochure to the tactile medium, and to illustrate this point, we will take an example from Fritidsresor's autumn-winter-spring brochure for 1999/2000 involving a holiday in Hurghada in Egypt.

The brochure does not include a map of the whole of Egypt, only of the coastal area where resorts and hotels are located, so we have to find a suitable map of Egypt to use as a model, it may also be useful to include a map of Africa, Europe and the Middle East.

Since Egypt is a country rich in history, the tourist usually has a wide range of trips to choose from. On a modern map of Egypt, the historical names of these places of interest are seldom shown, so we have to get our information from a historical map.

On the relief map (figure 11), the present borders of Egypt are indicated, along with modern places the tourist may be expected to visit. Areas beyond Egypt's borders consist of a dotted pattern. The River Nile is wide and easily identifiable, as is its extensive delta. Its famous cataracts or rapids are indicated, the first of them at Assuan, and the course of the Nile through Sudan is marked on the map, since this region formed part of the Kingdom of Egypt in ancient times. The mountain running parallel to the Red Sea is shown on the map, since the tourist will generally be staying on the Red Sea coast, while most of the historic sites are located on the west side of these mountains.

The map has a series of co-ordinates with each square representing 300 × 300 km. All the essential items on this map are located in squares 3B and 3D, but the other squares (including the empty ones) have to be there to give the reader a general impression of the country and to illustrate the course of the River Nile.

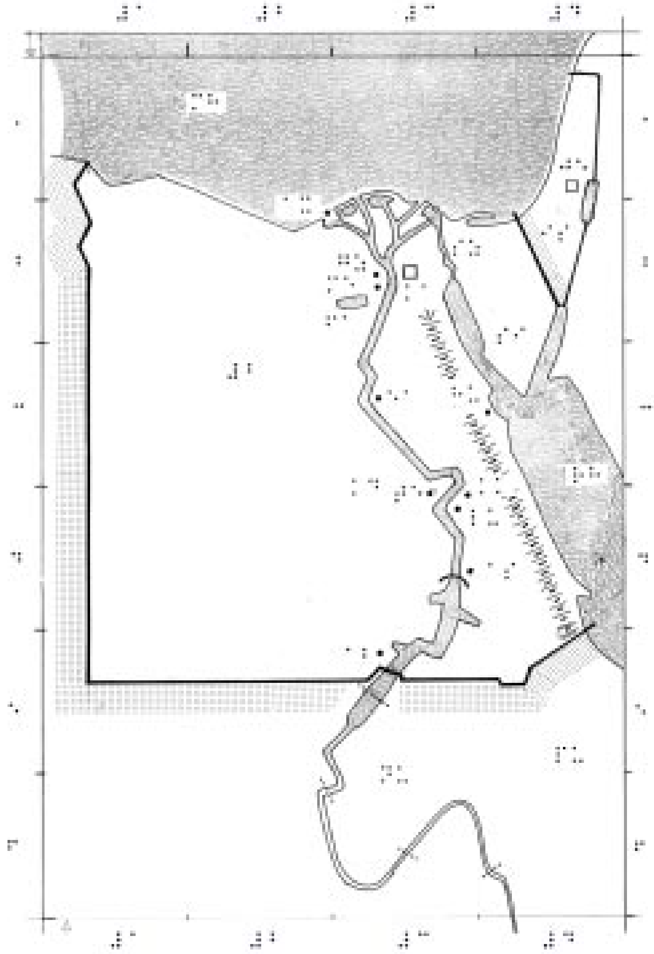


Figure 11: Relief map of historic sites in Egypt, by Monica Strucel.

Someone who has never visited a particular place, region or country can have certain doubts when designing a map. It is, of course impossible, for the map-maker to have first-hand experience of vast numbers of places, particularly when they are far away from where he lives. One of the historic sites that visitors to Egypt will probably visit are the pyramids at Giza. It is difficult to find a good map of this area, and the one we found gives ambiguous information. This type of tourist map (like the one of Giza) often contains insufficient information, and if there is any doubt about the accuracy of the information, it is better to leave it out.

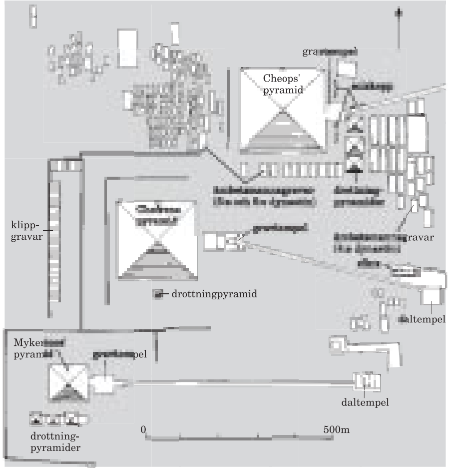


Figure 12: Pyramids at Giza, AB Typoform / Bertil Hjerpe.

When we look at the drawing on which the relief map was modelled, we note that it has been somewhat simplified. The tombs are marked on the drawing, but on the relief map they are indicated only as surfaces. The relief map, however, includes the River Nile, which was not indicated on the original, to make orientation easier for the tactile reader.

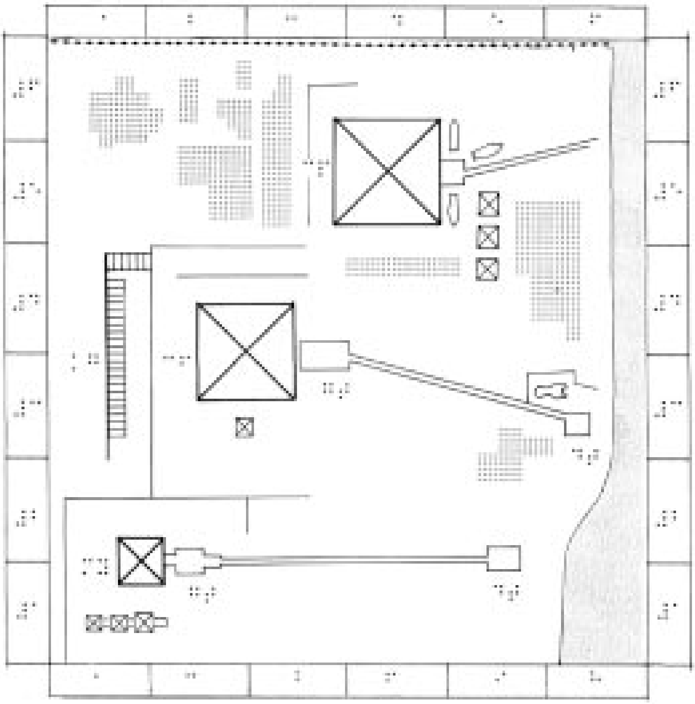


Figure 13: Relief maps of the pyramids at Giza, by Monica Strucel.

City plans

City plans usually serve a variety of purposes, for the sighted as well as the visually impaired. A city plan can be used as a general picture of how different parts of the city relate to one another, in which case it need not be detailed; a plan of districts and main arteries will be sufficient. Let us take as an example the relief plan of Stockholm, with the city centre and the main roads which traverse it.

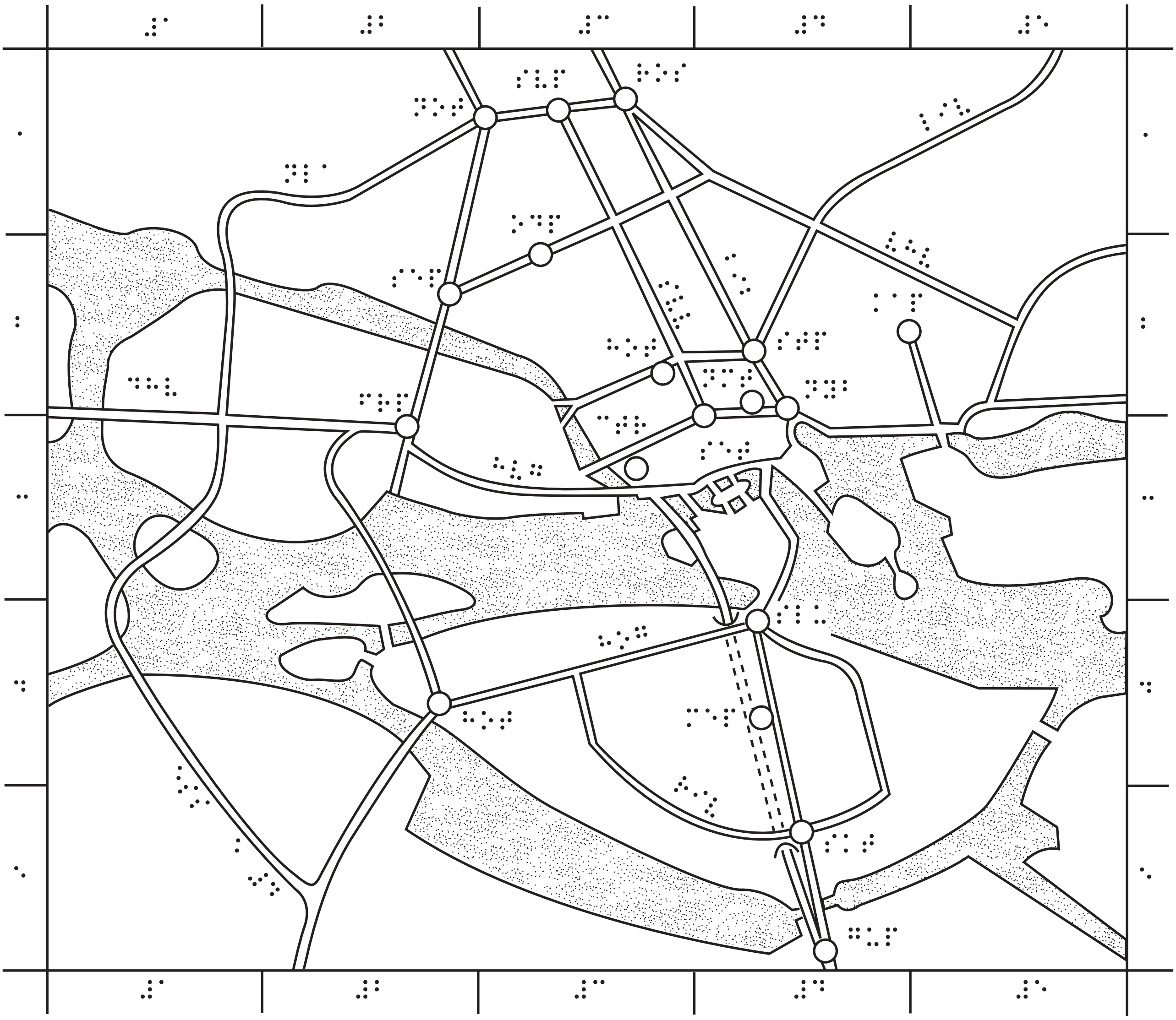


Figure 14: Plan of central Stockholm, by Monica Strucel.

If we want to know more about a particular district, we need a more detailed plan. The following plan of central Södermalm shows the major streets and some of the buildings. The map is included in *Getting in touch with Stockholm – city guide for visually impaired people*. It contains detailed descriptions of some of Stockholm's most well-known buildings and monuments, so the reader must have a plan on which they are clearly indicated, if he is to understand how they relate to each other and to their particular surroundings.

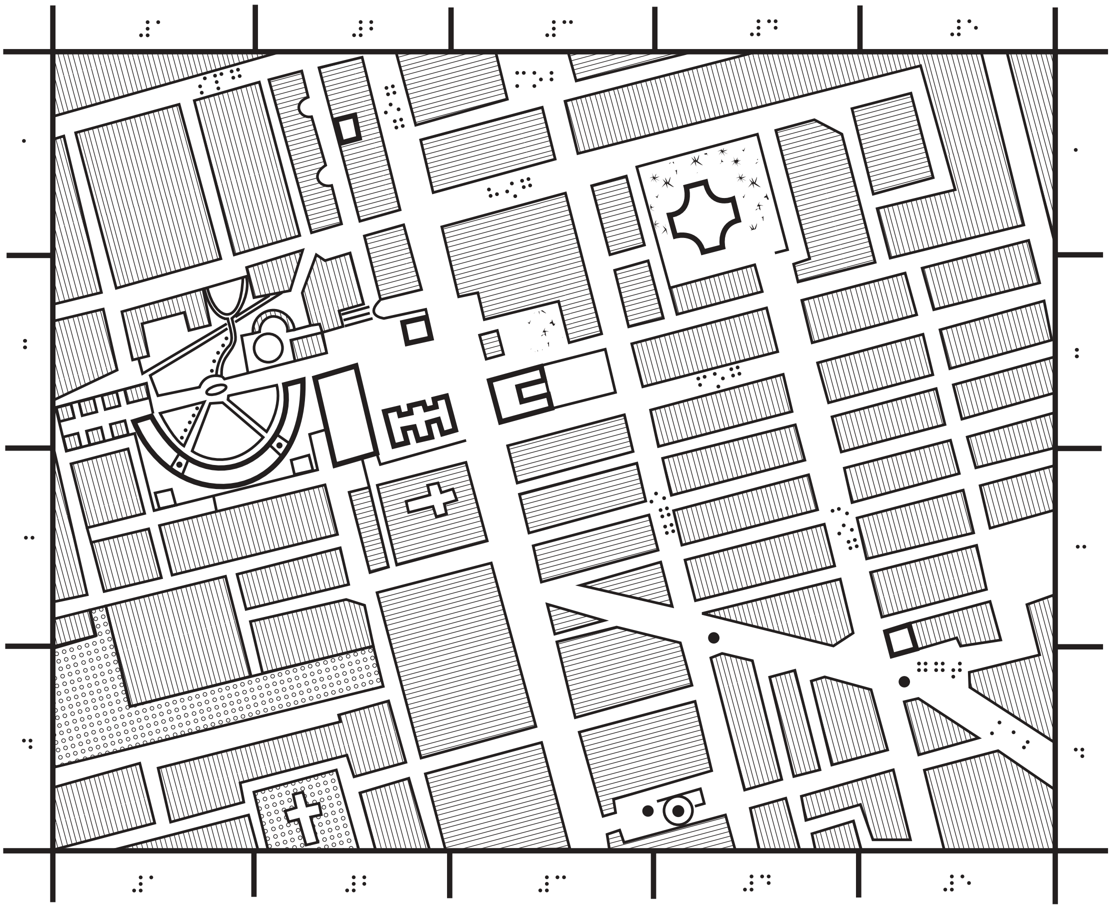


Figure 15: Relief plan of central Södermalm (Stockholm), by Monica Strucel.

Since interpreting a city plan is a relatively complicated task because of the vast amounts of information usually provided, it is important, in the case of a tactile plan, not to include too many details. Although this plan of the Södermalm district has been fairly drastically simplified by removing unnecessary information, we need a further enlargement of Medborgarplatsen Square to enable the reader to locate the pathways leading to the building known as “Bofills Båge” (Bofill’s Bow).

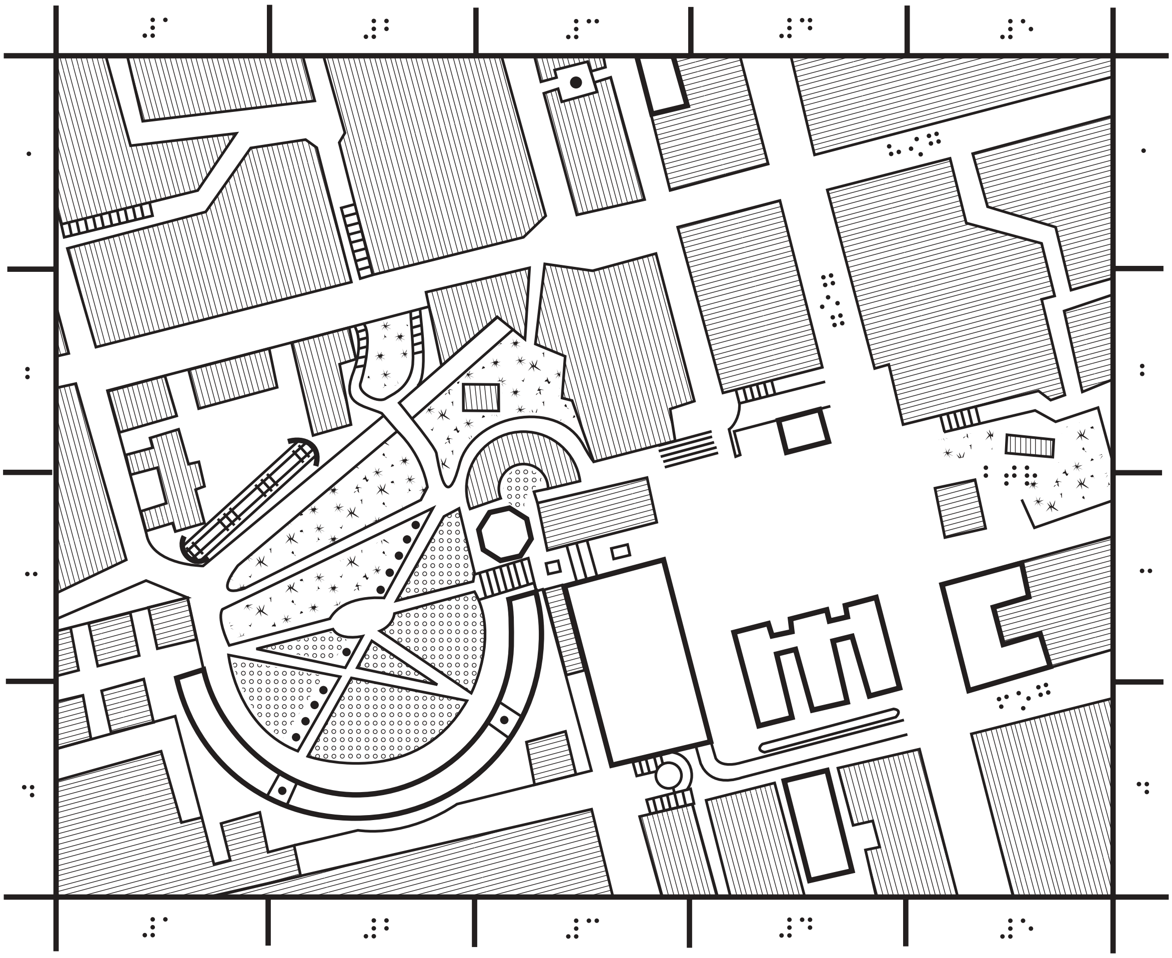


Figure 16: Relief picture of Medborgarplatsen (Citizens’ Square), by Monica Strucel.

City plans can be further simplified in order to make them even easier for the tactile reader to understand. On the general map of Gothenburg and its suburbs, the harbour channel and docks are indicated; districts are indicated by their initial letters, which is sufficient for the reader to understand how they relate to one another.

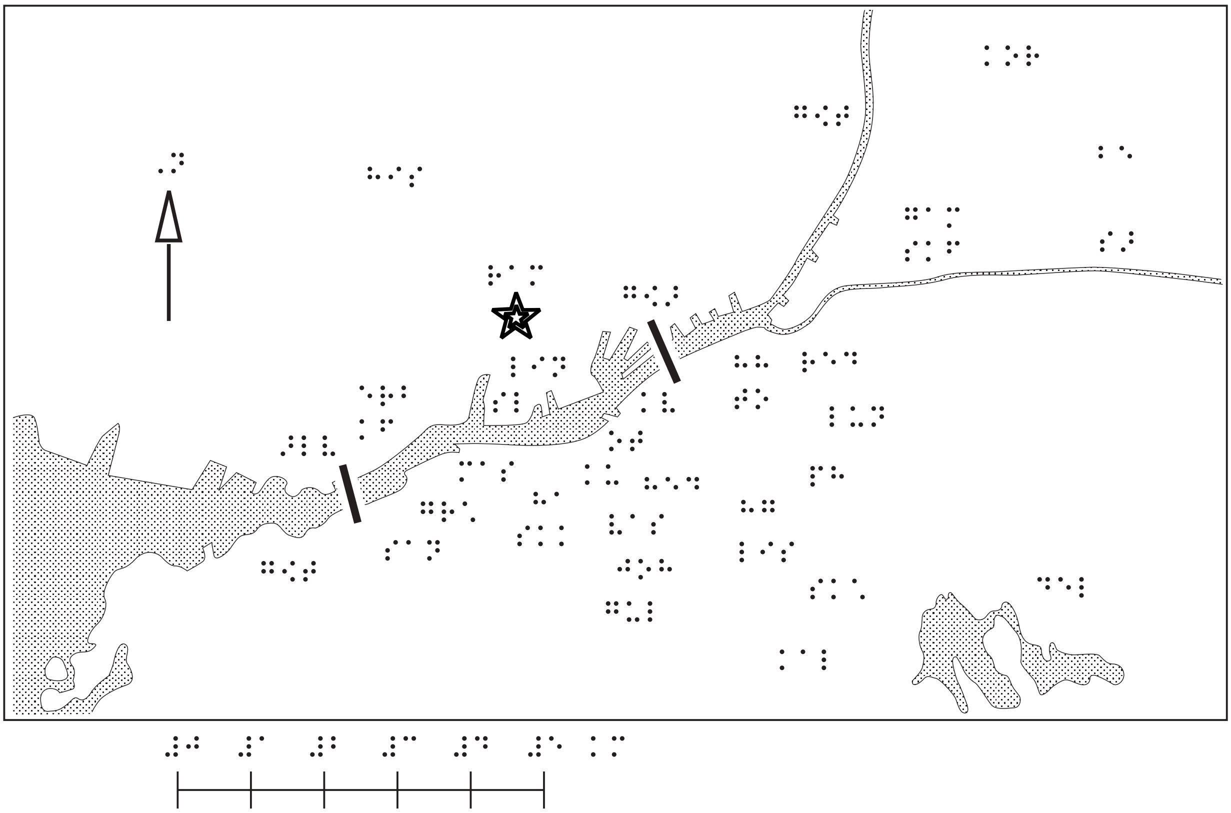


Figure 17: General relief plan of Gothenburg, by Eva P. Eriksson.

This plan gives no information of how the city centre is spread out or the main traffic routes, which would require a more detailed plan.

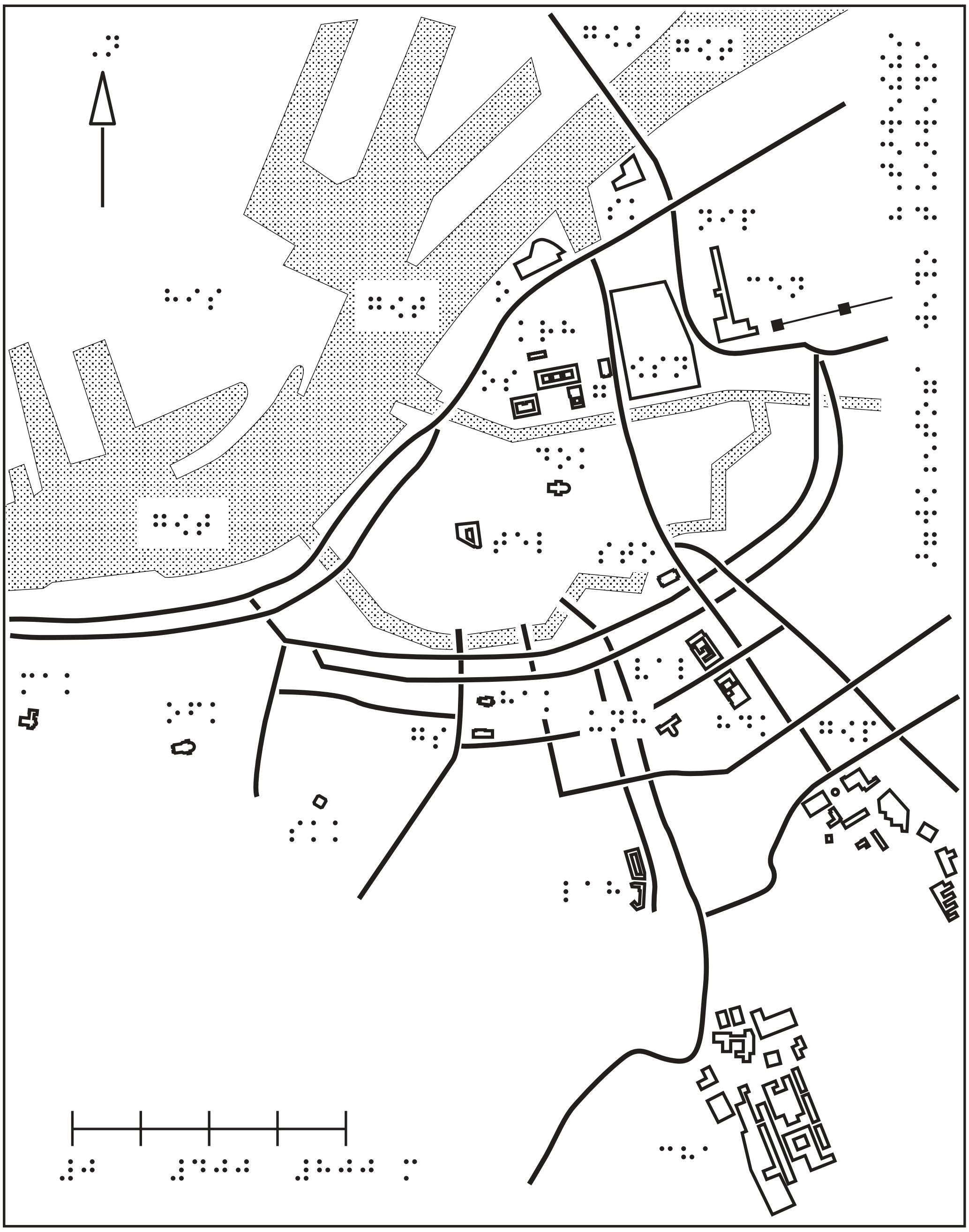


Figure 18: Relief plan of central Gothenburg, by Eva P. Eriksson.

The difference between this plan of central Gothenburg and the plan of central Stockholm is that in the case of Gothenburg we chose to represent the street system by single lines. In other words, we retained only what we considered vital information; that is, how different parts of the city centre relate to one another and the length of the main streets.

The street map showing Kungsportsavenyn leading to Götaplatsen Square is long and narrow, just like the avenue it represents.

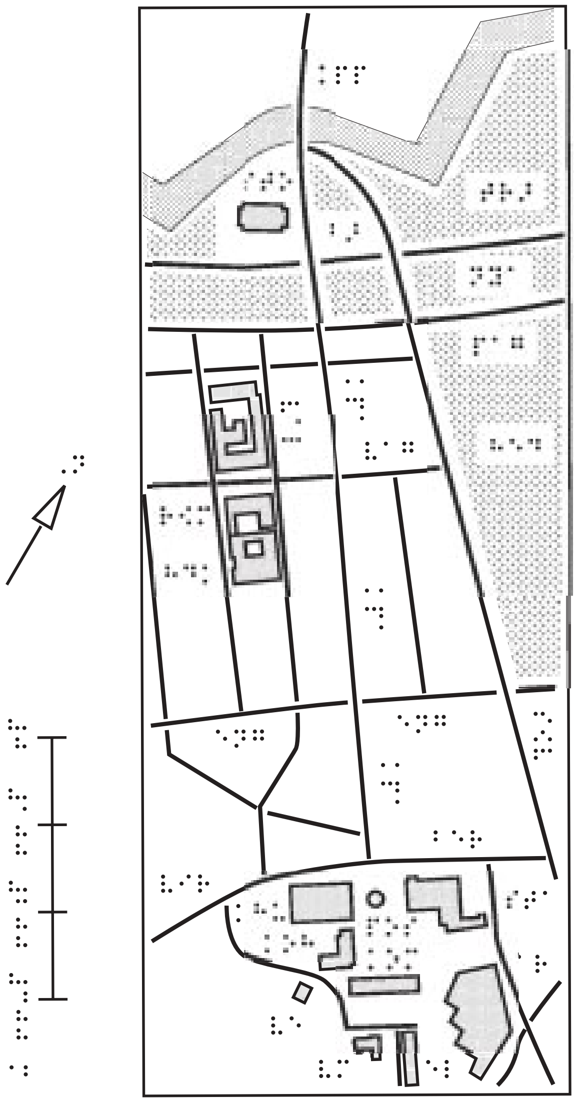


Figure 19: Relief map of Kungsportsavenyn as far as Götaplatsen, by Eva P. Eriksson.

The reader’s finger has no difficulty in following the line representing Kungsportsavenyn, and some of the buildings along the avenue have been indicated, as the plan comes with a descriptive text mentioning them. When we reach Götaplatsen Square, we need yet another map in order to identify all the buildings situated around this square and the central fountain with its statue of Poseidon.

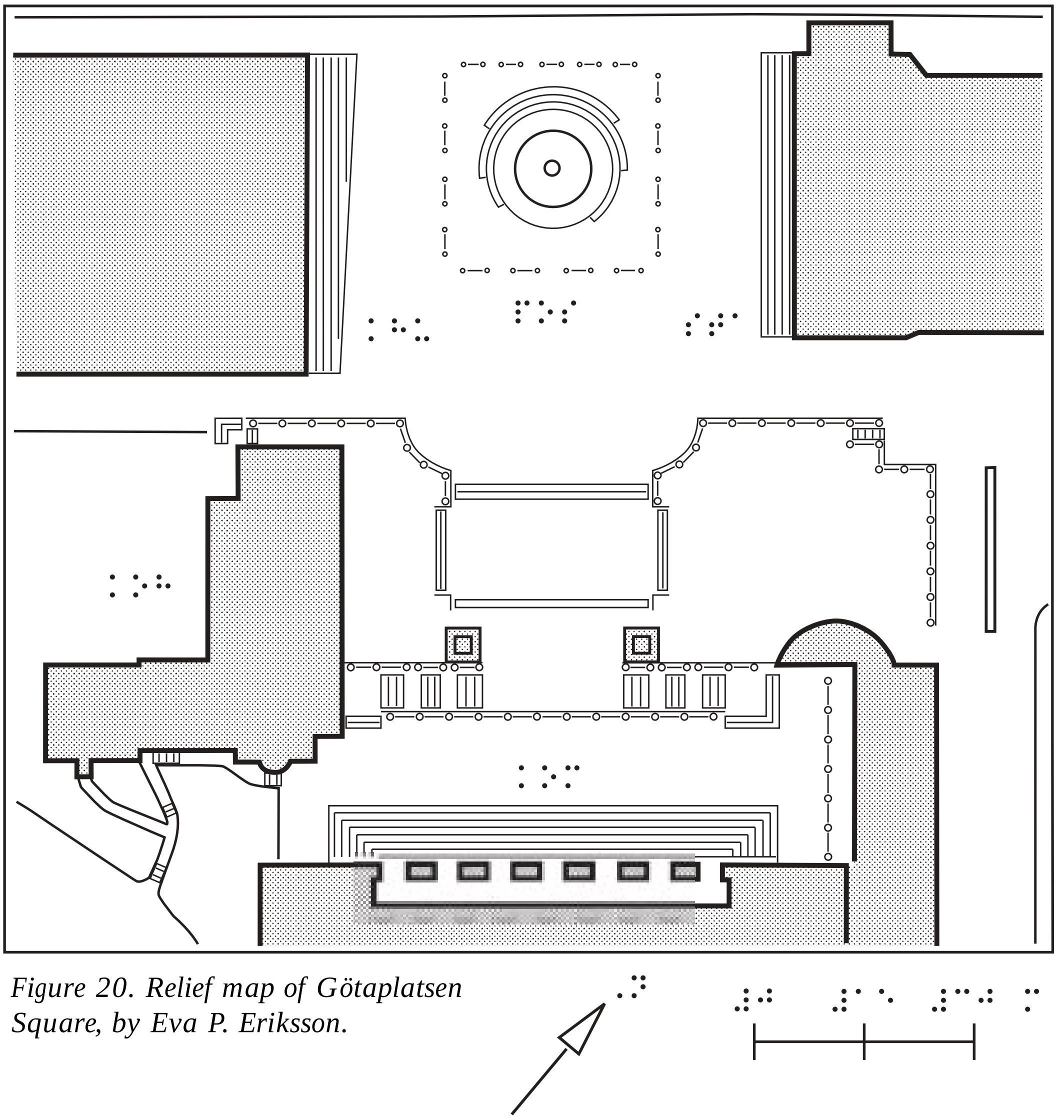


Figure 20. Relief map of Götaplatsen Square, by Eva P. Eriksson.

City maps are often produced at someone's request, and it is important to find out what type of information that person really needs. When we design a relief map, we need to know which part of the city or town the person in question lives in. We also need to find out where he or she works, what educational centre he or she attends, where he or she usually shops, etc. When we know all this, we then have to study how the district relates to the rest of the city or town, or the community as a whole. Someone who orders an individualised plan may in fact not be interested in a plan of the whole town or even the whole district; he or she may only want a plan of the local area.

It is best to start with a general map without a great deal of information; more information can always be added, while it is more complicated to get rid of unnecessary details.

Plans

Tactile plans are often in use as they are very useful for orientation in buildings or in parts of buildings. Plans of this kind are often made on order by individuals. The material available for this type of order is often unsatisfactory, frequently consisting of architectural plans with far too many details, on faint, almost indecipherable photocopies.

In order to produce a tactile plan that can really be used by someone with visual impairment, we must start by identifying the essential details. The first example provided here is a plan of the Vision Centre in Eskilstuna.

Plan without settings

The Vision Centre at Eskilstuna wanted a plan of their premises, which form part of the local hospital, but have a separate entrance. The plan they sent us as a basis for transfer was quite clear (see figure 21). Although it looks simple enough, careful examination was required before drawing could begin. The plan in itself is simple, and the format (A3) suitable for transfer to relief. All the doors are clearly indicated, but when we take a closer look, they appear to have been moved. This is not of major importance, but worth mentioning, in order to avoid misinterpretation, as the walls are not very clearly indicated.

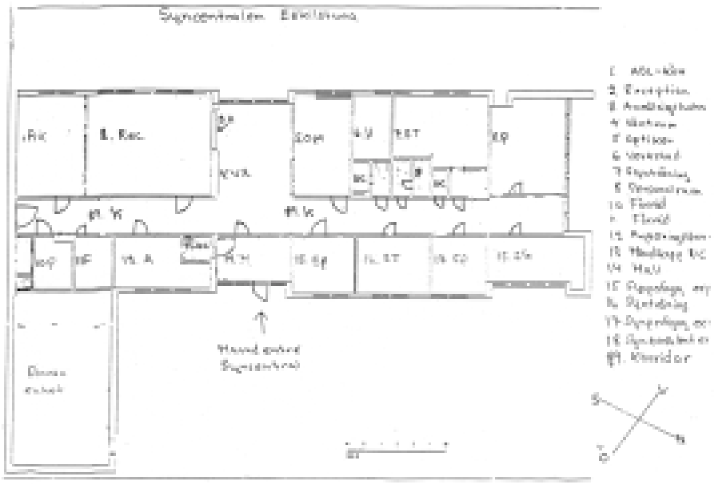


Figure 21: Plan of Eskiltuna Vision Centre.

The drawing gives the points of the compass, with a note that “up” and “north” do not in this case coincide. The building extends south-east to north-west, with the main entrance in the north-east. This doesn’t mean much to the visitor, who probably arrives by car at the main entrance and is better served by a plan which indicates simply what is to the right and left once he or she is inside the building.

All the outer walls are represented in bold, easy to identify, continuous lines. The purpose of emphasising the walls (which might not seem necessary) is to make the general plan of the building clear to the tactile reader. As the reader cannot see or visit the whole building, the only thing he can go by are the outstanding features marked on the plan. The different thicknesses of the lines indicating walls provide him with information he can make use of to distinguish the exterior from the interior walls. Details like these on the plan can make it easier for the tactile reader to orientate himself within the building.

The walls which have windows are represented by thinner lines. Walls with windows are normally of the same thickness as the rest of the walls, but if a different line is not used, it will be difficult for the reader to feel where the windows are situated.

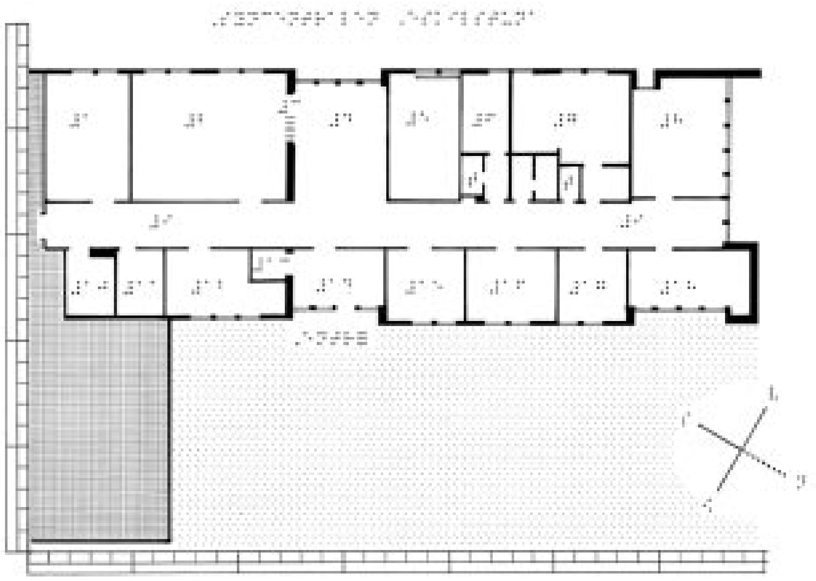


Figure 22: Relief plan of Eskilstuna Vision Centre, by Monica Strucel.

The space in front of the entrance has a distinct, dotted pattern and the parts of the building where other activities take place are also patterned in a similar way. As the Vision Centre is part of a larger building, it helps to show where other activities are located. For the reader to find his way about inside the building, we must indicate where the other activities take place.

The Vision Centre's premises include a number of rooms situated along a corridor. All the rooms have doors opening onto this corridor. On the tactile plan only the doorways are indicated. If the doors themselves were indicated as well, the plan would be confusing for tactile readers.

On the plan sent by the Vision Centre as a model for the tactile version, every room is indicated by a number, the explanation of which is given in an index. We usually recommend the use of initial letters, but in this case, and as the original uses figures, we have kept them on the tactile plan.

Instead of indicating the scale of the plan, the tactile version gives the measurements (length and width) on sides of the plan (a way of indicating measures developed by Arne Yngström). It may be helpful to know that when you enter the corridor you must walk 16 metres to the right to get to the door of the vision consultant.

On this plan, the interior fittings of the different rooms are not indicated. If it were really necessary to indicate these, too, it would have been done on a partial enlargement of each room to allow for this detailed information.

Plan with settings

The purpose of the plan described above is to enable the visitor to find his way about the building, while the purpose of the exterior plan of Farsta Central Church (Centrumkyrkan) is to familiarise the visitor with the milieu. Farsta Centrumkyrkan, to the south of Stockholm, was designed by Bengt Carlberg and Börje Stigler and built in 1961.

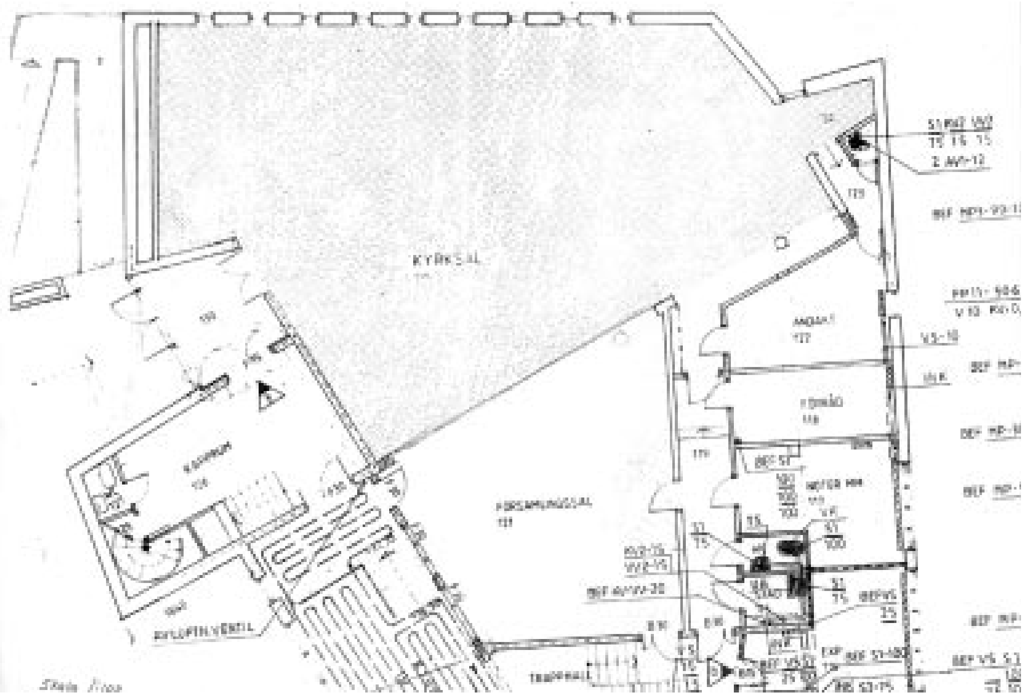


Figure 23: Plan of Farsta Central Church (Centrumkyrkan), by Bengt Carlberg and Börje Stigler.

The tactile plan of the church is relatively complex and requires explanatory text to assist the visitor in orienting himself on the plan and in the church building. The description reads as follows:

Begin at the square 1E by figure 1. Follow the arrow to the main entrance of the church, up a couple of steps and into the **vestibule** (2). The doorway is wide, with double doors which open in the direction indicated by the small marks.

To the right of the vestibule there is a **cloakroom** (3) with two toilets, a long coat-rack and a table with a mirror above it. A staircase leads to the second floor where there is a hall for studies and young people’s activities. Next to the staircase there is a door leading into the church’s **assembly room** (4).

If you go straight through the vestibule (2) and through another pair of double doors, you enter the **church hall**, with pews to the right and left. At the front of this area (5) a raised section or dais crosses the main body of the church. The pulpit is on the left of this platform, a communion table in the centre and at the very back there is a baptismal font large enough for total immersion. On the right-hand side of this raised section there is space for a choir and musicians.

A double broken line which runs lengthwise down the right-hand side of the main seating area indicates the position of a sliding door or wall by which the assembly room can be closed off from the church hall. The main part of the church has fixed benches or pews, while the assembly room is furnished with chairs. Doors lead from the main body of the church into the administrative section. There is also access to the administrative offices from the street.

Begin at the square 5H. Follow the arrow from 6 through the entrance and up a couple of steps to 7, where there is a slightly longer staircase at the side leading down to the basement where youth and other activities take place. Straight ahead is the **registrar’s office** (8), with a small ante-room.

A corridor runs from 7 to the platform. Along this corridor there are doors which open into the main part of the church. To the right there is a **kitchen** (9) where the church serves porridge for breakfast on Saturdays. At the very front, there is a single step up to the dais.

There is also a **leaders’ room** (10), from which a short corridor leads to a dressing-room and to the steps down the baptismal basin.

Toilets are indicated by the letter T. There are two in the cloakroom at the main entrance and another outside the registrar’s office.

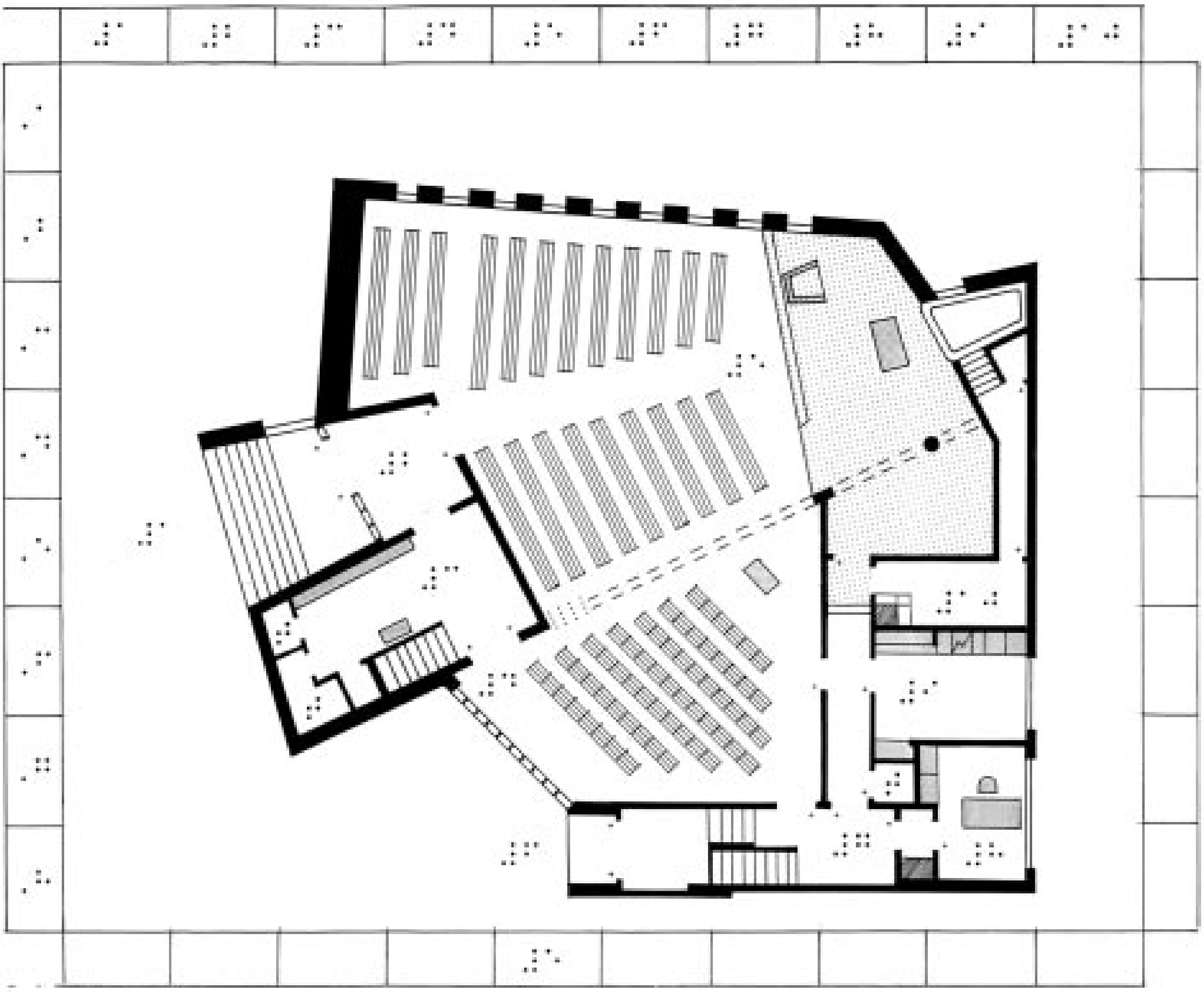


Figure 24: Relief plan of Farsta Central Church, by Monica Strucel.

SUMMARY

When a tactile map or picture is being produced, it is important to emphasise the characteristic features of what is being depicted. This is the case whether it is a tactile map of the world, a particular area or a plan. Simplification with a view to facilitate tactile reading, however, does not mean that content should suffer. There are no existing drawing programmes capable of automatically making a visual map tactile. In each case, the needs of the user must be our starting point, plus the specific demands of tactile reading.

It is virtually impossible to specify categorically the width of the lines, the symbols or surface patterns which should be used in the production of tactile maps. However, we can give some advice on the relationship that should exist between lines. To enable the reader to distinguish the difference between lines of the same type (continuous, dotted, broken, etc.), these should be of different widths (twice as wide, one from the other). The boldness of the line depends on the degree of enlargement and on the number of other details on the map. In general, we should be careful not to include too many details on the same map.

The symbols used (lines, dots and surfaces) must be chosen carefully if they are to function well in combination. Bold lines, for example, should not be combined with small dots on a map, as it may lead to difficulties perceiving the dots or even finding them on the map’s surface. It is also important to plan the design of the tactile map so that the essential features are clearly identifiable, giving less prominence to less important details.

Tactile maps should always be accompanied by text indicating the name of the area, country, continent, ocean, lake or river depicted. On town maps, street names should always be given, as well as the names of parks and squares. Braille text takes up a lot of space, so it is rarely possible to give the full names on a tactile map. Initial letters should instead be used, accompanied with an index giving the names in full. The index should give the initials shown on the map in alphabetical order; if more than one map of the area is needed, each should be accompanied by an index.

Each map requires an individual solution, the two basic questions we should ask ourselves being: Who is going to use the map? For what purpose? On the basis of these two questions, we can produce maps which will suit the needs of the target group, regardless of whether this is a single individual or several people.

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TACTILE MAPS – OVERVIEW OF RESEARCH AND DEVELOPMENT

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In an ideal world, readers of tactile maps would be able to find the information they want after a short exploration of the map, and there would be no mistakes. Unfortunately, we do not live in an ideal world. Therefore, it has often been found that tactile maps are difficult to read and that the results of reading are incorrect in many cases. It happens even that readers give up exploring a map without having found what they wanted. Sometimes this has given rise to the idea that it is not possible to get information from exploration of a tactile map. However, that is not the only possible conclusion.

Instead, it may be that it would be possible to find the information wanted after a not too long exploration and without making too many mistakes if tactile maps were constructed differently. The goal of many efforts, scientific as well as practical, has been to find solutions that make tactile maps user-friendlier. If these efforts were successful, information would be found in a shorter time and with fewer mistakes. How can this goal be reached?

It is a reasonable hypothesis that, when we have constructed tactile maps so far, we have, unintentionally, not adapted them maximally to human perception and cognition. These functions have been developed over millions of years, even before the rise of mankind, in interaction between the living creatures and their natural environment. For instance, the hand as a perceptual system functions as it does on the basis of this development. When we make artefacts, such as tactile maps, it may easily happen that our products depart in some way from what would be ideal for the human way of functioning. To find out how the relevant functions work is a main goal for the scientific efforts and the results contribute, hopefully, to making tactile maps user-friendlier.

Another goal is to find out to what extent readers of tactile maps can develop their skills in reading the maps. Human beings have an enormous capacity to cope with new situations. This skill can be developed spontaneously, but it may also be obtained by teaching taking into account human ways of functioning.

In sum, in order to get tactile maps more useful for readers, we need to study both how the maps can be more adapted to human perception and cognition *and* how map-readers can be more skilled in getting the information they want from the maps.

The aim of this report

Tactile maps are among the earliest kinds of pictures for the blind, and they have been produced for several different purposes with a variety of methods (for a historical review, see Eriksson, 1998, especially Chapter 5, ”The tactile map”). Many efforts to make them user-friendlier and to instruct visually impaired people in the use of them have built on intuition and trial and error, but there have also been scientific efforts to solve problems by scientific research. The aim of this paper is to give an overview of these efforts (for earlier overviews, see Jansson, 1983 b, 1984, 1988). The intention is not to cover all aspects in connection with tactile maps, but to concentrate on those that have been the subject of experimental or theoretical studies. In some cases problems will be indicated that have not yet been worked on, but that ought to be investigated. The paper will also discuss technical development that may be important for the availability of map information in tactile form.

In an applied context, scientific results have to be fused with practical experience, which is especially important for aspects not well covered by scientific studies. Extensive overviews combining practical work and scientific research on tactile maps can be found in James & Armstrong (1976)[1], Edman (1992, especially Chapter 6, ”Maps”) and Bentzen (1997). Instructions especially aiming to vacuum formed tactile maps were presented by Gardiner & Perkins (2002).

It may be important to note that not all aspects have to be subject for research. If a practical solution can be found which works satisfactorily, research may not add anything. The need of research arises when problems appear to which there is no apparent solution, or when options are available between which a choice is difficult. Research may also contribute to the formulation of general rules for making tactile maps and to an understanding of functions of touch useful in new situations. Sometimes it may demonstrate that widely hold opinions are not tenable.

This review consists of the following main parts: (1) Map information to include, (2) Tactile presentation of map information, (3) New technical development, and (4) Understanding of geographical information. It ends with (5) Suggestions for further research and development.

Map information to include

Roughly, there are two main groups of maps: (a) maps aiming to provide geographical information without considering the reader's potential travelling in the area and (b) maps specifically aiming to guide travel in the mapped area. They can be called *geographical maps* and *mobility maps*, respectively. It should be stressed that these categories are broad and can be broken up into several subgroups. There are also maps that can be said to belong to both groups, for instance town maps.

For geographical maps the information needs of a visually impaired reader are probably not different from those of a sighted reader. A first thought may therefore be that such a tactile map should contain the same information as corresponding visual map. However, the amount of information that can be read in a tactile map is more restricted because of the lower spatial resolution of touch and the difficulty of getting an overview of the map. It is well known that, in many cases, copying of a visual map without revision into a tactile form of the same size would result in a map that is difficult or impossible to read because of its being too cluttered. The option to increase the size in order to make reading of details possible is usually not an alternative because of the problem of tactually getting an overview. A much-used alternative is to delete some of the information or to distribute the information over several tactile maps, for instance, with rivers on one map and roads on another.

For mobility maps the content problem is partly different. Suggestions about what is important for visually impaired readers wanting information for travelling in the area covered can be obtained by studying how they describe a route. Brambring (1985) studied verbal descriptions by sighted and visually impaired persons of routes well known by them. He found that the blind used much more information in their descriptions than the sighted. Furthermore, their descriptions contained less information obtainable from the environment and more information relating to the person, such as distances from the traveller to objects in the environment as well as body rotations. Passini & Proulx (1988) got similar results when studying route descriptions trough large buildings, as did Edwards, Ungar & Blades (1998) in an investigation of children's route descriptions[2]. These results demonstrate that the information blind people need in advance of travelling is greater than the information sighted people need. Sighted people can obtain much of the information needed by direct visual perception of the environment, for instance, information about landmarks at a distance, location of street crossings, and degree of slant and kind of material of the ground.

Thus, tactile mobility maps need to be more detailed than maps for sighted people in order to give sufficient amount of information, but at the same time they should not contain too much information because of the risk of being so cluttered that they are difficult or impossible to read. This means that, when you translate a visual mobility map into a tactile one, information has to be both deleted and added.

Information from digital maps

The role of computers for tactile maps has so far mainly been to assist in the production of traditional maps and to store information from produced maps. This use of computers for production of tactile maps started about 30 years ago (Gill, 1973), and this is still important. However, the existence of digitised map information stored in Geographic Information Systems (GISs) provides new options. In these systems different kinds of information are stored in diverse layers. What information is included depends of the purpose of the maps. One common purpose is to provide a car driver with information about how to reach his destination; another purpose is to provide city planners with information about, for instance, the distribution nets for electricity and water. An important advantage of this stored information is the possibility of choosing between layers to include, thereby producing maps with different content, such as a general overall map of an area and separate maps with special kinds of information.

For visual maps this is a well-developed area; the maps stored in GIS form are presented on a computer screen or printed out. Principally, it is not different to use such files in the production of tactile maps. You may also use GIS technology to create tactile maps starting with a visual map, digitise it, and add layers with information relevant for a visually impaired person. A selection of layers can, for instance, be printed on swell paper and embossed by heating (Clark & Clark, 1994). There are also other efforts to catch a virtual[3] image and transform it to tactile form (Gardner & Bulatov, 1998). Digital maps can also be used as a starting point for manual editing of tactile maps to be produced in any form, as is made by, for instance, Metria, Kiruna, Sweden (Hans Dahlberg, personal communication).

Deletion of information

The map information in the presently available GIS maps is primarily intended for visual reading and would, in most cases, be too cluttered when presented for tactile reading. There have been efforts to utilise computers for automatic simplification of visual pictures when they are translated into tactile form (e.g., Pun, 1982), but the development in this area has been slow. However, there are recent efforts to delete information automatically from virtual maps. Michel (1999) demonstrated that this is possible, but how well this can be implemented differs with the file format[4] of the map. So far as I know, these interesting problems have not been followed up anywhere, but they should be.

Another way of GIS use is to develop a partly automatic procedure to transform ordinary GIS data into simplified form, maybe similar to what has been done for schematic maps such as underground maps (Elroi, 1988). This is possibly a suitable way to get strip maps useful for the guidance of travelling (Hamel, Michel & Strothotte, 1995).

This deletion will probably be possible at present only for expert computer users. However, it is conceivable that software can be developed that makes it possible for ordinary visually impaired computer users to load down a GIS-file from the web, edit it to their own needs and make it available in tactile form.

Adding of information

Especially for mobility maps, it is necessary to add information to tactile versions that is lacking on visual versions, for instance, availability of sidewalks, location of pedestrian crossings and properties of the ground (Jansson, 2000 b). Unfortunately, such information is not usually available in digital form, and so a great amount of work is involved in adding it to tactile maps. Ideally, people knowledgeable about the needs of the visually impaired population should visit each area and judge what information should be added. In fact, such site visits are often made when maps for the visually impaired are prepared for smaller areas, but doing so for larger areas is a huge task.

Transformation of information by ”distortion” of spatial relations

Maps are not, in all respects, a faithful representation of the geographic environment. Distortions are sometimes used because they are useful for some specific purposes. For instance, an underground map reproduces the relative location of the stations correctly, but not the paths and distances between them, as this information is not relevant for the travellers and may possibly confuse them. Similarly, in order to increase the readability of a tactile map, it may be suitable to enlarge portions that are difficult to interpret, such as a complex street intersection or a narrow valley with a road and a railroad, as well as a river. As increasing the whole map may make it too bulky, it may be desirable to decrease the size of other, less difficult parts of the map. Michel (1999) has developed software, called Map Wizard, to make such ”distortions” possible by interaction between user and computer. In principle, visually impaired computer users ought to be able to make such adaptations of digital maps themselves.

Tactile presentation of map information

In most cases a tactile map utilises information provided by a visual map of the same area, but this information has to be translated into a form suitable for the tactile sense. When this translation is made the similarities and differences between the two senses should be taken into consideration. The basic change is that variations in brightness and colour on the visual map have to be substituted by changes of elevations over the background, thus in relief, on the tactile map in order to be picked up by the fingers.

Overviews of the special properties of touch can be found in Loomis & Lederman (1986), Schiff & Foulke (1982), Heller & Schiff (1991). The two latter references include chapters of special relevance for the problems of visually impaired people.

Translation of visual properties into analogue tactile form

In some important respects there are similarities between vision and touch. Both senses can pick up information about edges, forms, textures, sizes, and locations, even if the psychophysical thresholds making it possible to detect information about these properties and to discriminate between varieties of them are in general not as good for touch as for vision. This means that the tactile sense cannot always detect as small details and differences between details as vision. When the tactile information is sufficient to pass these thresholds, *analogue* kinds of tactile information are often to be preferred. This means that edges, forms, textures, sizes and locations can, in these cases, be copied from the visual map into the tactile one. An advantage of this possibility is that the understanding of the tactile information may be facilitated, at least for visually impaired people with experience of visual maps. For instance, borders between countries and between land and sea, form and size of lakes, locations of towns and mountains etc can be analogously translated.

The problem of getting an overview

It is a well-known fact that it is much more difficult to get an overview of a map tactually than it is visually. Vision provides a practically immediate overview, while touch makes an often laborious and time-consuming exploration necessary. The situation for tactual exploration is similar to what it would be for visual exploration if we were allowed to see only through small holes in a cover moving over the map. The problem for touch is to get an integrated perception of an object that is at each time only partially perceptible.

Ways of compensating touch for its problems of getting an overview is (a) to provide suitable information in words, (b) to utilise the general perceptual ability to discriminate between figure and ground, and (c) to use maximally efficient ways of exploration (cf. Berlá, 1982, pp. 368 ff.).

Verbal descriptions

A suitable verbal description may function as a vehicle for an overview (Levi & Amick, 1982). In addition, it may contain general instructions about how to read the picture. Such ”picture guidance” can be quite elaborate and is critical for the usefulness of the picture (cf. Eriksson, 1997, especially pp. 54–73).

If the readers have earlier acquired knowledge of what is depicted, the exploration may be considerably facilitated by verbal information. For instance, if they know that the form of Italy is similar to a high boot and then get the information that the map content is Italy, they can explore the map more efficiently.

When a reader has less advance knowledge, detailed suggestions about how to explore the map may be useful. For instance: start in the upper left corner, follow the slightly oblique contour downwards and so on.

Figure-ground

In visual pictures there is, in most cases, not much trouble of distinguishing between figure and ground. Contours are usually easily identified as belonging to an object in front or as belonging to the background. This is not as evident in a tactually read picture (Kennedy & Domander, 1984). Brambring & Laufenberg (1979) discussed the difference in performance with two types of tactile maps as depending on differences between them in figure-ground relations. One way of making a perceptual separation easier is to vary the height of what is figure, for instance by making point and line symbols higher elevated than surrounding areal symbols (cf. Edman, 1992, pp. 218 f. and 233). It has also been suggested that a code indicating different function of edges should be used (Campbell, 1997), but the usefulness of this has not been sufficiently demonstrated.

Exploratory movements

Touch has a large repertoire of exploratory movements (Lederman & Klatzky, 1987). The number of available such movements is, however, restricted when information in tactile maps is picked up in the usual way of map exploration, that is, by two-dimensional (2D) movements. But also under these conditions there are several options, and some exploratory movements are more effective than others.

Berlá (1982) found that scanning to and fro the body is more efficient than scanning left and right. When the movements are performed left and right the fingertips come successively to the same area of the map and the risk of skipping parts of the map is large. The risk of a similar skipping is not as great when the fingers are moved to and fro the body. This means also that the amount of information is larger in the latter case than in the case when they are moved left and right. The difference is related to the construction of the arms and hands. You can orient your fingers in a left and right sweep such that you get the same information as in a to and fro sweep, but then you must hold your hands in very awkward orientations.

How many fingers are used during the exploration is also of importance. For exploration of real objects the efficiency is dramatically increased when one finger is replaced by two fingers, while it is not very much higher when more fingers are used (Jansson & Monaci, in press). For yet unknown reasons an increase of the number of fingers does not seem to have the same effect on the efficiency of reading tactile maps (Jansson & Monaci, 2003).

The importance of training map-reading skills was emphasised by James (1982). He pointed also out the differences in method needed for individuals differing in age, degree and onset of visual impairment, as well as in abilities of relevant kinds (cf. also Hampson & Daly, 1989, and Vasconcellos, 1996).

The problem of discriminating details

Touch has sometimes a capacity to make discriminations as well as or better than vision (Heller, 1989). Examples are judgements of quality of cloth and detection of unevenness of a surface. Also sighted people may prefer to use touch in these cases. In general, touch has not the same capacity to discriminate details as vision has. However, it should be noted that its capacity has often been underestimated when the measurements have been restricted to passive touch, that is, the sensitivity of the not-exploring skin surface, stimulated by a stationary stimulus. When the stimulus is moving sensitivity increases (Loomis and Collins, 1978; Shimizu & Wake, 1982). When touch is active, for instance when a hand is exploring an object, its sensitivity is higher than when it is passive, but it is a complex problem to understand why. Many factors are involved, such as the skin, the muscles, tendons and joints, as well as cognitive functions. However, even if touch has more capacity than is often thought, it may in some contexts be compared with blurred vision (Apkarian-Stielau & Loomis, 1975).

Three-dimensional (3D) information in tactile representations

There are tactile maps that are miniature copies of the geographical area. They depict heights by embossment to a degree related to the real heights. However, most maps are in principle two-dimensional (2D), that is, the embossment appearing in them corresponds only to the visual points, lines and surfaces without much variations in height over the background. There may be some variation in height for other reasons than depicting real heights, for instance, in order to facilitate discrimination of different kinds of symbols. Point symbols may be more embossed than line symbols, which in turn may be more embossed than areal symbols. There are also matrices of point stimuli (further described below) that allow each point to be elevated in many steps (Shimizu, 1986; Shinohara, Saida, Shimizu, Muchizuki & Sorimachi, 1992; Saida, Shinohara, Shimizu, Esaka & Shimura, 1992).

Visual pictures often depict 3D properties of, for instance, an object or the slant of a surface, by drawing in perspective. A 3D object is then reproduced as a 2D (flat) surface. A classical problem is if this way of depicting 3D objects works for tactile pictures. In other words: If you make a tactile copy of a visual 2D perspective depiction of a 3D object, can you expect that the object is experienced in 3D when the picture is explored tactually? It is not seldom said that tactile reading of such a 2D picture is an impossible task[5], but it has also been stated that perspective can be reproduced in a tactually readable form consisting of surface outlines (Heller, Calcaterra, Tyler & Burson, 1996; Heller & Kennedy, 1990; Kennedy, 1993).

Perspective information can be available not only in contours, but also in surfaces. In 2D visual pictures 3D properties, such as the slant of a surface, can be depicted by so-called texture gradients. What this is, can be explained in the following way. The texture of a real surface consists usually of a number of units of about the same size and form. If a 3D object consisting of surfaces in different orientation and such a texture is depicted in perspective the units' size, form and internal distances are reproduced in a lawful way in the 2D representation. If a real surface slants away from the observer the units within the texture that are furthest from the observer are represented by smaller units in the picture than the units that are closer to the observer. Vision registers automatically such a surface as a surface slanting in depth. Holmes, Hughes and Jansson (1998) demonstrated that the slant in such a picture can be judged correctly also in a corresponding tactile picture, and Jansson & Holmes (2003) that it should be tried to use this type of information also in tactile pictures. Continued research and practical experiences will show to what extent this kind of information is useful more generally. Potential applications for maps might be to depict, for instance, the slant of the sides of a mountain in a geographical map and the slant of a pavement in a mobility map.

Tactile map symbols

Representations of geographic environments consist to great extent of symbols. There are three main types of map symbols: point, line and areal symbols. Some of the tactile map symbols are analogue copies of symbols used in visual maps; other tactile symbols have a form specific for tactile maps. When the usefulness of tactile symbols is considered, it is important to be conscious about the insufficiency of visual examination of the symbols to be discriminated tactually. They have to be investigated tactually without assistance of vision, as symbols easy to discriminate visually may be impossible to discriminate tactually.

Some decades ago there were several experimental efforts to find symbols useful for touch. Much of these efforts intended to find sets of symbols that are easily discriminable (for instance, Nolan & Morris, 1963, 1971; Jansson, 1972, 1973 b). The results of these efforts will not be reviewed here (an overview can be found in Edman, 1992, pp. 209–233), but some problems of principal importance will be discussed.

Sometimes, the option of skipping a kind of symbols used in visual maps is utilised in tactile maps. This is often the case with colours, especially when the information they provide is not too important.[6] This option is strengthened by the fact that no analogue translation is available, as the fingers cannot perceive colours. An alternative option is to replace colours with tactile textures, but this reduces the number of available alternatives that can appear in each map, as the discriminability of tactile textures in maps is much lower than visual discrimination of colours. This is astonishing considering the great skill of tactile discrimination of textures found in many other contexts. However, as textures seem to be easier to discriminate in tactile pictures consisting of applications of different materials, it is a reasonable hypothesis that the lower discriminability in ordinary tactile pictures depends somehow on the condition that they are produced in the same material. This may mean that important properties are not sufficiently different in the common material or that this material masks the tactile properties.

Even if it is sometimes suitable to skip some property available to vision, it should be noted that this usually means that the information loses in redundancy, which is an important property in many perceptual contexts. This means that information that is represented in two ways visually, for instance in both colour and form, differs in only form tactually. The result may be that the symbols are more difficult to discriminate. That this is true concerning tactile symbols was shown by Schiff & Isikow (1966).

When considering tactile symbols, it is important to be aware also of other differences between vision and touch than those already mentioned. One example concerns the use of open and filled small forms. For vision it may be suitable to use, for instance, an outline and a filled circle as different symbols. However, in small sizes the two kinds of tactile circles are perceived similarly and easily confused. The useful information is bound to the contour while the inner parts of the two kinds of form are not discriminated (Jansson, 1972).

Another example is symbols consisting of parallel lines oriented differently (vertically, horizontally or obliquely). Symbols of this kind are easily discriminated visually but are often mixed up tactually (Berlá, 1982, pp. 370 f.).

The utilisation of specific capacities of touch

Touch is not in all respects less effective than vision. It has also specific capacities that can be used in translation from visual into tactile form. A principally interesting example is a tactual symbol based on the capacity of touch to pick up successive changes in the stimulation when a finger is moved over a surface.[7] The specific example is the tactile arrow suggested by Schiff, Kaufer & Mosak (1966). This symbol indicates direction by being a line, which is felt smooth when explored in the direction it indicates and rough when explored in the opposite direction. An extra advantage of this symbol is that it provides direction information along the whole line, not just at the endpoint(s) as most visual arrows do, thereby compensating for the difficulty of touch to get the same overview as vision.[8]

The sensibility of the fingertips for successive changes in height over background has been used also in a few other contexts. Information about the slant of a path or road can be indicated by a series of points or a surface with increasing/decreasing height (Edman, 1992, p. 276) and the same kind of information can be used for stairs (James & Gill, 1974).

Unfortunately, there seems to be no more example than those mentioned of a successful translation between vision and touch where a genuinely tactile capacity is utilised for translation between the senses.

Efforts to standardise tactile symbols

The problems of finding easily identified and discriminable tactile symbols have given rise to several suggestions of standardising such symbols. The suitability of such a measure is an often-debated issue. An early effort was made in Scandinavia by the production of a ”Nordic Atlas for the Blind” according to an agreement in 1965 (Nordiska Kartkommittén, 1966; see also Edman, 1992, pp. 233–234). In spite of its being a very ambitious effort, it was later found that some symbols were easily confused and the maps were found difficult to read.

Another effort was made in connection with a conference on tactile maps organised by the Blind Mobility Research Unit (BMRU), Nottingham University, Nottingham, England, in 1972. A background for the discussion was an article by James (1972) suggesting a standardisation of mobility maps using a set of symbols developed at the BMRU. A special kit simplifying the use of the set was also produced, The Nottingham Map Making Kit (James, 1975; see also James, 1974). During a discussion at the conference it was suggested that this set of symbols should form the basis for a standardisation of tactile symbols, and there was a vote in favour of this suggestion. However, the vote was not unanimous, and the result in practice was probably only that some of the symbols suggested came into use in a few other contexts. I myself reported that I thought that the decision was premature (Jansson, 1973 a).

At conferences in Brussels, Belgium, in 1983 and in Marburg, Germany, in 1985 attempts were made to standardise symbols for tactile town maps, and a Euro-Town-Kit was developed, mainly for tactile maps produced with vacuum-formed plastic sheets from multi-level masters. Suggested symbols based to a large extent on the two kits mentioned can be found in Edman (1992, pp. 272–296).

A set of symbols was also developed at American Printing House for the Blind (Barth, 1982) and there have been suggestions of standardised symbols within the Scandinavian countries (cf. Jansson, 1980).

The importance of taking production method into account

In addition to the problem of finding enough symbols to be uniquely used, there is the problem of there being no standardisation of production methods. Tactile symbols similar in the meaning that they can be described by the same visual picture but produced by different methods may not be perceived similarly. It is therefore not sufficient to define a symbol by describing its geometric form and other 2D properties, which may be the same in different methods, but other tactually important aspects should be added to the description. Especially, it should be observed that units such as points, lines and texture units can be elevated in many different ways over the background when different production methods are used. The cross-section of the embossment may be different for different production methods, which is often important for how they are perceived (cf. the discussion above about the sensitivity of touch for successive changes). Further, there may be unintended variations in embossment over background, which affects the efficiency of the symbol set.[9] All symbol sets have thus to be studied for each production method. This is probably the largest difficulty for the efforts to establish a general standardisation of symbols for tactile maps.

New technical development

In parallel with the traditional (real) tactile maps, such as thermoform and swellpaper maps, new kinds of equipment allowing new kinds of maps that can be read tactually are emerging. Here three kinds will be discussed: (a) matrices of tactile point stimuli, (b) haptic displays and (c) multi-modal systems.

Matrices of tactile point stimuli

Braille is based on a capacity of touch to perceive a group of points as a unit. The pattern of points consists usually of embossed points produced by a Braille printer. Braille may also be reproduced by a display of pins that can be elevated according to the Braille code. In principle, maps and other pictures can be represented in the same way by computer-driven matrices of pins that can be elevated over the background.[10]

These devices have sometimes been called tactile television, which might have produced much expectation among potential users. They are matrices of point stimuli in greater number than those intended only for braille. Two of the most well-known are the Tactile Vision Substitution System (Bach-y-Rita, 1972; Jansson, 1983 a) and the Electrophthalm (Palacz & Kurcz, 1978; Starkiewicz & Kuliszewski, 1963). An important difference between the Braille displays and these displays is that the patterns on the matrices usually represent visually continuous pattern in spite of being only patterns of points. It is not self-evident that point pattern are perceived in the same way as line patterns.[11]

Anyhow, many prototypes of this kind have been build and evaluated (cf. Kaczmarek & Bach-y-Rita, 1995). Many of them are most interesting prototypes, and it was often hoped that they should be useful in several contexts. However, a basic problem has all the time been how it would be possible to build a device with sufficient number of points to represent a complex pattern to an affordable cost. If you increase the number of points by building a large display, such as the DMD 12060 device[12], the cost is far beyond what most potential users can pay, in spite of a spatial resolution that is much lower than you would like to have. If you give priority to a high spatial resolution, you have to reduce the size of the matrix substantially and you will still get a very high cost.[13]

One way to get an affordable cost for a device with a matrix of point stimuli is to make the display relatively small with a relatively low number of stimuli but allow it to move over a larger area. The total picture is then explored successively one part at a time. An early prototype to a display of this kind was built by Sueda (1976), but the most well-known, and until recently commercially available, device is the Optacon[14]. In its last version (Optacon II) it presents a (usually changing) pattern within a matrix of 100 vibrators. Normally the pattern is governed by a miniature camera moved by the user over a 2D surface containing the information, but it can also be governed by a computer-stored virtual map which is successively presented when the display is moved with its path registered. A computer file determines what points in the matrix should be raised when the display passing the different locations.[15]

A computer mouse, the *VirTouch Mouse*, is based on the same concept as the Optacon and presents matrices of altogether 96 pins to three fingers (Gouzman, Karasin & Braunstein, 1999; information also at http://www.virtouch.co.il).[16] Combined with a computer this device allows exploration of virtual maps and other pictures. That a picture is virtual means that there is no real picture but the information is digitally stored and is made available via a computer. Its usefulness has not yet been investigated in independent studies, but it would be interesting to find out to what extent it might be suitable for the presentation of tactile maps.

Haptic displays

In one meaning all ways of presenting tactile pictures and maps can be called haptic displays. However, this term has often been reserved for a kind of newly developed displays, sometimes also called force feedback displays. As the latter term indicates, these displays give the user feedback in the form of resistance to movement in a way similar to the resistance produced by real objects. They can allow the reader to move his/her hand over an invisible map, and the device makes a similar resistance to the movements of a hand as a real map would have given. These displays are technically more complicated than real maps and a computer with adequate software is required, but in some respects they simplify the task of producing the map. There is no need for embossment in paper or plastic, and the map is easily modified, for instance, by deleting or adding information or by zooming in to some part of it. The most important of these devices, the PHANToM, will be described (a more complete review can be found in Burdea, 1996).

The PHANToM

This is the only of the new technical devices mentioned so far that is capable to represent 3D-properties directly in full scale. The VirTouch Mouse and other computer mice can only do it in the form of a small elevation over the 2D background and otherwise indirectly in 2D via perspective form and texture gradients. The PHANToM is a robot making resistance in 3D in a way similar to the resistance made by real objects. An interesting feature for reading maps is that it is possible to present an exploration path, for instance corresponding to a route for travelling, to which the user is ”magnetically” drawn. The PHANToM as an aid for visually impaired people has been evaluated in several respects (Jansson, 1999 a, 2000 a, 2001 a, 2001 b, 2001 c; Jansson et al., 1999; Sjöström, 2002).[17]

One important aspect is what practice in the use of it can mean for the usefulness of the device. It has been shown that practice can result in dramatic improvement of performance (Jansson & Ivås, 2001). As concerning all new devices much evaluation work has to be done, before the usefulness of this display for the reading of tactile maps can be judged more fully. One of the aspects that is not yet demonstrated sufficiently is how complex maps and 3D objects can be read with the help of the PHANToM (cf. Jansson, 2002; Jansson & Larsson, 2002).

Multi-modal systems

The usefulness of adding exploration instructions in figure captions was mentioned above. A related method is presentation of information simultaneously to more than one sense, thus to offer multi-modal information. Such information to sighted computer users is undergoing a fast-growing development (see, e.g., Cohen et al., 1999; Oviatt, 1999). In the latter reference, Oviatt suggested that the advantage of using multi-modal interaction is not primarily enhanced speed, but rather a decrease in task-critical errors, as well as the flexibility of kind of interaction. It is reasonable to assume that this reasoning is applicable also to visually impaired people’s interaction with a computer in order to get map information.

Co-ordination of tactile and auditory/verbal information

A direct relation between verbal and pictorial information can be obtained when a tactile map is placed upon a touch tablet connected to a computer. Verbal, or any kind of auditory, information is obtained when positions on the map are pressed by an exploring finger. Pioneering work of such a co-ordination of auditory and tactile presentation was developed by Parkes (1988) with the NOMAD device. Other efforts are the interactive auditory learning tool TACTISON (Burger, Mazurier, Cesarano & Sagot, 1993) and the dialogue system AUDIO-TOUCH (Lötzsch, 1995). The usefulness of a device of this kind for blind children's understanding of the environment was suggested by Spencer, Morsley, Ungar, Pike and Blades (1992). An increased efficiency by using such a presentation of map information to two senses simultaneously can be expected intuitively and has also been experimentally demonstrated (Holmes, Michel & Raab, 1995; Holmes & Jansson, 1997; Holmes, Jansson & Jansson, 1996; and Holmes, Jansson & Olsson, 1996). A larger such device, a ”Talking Kiosk”, has been installed at a railway station (Kelly & Schwartz, 1999).

Within the project TACIS a new computer-based device has been developed which can produce a tactile picture/map embossed in paper, as well as auditory information. The picture/map is placed on a specially made touch pad allowing speech and other sounds to be combined with the tactile information (http://www.audiodata.de/e/projekte/index.html). The equipment exists in prototype form, and the possibilities of getting a product are studied. No reports of its educational potentials have been published.

It should be noted that also the other new technical displays rendering virtual maps can be enhanced by adding speech and other sounds (cf. Fänger, 1999, and Sjöström, 2002).

Maps used in Electronic Orientation Aids (EOAs)

The use of tactile maps in connection with an electronic system for indoor guidance of visually impaired people was suggested by Preiser (1985).

Two EOAs are based on digital maps: *the MoBIC Travel Aid* (MoBIC Consortium, 1997; Jansson, 2000 b) and the aids *Atlas Speaks* and *Strider*, originally developed by Arkenstone and further developed by the Sendero Group (Fruchterman, 1996; LaPierre, 1998; http://www.SenderoGroup.com). Both EOAs have two separate functions, planning before travel and guidance during travel.

When using the EOAs the geographical data necessary for planning are provided by digital maps read with the aid of a computer. The software can suggest a suitable route for travelling between a start and a goal, and a user can practice the route by travelling along the virtual route. In the present devices moving is accomplished by pressing cursor keys on the keyboard and getting information about the route in synthetic speech. The reason for not utilising a real tactile map is mainly economic, as that would necessitate an extra piece of equipment and work for producing the tactile map. However, studies have demonstrated that combining verbal and tactile information via a touch tablet is advantageous for the understanding of map information (Holmes & Jansson, 1997).

During travelling with EOAs tactile maps do not seem to be used very much, maybe because of attention being concentrated on the electronic device (Bringhammar, Jansson & Douglas, 1997; Jansson, 1999 b). However, when the traveller is not using an advanced aid tactile maps can be very useful also during travelling (Armstrong, 1978; James & Swain, 1975; Leonard & Newman, 1970).

Understanding of geographical information

The usefulness of encounters with the area to be mapped

A map is a representation of a geographical area, which may not be intuitively understood by a novice reader. It cannot just be put in the hands of a reader and be expected to function well without instruction. Training in reading tactile maps is important (Berlá, 1982). One way to promote understanding is to let new readers start with moving around in the area to be mapped and then work with models of the objects to be represented in it. Yngström (1988) developed such a program for training visually impaired children in the use of tactile maps, and Hinton (1996, pp. 20–22, 51–53) developed a related program. Educational material for teaching tactile maps to visually impaired children is also commercially available: Maps Represent Real Places: Map Study I and II (http://www.aph.org/mapstudy.htm). That a tactile map can be meaningfully related to the real world also by a 4-year-old congenitally blind child was demonstrated by Landau (1986).

Combination of direct encounter with an area and use of a tactile map

Visually impaired people often get acquainted with a new environment by being guided by another person; some may be brave enough to explore a new environment on their own. Such direct experience has been suggested as the most effective method (Lindberg & Gärling, 1983). However, it has been found that examining a tactile map considerably facilitated the performance of totally blind children in large-scale environments (Ungar, Blades, Spencer & Morsley, 1994; Ungar et al., 1998). Espinosa & Ochaíta (1998)[18] found that the participants' spatial understanding was better in a condition where they used a tactile map when directly experiencing a route than in conditions where they had either direct experience alone or verbal description together with direct experience. These authors concluded that a reason for the advantage of combining direct experience and tactile map reading is that the combination overcomes limitations of each of the two methods used alone, the map providing better possibilities for memory and attention and the direct experience better exact position and orientation information. The result that verbal description was not as good as tactile map information as supplement to direct experience was interpreted to depend on problems for the participants to attend to the verbal instruction simultaneously as they attended to information from the environment.

Cognitive representation of geographical information

A common view of maps is that they are representations of the geographical environment decreased in scale and with a selection of features. Cartographers have, for many different purposes, chosen features to represent, and readers extract the specific information they want from the content of the map. This means that cartographers are not only interested in how effectively a map can be perceived, but also in how readers work with the information presented. This includes problems of how needs and previous knowledge of the readers interact with the information in the maps (MacEachren, 1995, pp. 1–16).

A term often used in this context is *mental* or *cognitive map*. Tolman (1948) introduced the term cognitive map when he discussed how rats can utilise experience from learning to *walk* through a maze when they have to *swim* through the same maze. Since then these terms have been defined in many different ways and used in several contexts (Downs & Stea, 1973; Kitchin, 1994). According to Kitchin, a cognitive map has been said (1) to be like, (2) to be used as, or (3) to be used as though it were a cartographic map. It has also been suggested that it is a hypothetical construct, that is, something that is assumed to be there but the existence of which cannot be directly proved.[19] The necessity of including a cognitive map in theories of mobility without sight was stressed by Strelow (1985).

If you accept the concept cognitive map, a distinction between vector maps and network maps is suitable (Byrne, 1979, 1982; Byrne & Salter, 1983). A *vector map* is rather similar to a geographical map by providing a bird's-eye view of an area. It contains features, their locations relative to each other, and distances between them. A *network map* is more similar to a labyrinth map describing a route from one point to another with ”strings of nodes each … potentially a choice point” (Byrne & Salter, p. 298). The two kinds of cognitive maps may be seen as complementary. It seems probable that many cognitive maps with information about geographical areas, such as a country map that is not meant to guide the user along any specific route, have the character of vector maps. Cognitive maps used for guidance of travelling may more often be network maps. This is at least the case for visually impaired people (Hollyfield, 1987).

A related question is if an indoor tactile map for the guidance of new visitors should present the physical structure of the environment or mimic the path of travel through the route. Holmes & Arditi (1996) found that performance was better with the former kind of map.

Visual and tactual imagery

Sighted people have visual images. They can ”see” with their ”inner eye”. A delicate question is what kind of imagery is available for visually impaired people. Visually impaired people often use the same vocabulary when describing their imagery but their words may relate to other experiences than sighted people's words. Arditi, Holtzman & Kosslyn (1988) found that visually impaired people tend to describe imagined objects within arms' reach. A classical problem is if there is any innate spatial frame of reference in which the experiences are ordered, or if all our imagery has to build on individual perceptual experience. Discussion of blind children's imagery can be found in Warren (1984). What it means to perceive space for a congenitally blind person was analysed by Guarniero (1977). Ungar, Blades & Spencer (1996 b) discussed the construction of cognitive maps of visually impaired children.

Most research on imagery has been devoted to visual imagery. Also a recent overview (Richardson, 1999) mentions non-visual imagery only in passing. However, a comprehensive discussion of theory and empirical evidence about blind children's understanding and representing 3D space was provided by Millar (1994).

Imagery used by visually impaired people is complicated by their large differences in visual experience. However, it is safe to assume that the imagery varies quite a lot between people, important parameters being amount and kind of visual impairment, as well as length of time of their having been visually impaired. Two extreme groups are congenitally blind people who lack visual experience totally and late blind people who have had visual experience for many years. A practical conclusion is the suitability of trying to consider for each visually impaired person expected to read a map what imagery might be available for him/her (more discussion can be found in, for instance, Heller, 1991).

Suggestions for further research and development

On the basis of the results of research and development of relevance for tactile maps so far I would like to make some suggestions for further efforts.

Use of computers for adding, deleting and ”distorting” information

The transformation of geographical information from a visual or digital map to tactile form is a laborious task, which at present much reduces the availability of maps to be read tactually. A start has been made in using GIS maps as a basis also for these maps. Layers of information from maps in digital form can be deleted automatically or by a computer user. Michel’s (1999) studies can be a starting point for efforts to make more general use of computers in the choice of information to include, as well as his method of ”distorting” information in a meaningful way.

Organisation for collecting and storing the special information useful for visually impaired map-readers

To collect the special information that is so important for successful guidance of visually impaired travellers is an enormous task. Ideally a person with knowledge about the needs of visually impaired people should visit the area to be mapped and make notes about what should be added. This is probably done in many cases, but to do it in a larger scale requires formidable amounts of work. It can only be done piecemeal and it must be a long-term undertaking. However, it would be worth trying to get an organisation collecting the information in digital form and making it available to all interested people. As conditions are different in different countries the organisation should probably be national. In some countries there is a tradition of contributions of volunteers; maybe this can be introduced in other countries. Some courses for people accepting this task would be suitable.

An important complication is that much of the information for mobility map is perishable and needs updating. In order always to be really useful for safe travel, changes in the geographical environment, for instance, new streets, pavements, street crossing, road-work and so on, should be immediately recorded in the GIS file, but this is, of course, impracticable.

What is said above is applicable to mobility maps. The situation for geographical map is much easier, as the differences in the information needed for sighted and visually impaired map-readers are smaller, as discussed above, and the rate of changes is lower.

Pool of tactile map symbols

Standardisation of symbols for tactile maps is a controversial issue and no suggested standardisation has been generally accepted.[20] Jansson (1987) concluded that the most reasonable solution to the standardisation problem would be to build up a pool of symbols found useful in different contexts. In this pool the description of each symbol should not only contain the general form of the symbol, but also a detailed account of other tactually important physical properties, such as height and cross-section of points and lines included. Production method used should also be reported.

A producer could use such a pool to get suggestions about useful symbols. However, if another production methods is used the symbols as part of the new context have to be tried out with the different production method used. The meaning of the symbol when used in each specific context should be explained in a key. This is common also for visual symbols.

Some organisation for collecting, storing and conveying the information about the symbols should be considered. It may very well be international.[21] The task of the organisation would be to collect descriptions of sets of symbols and to make them available via the web, possibly also by sending embossed copies.

Preparations for the use of new technology

It is important not to be too easily impressed by technical inventions as aids for the visually impaired. It is instructive to consider that the most useful travel aids is still the long cane invented more than half a century ago. Tactile maps are much older (Eriksson, 1998), and there are many similarities between the older maps and many of those used today. Old technology should not be turned down straight off.

However, it is evident that there are problems with the kinds of map dominating now, and it is therefore wise to investigate if versions available with new technology can make geographical information more accessible to visually impaired people. There may be reason to use old and new technology in parallel.

For sighted people, many versions of maps are available, including maps via the web that can be read on the screen or printed on paper. The same should be made available for the visually impaired. The new haptic displays with matrices of point stimuli and force feedback offer a possible solution to this problem. The investigations so far indicate that they may be useful, but to what extent this is true is still an open question. More research on this is needed, concerning both old and new kinds of maps. The usefulness of this new technology would be considerably greater if the activities just mentioned concerning availability of methods to modify digital maps were also developed. These efforts would be promoted by an increased co-operation between technicians, researchers, potential users and persons working with visually impaired people's rehabilitation.

The preparations should also include multi-modal presentation of map information, both presentations of NOMAD type and via computer-driven haptic displays.

Teaching of effective reading of tactile maps

For efficient reading of visual maps guidance is often necessary, especially for not very experienced readers. The same is still more important for tactile maps. It has been suggested that teaching strategies for learning from tactile maps would improve memorising them (Ungar, Blades & Spencer, 1995), and that strategies have importance for blind children's performance in locating themselves on a tactile map (Ungar, Blades & Spencer, 1996 a). Ungar, Blades & Spencer (1997) demonstrated that visually impaired children can learn to make judgements of distances from tactile maps after suitable training. More knowledge about these functions would be useful.

Final words

In a survey carried out via telephone interviews in Uppsala, Sweden, Runnsjö (1975, personal communication) found that only 40 % of 118 visually impaired interviewees had ever explored a tactile map. A pioneer in promoting tactile graphics (Schiff in Schiff & Foulke, 1982) concluded, after having organised a conference and edited a book on tactile graphics, that ”In spite of the usefulness of tangible graphics, they appear to be significantly underutilized” (p. 450). I do not know of more recent figures, but it may be that the situation is not too much better today, a few decades later. In spite of figures like these, I am convinced that there is a large potential in tactile pictures, including maps, especially if we manage to make them user-friendlier and provide effective training to the map readers (cf. Jansson, 1994).

Notes

[1] A Swedish translation and adaptation to a Swedish context of this review has been published (James & Armstrong, 1977).

[2] Verbal route descriptions have been found useful also as an evaluation tool for aids providing map information (Bringhammar, Holmes & Jansson, 1996).

[3] That a picture or map is virtual means that there is no real picture or map, but the information is stored digitally and is available with the help of a computer.

[4] File format is the way information is stored.

[5] Also recent (1997) guidelines for the design of tactile graphics suggest that 3D figures should be avoided: ”Replace 3-dimensional figures with cross-sections or front-side-top views whenever possible” (http://www.aph.org/guides.htm).

[6] However, for visually impaired readers with colour perception at least partially functioning colours can be very useful.

[7] This is related to its capacity to pick up information about texture gradients mentioned earlier.

[8] That this symbol has not been used extensively may depend on its being difficult/impossible to produce with some map-making procedures. Originally, it was produced with a special wheel moved over an aluminium foil used as master for thermoform copies.

[9] For instance, the height of the relief is difficult to control with the common swellpaper method.

[10] Devices of this kind can also be called ”refreshable devices for tactile graphics” (Hinton, 1993). The pins can be elevated only or vibrate at the same time as they are elevated. Instead of pins the matrix can consist of electrodes where the points in the pattern provide a weak electric current.

[11] Vanderheiden (1994) found in an evaluation of such a matrix that all participants had much better performance with a stable raised line drawing.

[12] The Dot Matrix Display (DMD) was developed by the firm Metec, Stuttgart, Germany. It has 7200 pins with a 3 mm inter-pin distance (cf. Schweikhardt, undated). To my knowledge, only three devices have been built so far, probably because of the high cost.

[13] J. Craig & K. Johnson has built a matrix consisting of 400 points with an inter-pin distance of .4 mm that gives a total matrix area of 8 × 8 mm (personal communication, December, 1991).

[14] The Optacon was originally developed by Telesensory Systems, Mountain View, CA, USA. The reason for the discontinuation of producing the Optacon was not that it was not useful, but that there appeared another technical solution for making printed text available to visually impaired people in an easier way: synthetic speech of scanned text.

[15] An especially made equipment of this kind has also been developed in another context (Jansson, 1998).

[16] The most recent version is called VTPlayer and has 32 pins distributed in two 4 × 4 matrices.

[17] A more complex haptic display intended for manual exploration of works of art is under construction (Jansson, Bergamasco & Frisoli, 2003).

[18] Cf. the related paper Espinosa, Ungar, Ochaíta, Blades & Spencer, 1998.

[19] In the context of perceptual guidance of mobility it has also been suggested that there is no need of the concept cognitive map, but that the guidance can be explained in an alternative way (cf. Jansson, 2002 b, pp. 365–366).

[20] It is interesting to note that there is no general standardisation of symbols for visual maps either (MacEachren, 1995, pp. 2–3).

[21] One possible channel for international exchange might be the home page of INTACT, organized by the Commission on Maps and Graphics for Blind and Visually Impaired People (http://www.lgu.ac.uk/psychology/ungar/intact/).

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