Visual Navigation with Schematic Maps

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Abstract. A prototypical example of the operational dimensions of visual information communication is the use of schematic maps for visual navigation. The implementation of maps on location-sensitive or handheld devices has changed the preliminaries of common mapping techniques. By an analysis of selected examples, both historic and current, we want to open up the space for innovative map design options. Our approach blends art history and computer science, and is based on a systematic, operational perspective. It may be unexpected, though, that it starts from the way that graphic design supports imaginative navigation on the map, rather than considering its utility for navigation in the physical space directly.

1 Introduction

Navigation is a pervasive task, so that navigational information and instructions exist in audible, visual, tactile, or even multi-modal form. The most common tool to explore navigational opportunities systematically is the visual map. A map communicates comprehensive information about places and relations between them. It is a generic navigation aid if a-priori undetermined origins, destinations and paths connecting them can be singled out on demand. We are particularly interested in this process of instantiation, by which a user turns a map into an aid for a specific navigational task. With the goal to better understand the functioning of visual maps as navigation aids, we start from the proposition that the actual spatial navigation *with* maps is complemented by an imaginative navigation *on* them. This idea is not foreign to the vast literature on maps, see for example [1], [3], [7], [8], and [16], but the argument has not been elaborated systematically, yet. Our assumptions imply that users actually explore, experience, and validate navigational information by duplication: on the map and in space. Not only is a map design more intuitive and convincing if derived from first principles, but it is also easier to evaluate, because such principles suggest hypotheses that can be tested in user studies.

1.1 Dynamic Maps on Mobile Devices

Map layouts are often schematic in that physical reality is reduced to match a specific concept, which also emphasizes that "Design, however, is choice" [21, p. 191]. Since all maps are in essence conceptual [9], [17, p. 5], in an extreme

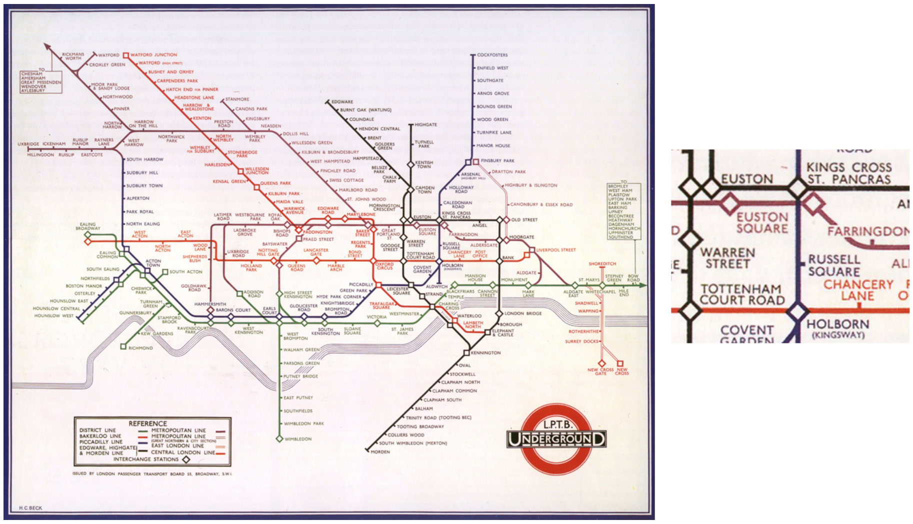

Fig. 1. The London Tube Map by Harry Beck, 1931.

view all map layouts are schematic. We ponder on this view because of the vast design space it implies. By reducing the content of the map its layout can be arranged so that the focused information is easier to read.

Static paper maps are restricted to a single layout. To remain useful for various use cases they are oftentimes generalized. The implementation of maps on mobile devices has changed this preconditions of the medium. Now, the map animation opens up new possibilities of tuning level-of-detail and schematization interactively. A user can interact with the map and thereby can adapt the layout on demand to support a certain use case. That way the map can be temporarily specialized to fit a specific situation and orientational configuration.

On paper maps finding an index remains in the hands of the user. To find his current position and facing direction a paper map has to be folded out and turned. A location-sensitive device can assist the search process by adapting the map dynamically. The device always keeps the map centered at the user's current position. Additionally the map might be rotated triggered by a change of the user's alignment. Also other layout parameters can be changed interactively. The user may want to change the level of detail or resolution, or select a different layout, etc. To apply these changes a digital map producer can take the time axis as an additional display dimension. Along this time axis several changes can be animated by: zooming, panning, information filtering, tuning level-of-detail or other transformations of the map layout.

Though mobile devices offer more possibilities for map visualization on the one hand, they cause some new demands in respect to their medium and use case scenario on the other. The main disadvantage of mobile devices is their small display size. To overcome this disadvantage is one task of current map visualization techniques [5].

1.2 An Operational Perspective

We focus on the process in which a user turns the map into an aid for a specific navigational task. Possible starting points, destinations, and routes have to be singled out. Schematic maps support these operations by reducing the world to an operational concept and by clearly visualizing its relations. Typical relations for operations are for example temporal or spatial distances or possible travel connections. Maps that depict the same places but visualize other relation types often also differ in scale, level-of-detail, or similar parameters.

To formulate these conceptual differences we break down the use of maps into different operational steps, or actions. Analyzing maps, we observed design options that address three basic aspects: to situate, to orient, and to navigate.

to situate
The act of situating identifies spatial relations as operational opportunities for a person who holds respective abilities and might be interested in using them. For example, looking at the London tube map on Fig. 1 (even while sitting far away at Sydney's Harbour Bay), travelling with London transport is imagined.

to orient
For the act of orienting, we imagine someone to be at a concrete position and identify the relations between his position and other places on the map: what is in the surroundings? What distances or connections to other places are there? This person can also be imagined with a facing direction. On the London tube map, for example, someone could be positioned at King's Cross, and lines are identified that are connected and aligned towards a neighboring station or towards one end of a line.

to navigate
The act of navigating is changing an orientational configuration iteratively, i.e. operational opportunities and conditions to reach a destination are identified. In the process of planning several operations are selected and combined to one route. For example, for navigating from King's Cross to Tottenham Court Road it can be deduced from the tube map that one has to change at Holborn.

The modular concepts are developed for looking on a flat map space. Sometimes the operations on the map can be linked to operations in real space. We call this *operational index*. Operations planned on the map are linked to operations and movements of our own body. Therefore we need to connect our perspective upon the flat map with our perspective to the real world [12]. Doing this we become users of the map. The gained spatial knowledge can be transferred in both directions: Either operations can be planned ahead in map space and then be transferred to real-world movement or real-world movements can be transferred to the respective operations on the map. For navigation on the go it is always important to keep all operations synchronized.

Some of our historic examples only sharpen one operational aspect. Though their layouts are convincing in displaying a certain information they are too specific to be actually useful for the whole process of navigation on the go. For that reason modern static maps for navigation usually incorporate all operational aspects at once. But as we stated in Sect. 1.1 maps implemented on a mobile device can instantiate more than one layout, so that different operational aspects can be adressed temporarily. Thus, we claim that dynamic map design can still learn from the historic mappers' know-how. Applying our modular perspective to maps on mobile devices we aim to reuse some strong schematic map layout ideas.

2 Operating on Maps by Example

The following examples, both historic and current, are selected and analyzed as design options that support the introduced aspects of operating with maps: situating, orienting, and navigating. We choose schematic maps that emphasize single aspects. In Sect. 3 we reflect how the observed design options can be recombined and animated innovatively.

2.1 Situating

Situating with maps on location-sensitive mobile devices Fig. 2 shows a map (here googlemaps[1]) implemented on a location-sensitive mobile device. Situating with a location sensitive device is a shared process, partly achieved by the user who chooses a certain kind of map, and partly achieved by the device that detects the user's current position and environment. A mobile device using AGPS identifies the user's approximate current environment and orientation by its approximate position within the cellular network and by interpretating GPS signals. Map tiles representing the current environment are downloaded and displayed. If the GPS signal fails, localization can only rely on the approximate positioning within the cellular network. Then the user's current approximate surroundings are encircled by a disconnected blue crosshair on the map. Within the circle the user's potential whereabouts and operational opportunities are represented.

The resulting map concentrates on a certain kind of spatial relation, here geographic distances. The map is adjusted to display areas that are assumed to be of the user's interest. That way the user is assisted in situating. If the exact position can be determined by GPS signals, this position is visualized by a dark blue dot on the map. Thus, the user would even be assisted in orienting.

[1] `maps.google.com`

Fig. 2. Googlemaps on iPhone

There are computer implemented maps that additionally enable the user to adjust the map himself to improve its usability for a certain situation. He can filter out specific details or mark specific points of interest. The user can even share such an annotated maps with others.

Golden Seal of Louis IV In Europe, 700 years ago, only an emperor could realize and distribute a map that represented places according to his interests.

Fig. 3 shows a midget map on the golden seal of the bavarian king Louis IV. It was made in 1328 AD, the year the king was crowned in Rome as Roman emperor against the pope's opposition. The seal has a circular shape similar to the blue rimmed circle on the google map. The circular form of the seal invites to understand the represented area as a specific situation. Anyone who is familiar with the city of Rome will recognize buildings that define the city as town of the roman emperors: the Colosseum, the Capitol, the Pantheon, an emperor column and a triumphal arch. The buildings are represented by small images, shown in perspective. Their positions within the town are defined by the city wall and the Tiber river. A point of view is created, that overlooks the selected buildings.

The recto of the seal shows Louis IV on his throne. The combination reflects the political claim to reign in succession of the Roman emperors. We argue that the emperor is depicted on both sides of the seal: On its recto side in effigy, on its verso side as the person who peers implicitely at the city of Rome and gives it the meaning of the imperial city. In fact at the end of the ritual of coronation the emperor left the town and climbed the Monte Mario. From there he looked

Fig. 3. Golden Seal of Louis IV, Staatsarchiv Bamberg, Brandenburg-Bayreuth Urkunde 142

back on the town lying to his feet [22]. With this final view the emperor took possession of Rome visually and tried to recapitulate places of his coronation way. In reality it was hard to carry out this task because the viewing point on the Monte Mario is too low and the symbolic places of interest are too distant. In contrast the midget map on the seal shows the situating of the emperor as a perfect visual scheme. It is even possible to imagine his ritual way through Rome: from St. Peter, where he was crowned, over a bridge, then up the stairs to the entrance of the senatorial palace. There he presented himself as the emperor to the people of Rome. From there he walked to the Porta Flaminia, represented at the bottom left of the seal, that leads to the Monte Mario outside the walls.

No matter who looks at the seal, the person who has to be situated on the map, is the emperor. The two sides of the seal – that is the map and the emperor who has to be situated on it – stand for a circular justification of power. Today companies like google and others suggest that we all may become little emperors, who can create their own maps. By doing so, the users should be aware that the companies can collect their personality profiles too. Collecting profile information from personalized maps is somehow similar to our interpretation of the golden seal as the emperor's crowning situation.

2.2 Orienting

Map of the Surroundings of Nuremberg The map of the surroundings of Nuremberg (Fig. 4) is one of the oldest printed maps in Germany [20], [6], [18] (1492 AD). It is famous as one of the first true to scale regional maps that was extracted from travel experience, written itineraries, and some additional measurements. As a common feature of systematical map layouts distances and directions can also be deduced that have not been set explicitly.

Nuremberg was the hometown of Erhard Etzlaub and Georg Glockendon who were maker and printer of the woodcut. Similar to the previous examples a circle is a prominent feature of the map. It surrounds potential points of interest around Nuremberg. The center of the circular map is marked by the city arms of Nuremberg. This central sign can be compared to the point "my place" on modern maps. Within the circle over a hundred names of towns are spelled out. Single letters encode additional information concerning the political state of a town, as "r" stands for “Reichsstadt” (ger. imperial town), or "b" for “Bischofsstadt” (ger. episcopal town). Rivers and their sources are represented by a straight line. Political borders are marked with a dotted line. The circle is enclosed by a rectangular frame. The cardinal directions are inscribed at the borders of the frame, "mittemtag" (ger. noon, south) is represented at the top of the map. Etzlaub may have derived this convention from the sundials he also produced.

The graphical entries are positioned on the map according to their true to scale distances. The scale bar and an explanation how to use it are printed at the bottom of the map. The radius of the circle scales to 16 german miles (ca. 120 km). By measuring the distance between dots on the map one can calculate the distance between the towns in real space. As the scale bar represents only 20 german miles, measurements through the whole diameter are not directly supported. But the bar is sufficient to translate distances between Nuremberg, as preselected center of orientation, and any other town. Thus, typical questions of orientation can be answered in relation to Nuremberg: how far is it from Nuremberg to town X? In which direction is town Y located?

It may be surprising, though, that neither streets are shown, nor bridges or other possibilities to pass the rivers. It is evident that the map was not intended to be used on the road for navigational tasks but rather to be studied in libraries or to be used for the documentation of places. As an indication the represented copy, colored by hand, was preserved by Hartmann Schedel, who included the map in his own copy of his "Weltchronik". The originally intended user of the map was the political establishment of Nuremberg. Certainly they were proud to show a map that represented their town as the prominent center of orientation within its surroundings.

Halos The historic examples arranged their circular layout around a given center of orientation. As we stated above, maps implemented on mobile devices can be dynamized. This offers the possibilty to dynamically adjust maps to the user's current orientational configuration.

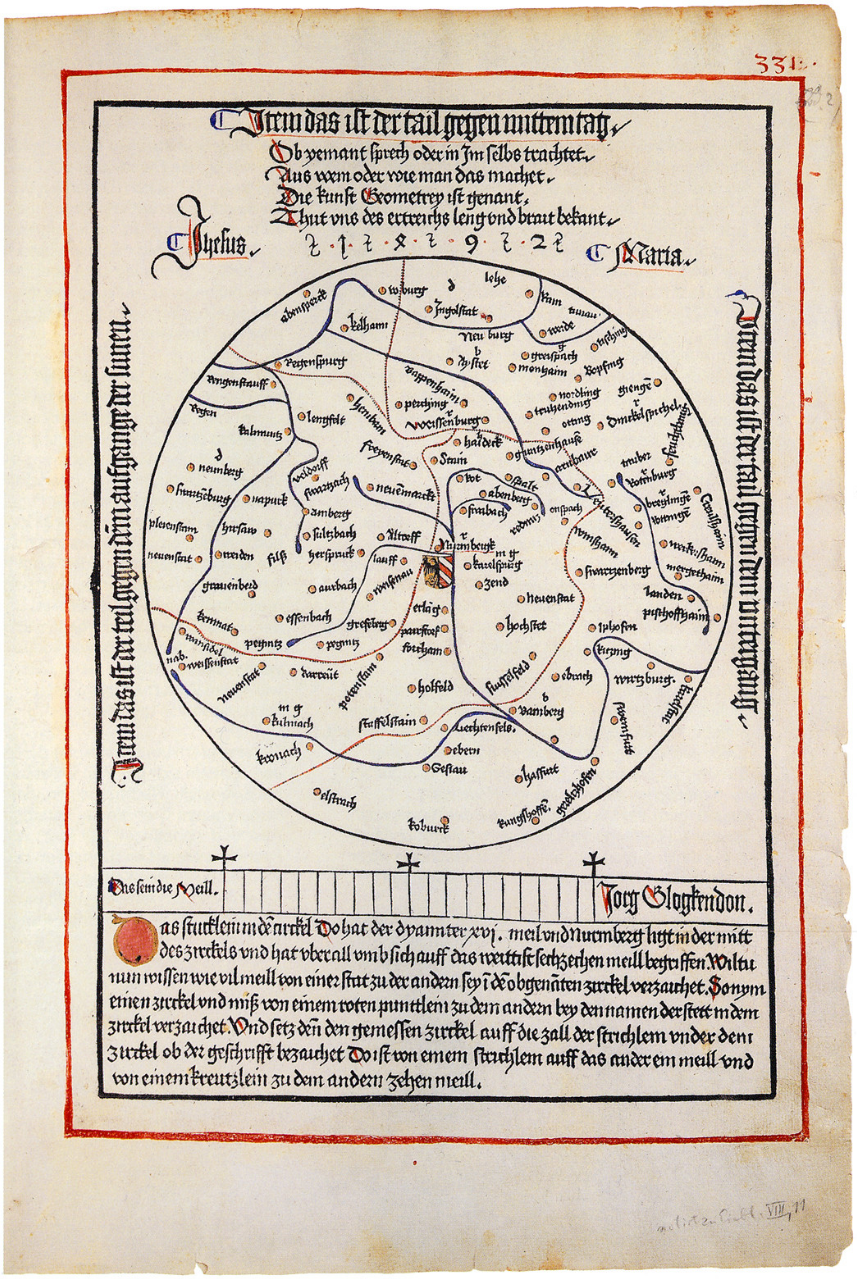

Fig. 4. Surroundings of Nuremberg (*Nürnberger Umgebungskarte*), Erhard Etzlaub, 29,7 x 27,3 cm, 1492, copy of Munich, Bayerische Staatsbibliothek, Rar 287, fol. 331r

Fig. 5. Halos, Baudisch et al. [2]

A typical orientational practice is to read out the direction and distance relations to certain points of interest. Favourably, these points of interests are displayed on the map. As the display of a mobile device is very small, some points of interest in the user's surroundings might not fit into the display. Unless the user pans or zooms to make them appear, he cannot read out any distances or directions towards off-screen destinations.

Halos, a focus and context technique developed by Baudisch and Rosenholtz [2], aim to overcome this disadvantage of maps on mobile devices (see Fig. 5). Here, an imaginary isoline circle is drawn around potential destinations (point of interest) that are located off-screen. These circles are dynamically resized until they extend to the border of the display. When changing location the map is updated in order to keep centering the current location and the radius of every circle is adjusted. Though only small segments of the circles are visible, the user is still able to anticipate the distances between his current location and his respective points of interest. The arc length of each circle segment is contingent on the distance to its respective point of interest.

Halos emphasize distances and directions to the user's points of interest. Their orientational configuration and possible destinations are visualized and dynamically adjusted whenever the user position changes. But since points of interest located further away are more noticeably visualized than places located closer, this visualization technique might confuse the user. User studies should be accomplished to evaluate this method.

Travel Time Maps Another example for maps on which the relations are calibrated on one point of orientation are travel time maps. A travel time map

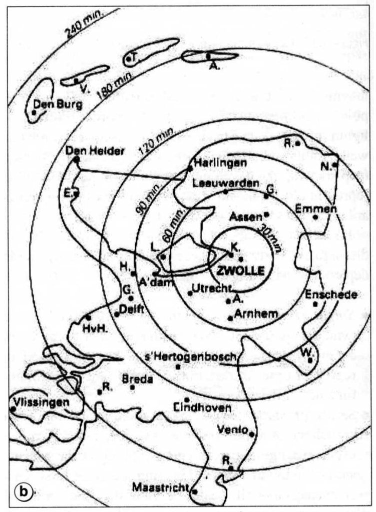

Fig. 6. Travel time map, Goedvolk [13]

visualizes temporal distances from one place to several possible travel destinations, for example if travelling by public transportation.

Fig. 6 shows a travel time map or cartogram of the author Goedvolk (1988) [13]. This map is centered on the town Zwolle (Netherlands) and visualizes temporal distances to certain travel destinations within the Netherlands. The map visualizes only one temporal distance between Zwolle and each of the travel destinations, i.e. the destination points are positioned on the map according to their shortest travel time distance starting at Zwolle. As an alternative layout the map layout could consist of a graph, in which Zwolle and all destinations would be visualized as nodes and travel time distances would be visualized as edges. Goedvolk chooses an area map to still display the whole Netherlands. He therefore distorts the coastlines and boundaries in respect to the time positions of the travel destinations. That way the map provides approximate temporal orientation to all places even if they are not marked on the map.

This results in a map that we would use if we were located in Zwolle and would want to orient ouselves in respect to our time-dependent travel opportunities. We might then align ourselves to one of the possible travel destinations. But for navigating on the go, we would want to take a different map at hand.

Circular Prospect of Nuremberg As another examples for retaining the principle of preselecting a center of orientation for all operations on the map Fig. 7 shows a circular prospect of Nuremberg. It is a large map, a woodcut with a square frame, commissioned at the end of the 16th century by the town of Nuremberg [20, p. 223]. It shows the surroundings of Nuremberg in an artificial circular prospect. There are earlier examples of such layouts from Vienna and

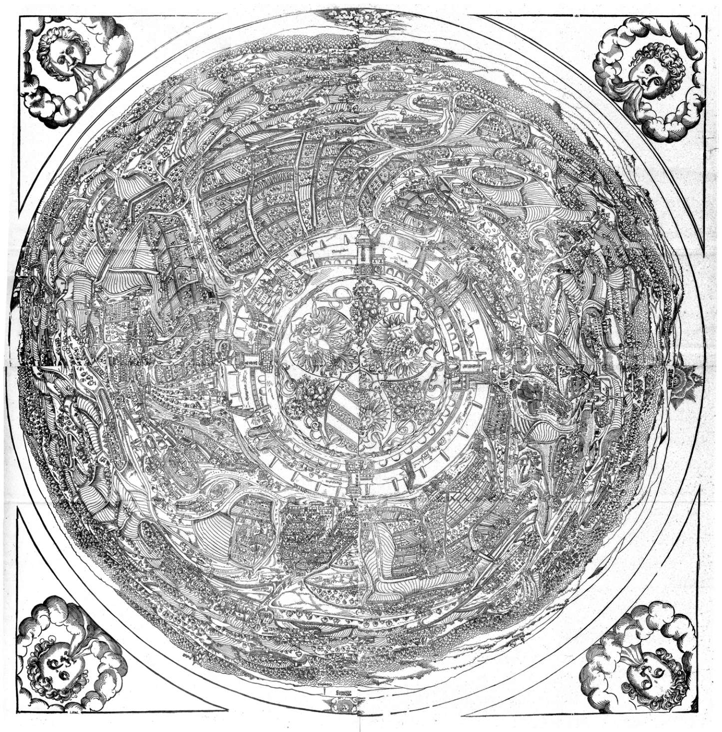

Fig. 7. Circular prospect of Nuremberg (Rundprospekt Nürnberg), Stefan Gansöder and Paulus Reinhart, 95,5 x 96,0, 1577-81, Staatsarchiv Nuremberg, Reichsstadt Nürnberg, Karten und Pläne Nr. 202

elsewhere. At the center of the map the municipal area of Nuremberg is represented only as a trefoil of wappons within an idealized circle. The wappons are two city arms and the national emblem of the German Empire. Besides the town walls that surround the municipal area and that serve for orientation no streets and buildings are shown. Cardinal points such as gates, towers, the entrance and exit of the river Pegnitz are represented and labeled. The map helps everyone who is familiar with the town to orientate himself in the surroundings.

The surroundings are represented by pictorial means: images of buildings, streets and hills, forests, rivers and fields (see Fig. 8). There are humans and animals inserted to give a vivid impression of possible uses of space. So, all these elements are stimuli to imaginative operations on the map. For a better orientation many places and streets are named. Cardinal directions are marked at the border of the horizon. At the edges personifications of the cardinal winds are placed, already known from the circular route maps.

The map explicates the concept of view-and-horizon or detail-in-context that also underlies all the other circular maps. Every image and letter is oriented towards the center, so everything seems to be viewed from the central town.

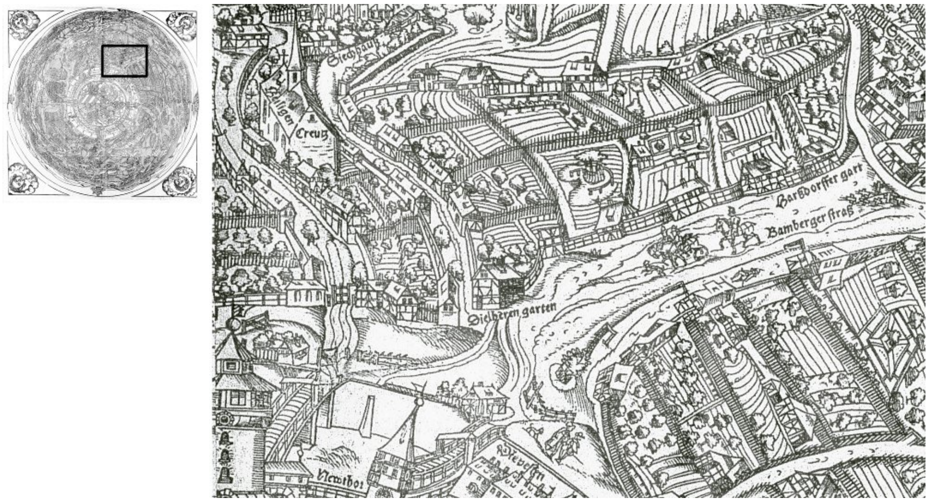

Fig. 8. Circular prospect of Nuremberg (Rundprospekt Nürnberg), cutout enlarged.

The artificial projection causes some distortions. Nevertheless, the map is useful not only for orientation but also for planning navigation. The user can grasp a lot of visual information for linking navigation on the map with navigation in real space. Crucial points for navigation as crossings, bridges or the skirts of a forest are depicted. But the ways trail away in the hills or the forests towards the horizon. So the perspective of the map is only useful for navigation within the immediate surroundings of the central town.

There are even current layouts that apply similar detail-in-context techniques. E.g., the variable-scale map layout of the authors Harrie, Sarjakoski and Lehto [10], that comprises different scales and levels of detail.

2.3 Navigating

Navigation Systems Without the use of a car navigation system the planning of the route and the interacting with the map had to be achieved by the user. Now common navigation systems are able to plan routes and display adequate maps. The navigation device interprets GPS signals and respectively pans, rotates and scales the map to always focus the driver's current surroundings.

Fig. 9 shows the display of a Falk navigation system on which the position and driving direction is indicated by a blue line and a small red triangle at the bottom. The displayed section of the map is in a bird's eye view that augments the driver's view through the windscreen. In addition, the further route is charted into the map, and arrows mark the points where navigational instructions have to be followed. That way navigation systems animate a map to display a sequence of navigational instructions. Once the user has started the navigation system he selects a destination. After that, there is actually no need for the user to be

Fig. 9. Display of a Falk navigation system.

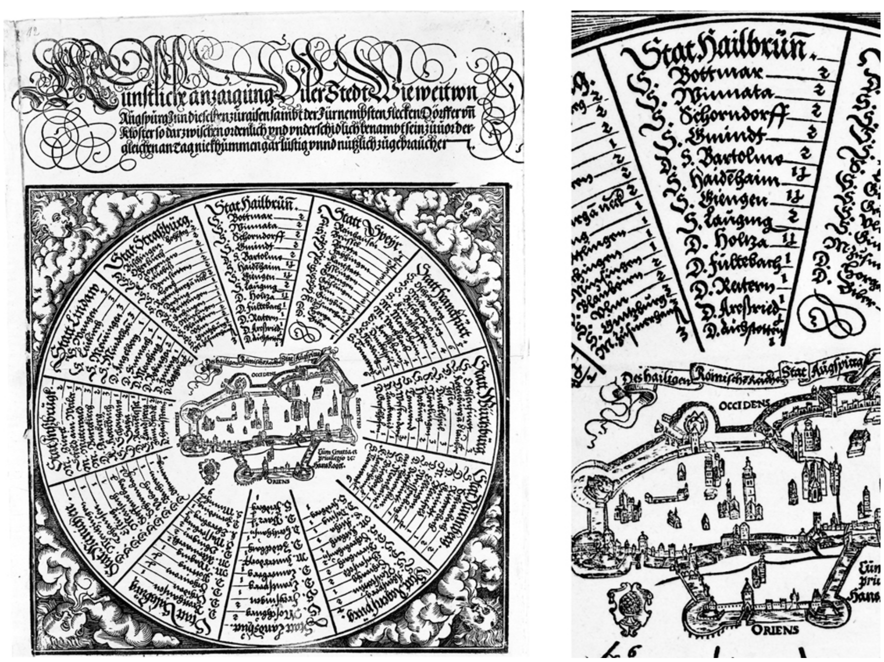

Fig. 10. Circular route map of Augsburg (Augsburger Meilenscheibe), Hans Rogel, 38,2 x 29,7 cm, 1565, copy of Augsburg, Maximilianmuseum, gr. 32

oriented in space all the time, as the navigation system tells him where he is and where to go next. If the driver is not following all instructions, the navigation system will recalculate the route and will adapt the displayed map accordingly. Thus, the system concurrently provides the user with navigational information towards his preselected destination.

Itinerary Maps Route maps that reduce space to a preselected path between starting point and destination have a long tradition. There are historical examples that display single itineraries in a list layout. They list the names of the route's stations and sometimes state the distances between them. The following example is a circular route map from the 17th century that integrates different itineraries into a single map. This way the user can choose between several destinations. There are more than 12 different disks known, that came up between 1650 and 1750 AD. Most of the exemplars were made in Nuremberg or Augsburg. One other example centers Erfurt.

Such a circular route map was designed as a concentric arrangements of several itineraries. They center one station as origin and display itineraries that emanate from there to alternative destinations. Until now they are only object of research to the history of roads, but are not regarded as cartographical invention [14], [15], and [20]. The starting point in the center is highlightened by an iconic element: in most cases it is a view over the focused town. The first Augsburg disk places a small map of Augsburg in the center that is derived from the 1550 AD edition of Sebastian Münsters "cosmographia universalis" (see Fig. 10). The circle is divided in 12 to 24 segments, and 10 to 30 concentric rings. Each segment contains a written itinerary that is represented along a ray emanating from the center. All itinerary stations are positioned in sequential order. The most distant destinations are written (furthest away from the center) at the border of the disk. These towns were well-known centres of trade like Strassburg, Frankfurt or Heilbronn. The layout aligns all items towards the center. Useful navigational information is displayed only along the rays emanating from the center, not on the concentric rings.

In the case of the circular route map the choice of a specific itinerary implies a concrete operation: the user selects a route by turning the accordant ray upward. The radial layout supports this operation. Along the rays the user can read the sequence of stations with their respective distances in both directions. He also gets information concerning the main orientation of the route: the names of cardinal directions are written at the center or at the border of the disk, and often are combined with personifications.

Other than the Halos or the circles of the travel time map, the radius neither represents exact distances nor the duration of journey, but rather the sequential order of the station within its route. But in other respects the Halo technique can be understood as the dynamic inversion of a static circular route map. The Halo circles are drawn around the points of interest and their radius is dynamically adapted due to movement.

The midget map of Augsburg, that is placed in the center of our example, helps to determine directions in relation to the main buildings and main gates of the town. But other than that such route maps often withheld any further details for local orientation. So in order to use such a map for navigation on the go one would have needed to complement it with other ressources of knowledge that provide more detailed information for the orientation at each station towards its respective subsequent station. Nevertheless we assert that the list feature of itineraries gets a new relevance for navigation instructions in car navigation system.

3 Applied Recombination of Operational Aspects

By analyzing current and historic map examples we described the impact layout can have on operations with maps. We observed that the step of situating may be supported by pictorial elements, a certain point of view, and information filtering. Circular layouts are appropriate to guide orientation from a given starting point. Preplanned navigational routes are best represented as clearly arranged sequences of selected stations. We will now introduce use these insights to introduce new approaches to map design. Their underlying operational concepts recombine the three observed operational aspects and design options innovatively.

3.1 Dynamic Detail-in-Context List for Navigation

A map on a common navigation system is concurrently updated triggered by a change of position and orientation (see Fig. 9). By looking at the display the driver can read out birds-eye view details about his local environment and can gain some additional route information.

But we claim that what is considered relevant information should differ dependently on the operational stage the user is currently in. On the one side, during navigation the user arrives at points where he needs to perform a navigational instruction. Then he needs to orient himself within his local environment, because the instruction has to be performed at the correct position and with the correct alignment in space. In that case the user needs a more detailed map about the local environment. On the other side, while only following one and the same street being oriented within his local environment is not as important. Only the sequential position within the route or distance to the next navigational instruction would rather be of the driver's interest. But a map would be of advantage that is showing orientational information about the local environment of the next navigational instruction. That way the driver could mentally prepare this step in advance.

On a navigation systems it is no problem to alternate layouts that either emphasize orientation within the route or orientation within a local environment. Inspired by historic itineraries (see Fig. 4) we propose to display a dynamic list layout that takes the differing requirements into account. A drawing of a circular googlemaps cutout[2] representing the surroundings of a navigational instruction is displayed in Fig. 11. In order to align all local cutouts in driving direction from bottom to top, just as most navigation systems do, we propose to connect the cutouts by Bezier curves. The hybrid connected list of map cutouts is then to be animated, so that the user's position is always centered on the display. According to the user's position either the schematic line passes the center, whenever following a street, or a local cutout surrounds the center, whenever the user needs to follow a navigation instruction. For orientation within the route a small true to scale map of the route should be provided in one corner of the display. On that the driver's position is concurrently marked.

3.2 Warping Zoom

Although a generalized map is capable of serving various situations, it might not always be the best choice for each separate situation. If a user only needs to consider a single situation he could more easily gain relevant information from a specialized map, since its layout and content is adjusted to fit the specific situational needs best. Consequently, such a map is useful in a smaller diversity of situations. For a combined navigation task a change of situations (i.e. navigational spaces) is required. So, for performing such a combined navigation task one would usually take two specialized maps at hand. When the user arrives at a situation his specialized map at hand does not support, he replaces it with a respective other one. After the user has exchanged maps, he has to find his orientational configuration within the new layout again.

For example beholding the case, in which we need to accomplish walking on the streets together with using a public transportation network. We have to

[2] maps.google.com

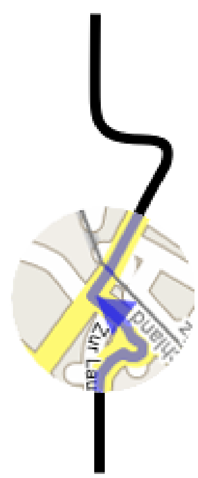

Fig. 11. Draft for a dynamic detail-in-context list for navigation

come to navigation decisions concerning the street level and the transportation net. We would take a schematic map of the transportation net and a common city plan at hand. However, there are even some ideas to overcome the necessity of two seperate maps for this task. One approach is a so-called Spider Map[3,4]. Here, a city plan cutout around a specific station is integrated in a schematic transportation map. But the original schematic transportation net layout has to be adjusted in a way that the cutout fits in. So these maps only provide street-

[3] sfcityscape.com/maps/spider.html

[4] tfl.gov.uk/tfl/gettingaround/maps/buses

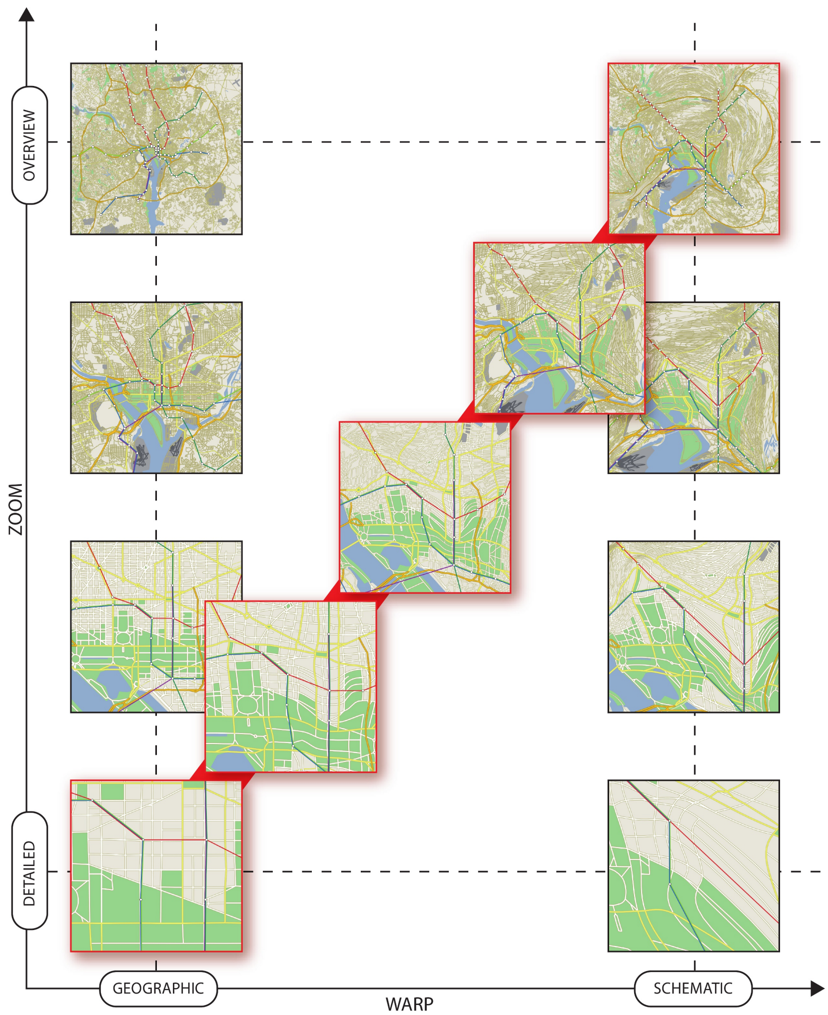

Fig. 12. Warping Zoom, Boettger et al. [4]

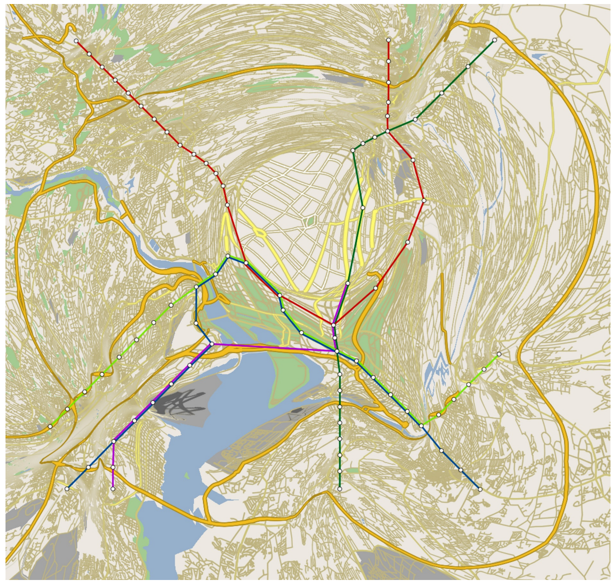

Fig. 13. Fisheye lens, Boettger et al. [4]

level details for a single station. Maps still need to be swapped whenever the surroundings of another station are of interest.

Another approach is to combine the different map layouts into one dynamic interactive map. This way the information of both maps can be maintained. The generation of a compound map by warping techniques is discussed by Reilly and Inkpen [19] and Boettger, Brandes, Deussen and Ziezold [4]. Basically, Reilly et al. use raster-graphics based maps. Their map distortion demonstrates that two optimized layouts can be morphed into each other. They additionally couple their warping animation with fading the respective other map. This simple morphing application aids index finding.

Boettger et al. use vector data and keep the operational information that was relevant in the previous situation as context information for the other respective layout. Furthermore, they account for other situational requirements, as there is a need to change level-of-detail and enlargement scale. The layout of the compound map of Boettger et al. is smoothly adjusted to facilitate the reading of the currently relevant information and to preserve the user's orientational index and embedding. This technique is called warping zoom.

Concretely, if we want to reach a nearby metro station by walking, we cover short distances and thus we only need street-level information of our current surroundings. But when arriving at a metro station, we can suddenly cover longer distances within range of the whole metro network. This sudden switch of situations is considered by the warping zoom technique. Switching from walking to riding metro trains, we zoom out and simultaneously warp the map layout to a schematic overview map of the metro network. Switching from riding metro trains to walking we zoom in and simultaneously warp back to the geographical layout of street level information (see Fig. 12 or the authors' demo video[5]). If the situation of the user can be determined by the device, the warping zoom could also be controlled automatically. For example, location sensitive devices can derive the user's current location and travel speed from GPS signals. As these parameters can serve as an indication of the user's current situation, the map can be zoomed and warped to the respective layout.

Boettger et al. suggest a second technique for the integration of two differing layouts into one map. Inspired by the circular prospect of Nuremberg (see Fig. 7 and 8) and by modern fisheye techniques [11] they implement a fisheye lens. This lens dynamically unwarps a circular area within the warped compound map layout (see Fig. 13). While under the lens street level information is easier to read, outside the lens the map is adapted to give an overview of metro network connections. Thus, if the user is in pedestrian situation he is provided with street level details in metro network context. If he is in the situation of a metro network user he can read out the network details in street level context.

4 Summary

Starting from the proposition that map navigation is understood best when also considering the imaginative act of navigating on the map, we discussed several design options that support the basic operational dimensions (situating, orienting, and navigating) in various ways.

We analyzed both current and historic maps to inform map designs that address complex and specific operations. We then formulated an innovative perspective on how to reactivate the ideas of historical maps. Our examples demonstrate how historical map features can provide design options for keyframe layouts in map animation. We thereby aim to motivate further map design variations.

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