INDOORTUBES

A NOVEL DESIGN FOR INDOOR MAPS

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ABSTRACT:

Efforts within cartography on indoor maps have previously not received a lot of attention. Work that has been carried out on indoor maps often focus on map design very similar to an architectural style (Klippel et al. 2006, Ciavarella and Paternò 2004). In some cases the design has been of a more novel character where approaches with augmented and virtual realities have been carried out (Radoczky 2007, Müller et al. 2006). Common to these approaches is the depiction of one floor per map. As well, the primary user task is often solely personal navigation. In this article we present an innovative approach to indoor maps. The design is directly inspired by underground tube maps first developed by Harry Beck (Garland 1994) and today a common design for public transport maps. The main advantages of the map design are its simplicity and the possibility of including all floors in one map view. This allows the map user to easier comprehend the structure of the building without using several maps, as commonly needed with today’s indoor map designs. We present several different map styles each intended to satisfy different user groups and tasks depending on the user’s familiarity with the environment. In addition we motivate for new application areas suitable for indoor maps, especially large hospitals. We hypothesize that the design proposed in this article leans very well to displaying real-time dynamic geospatial information, such as patients, staff, equipment and room availability within hospitals. Due to the early phase of the work presented here we outline the needed further work and possibilities of technological platforms as well as evaluations necessary in order for the design to gain acceptance and success.

KEYWORDS: Indoortubes, indoor maps, indoor cartography, cartography

BACKGROUND

In cartography much effort has been put into the study and analysis of the human perception of maps. This result in guidelines and different map styles which inherits different qualities suitable for different purposes, ranging from abstract maps to close to real life 3-dimensional augmented realities. Similar to mostly all of these efforts is the focus of the depiction of outdoor environments.

Maps focusing on indoor environments, such as large buildings, rarely receive attention in the cartographic community. Indoor maps are commonly used for emergency and evacuation maps. Typically found in corridors in large and public buildings. The standard style of these maps is very close to architectural maps used for construction, where one floor is depicted from above in a 2-dimensional fashion. The cartography generally receives little attention. Typically the orientation is not egocentric and the level of detail is very high resulting in a visual clutter and problems of finding the nearest exit fast.

Earlier work has addressed the cartography in emergency maps to some degree. Klippel et al. (2006) propose a set of general guidelines for "you-are-here-maps" (YAH maps). The guidelines are of a general kind and are suitable for evaluating the quality of already existing "you-are-here" maps. However, the guidelines are not directly applicable for other purpose indoor maps, or for the design of new maps. Additionally the architectural style of the maps seems to be accepted without discussion of alternative visual representations.

Radoczky (2007) discusses several visual representation methods for indoor maps and their different qualities. The traditional architectural style maps, named floor plans, are argued to be one of the better suited representation methods for indoor environments. However, 3-dimensional representation, such as virtual environments, is argued to be the best; although, the technological capabilities for this were not ready at the time of the writing (Radoczky 2007). The technological situation is different today, especially for mobile devices with medium sized high-resolution screens and enough computational power capable of displaying 3-dimensional virtual realities. However, it is not certain that virtual realities are good for all purposes in indoor environments. Virtual realities are often made to resemble the reality as close as possible. One of the strengths of traditional outdoor maps is the ability to get fast overview over large areas due to abstract representation of the environment. Virtual realities do not exhibit this kind of abstract representation and gaining fast overview will inevitably be harder for the user. This argues for the development of new visual representation methods for indoor maps.

Some prototypes using indoor maps have been made and tested out for different purposes in indoor environments. Müller et al. (2006) presents a mobile indoor navigation system. The system interacts with large printed floor plan maps positioned at important locations within the building. Thus, the mobile system never displays the map itself, but augments the path on top of an image of the printed map. This can be said to be an early variant of augmented reality. The cartography is not discussed thoroughly, and as mentioned a standard floor plan map is used as map style. Issues of orientation, overview and not least navigation across floors will inevitably occur.

Ciavarella and Paternò (2004) present a similar mobile system intended as a museum guide. The system reacts to the location of the user and displays information and a map of the current location. The map design is an architectural style floor map in two different variants, one detailed and one intended for overview. From a user evaluation the authors found that egocentric maps are preferred, as well the users gave feedback that the map design should be changed.

The earlier work briefly presented here indicates that the chosen map style for indoor maps are often basic floor plans. We argue that this map style is not the best at depicting user friendly indoor maps. Specifically mentioned are issues of easy perception of several floors, overview of one or several floors, level of detail, and the general perception of these kinds of maps.

Technological capabilities have increased tremendously since the early prototypes discussed here were implemented. Off-the-shelf mobile devices are now capable of storing and computing large amount of data as well as containing high-resolution screens. This argues for the study and development of new innovations focusing on indoor cartography and maps suitable for new usage scenarios.

APPLICATION AREAS

Earlier work has primarily focused on indoor maps for personal navigation (Klippel et al 2006, Radoczky 2007, Müller et al. 2006, Ciavarella and Paternò). Mobile systems with small screens, low resolution and computational capabilities have been a preferred technological platform. As mentioned earlier, the map style for these systems has not been discussed nor have alternatives been properly suggested. We strongly believe that the application area of indoor maps spans wider than solely personal navigation. With the technological capabilities of today several of the issues of the previous mentioned prototypes are now solved. In addition, users of modern mobile systems are now requiring real-time location and user specific information with high degree of interactivity. This suggests that the traditional approach of floor plans with route information does not meet the requirements of today, nor do they fulfil the potential of today's technology.

A technological issue that is of concern is the lack of proper and implemented indoor positioning systems. We hypothesize that the demand for more precise positioning systems indoors will increase in near future. Users are increasingly used to location aware systems for mobile platforms in outdoor environments. As the users, as well as the systems, become more adapt to integrating location as part of their experience the demand for using the systems indoor will occur. This will demand more accurate systems than today’s approaches can provide. Several attempts on this have been made earlier. The most successful and promising technologies seems to be the use of WiFi (Moen and Jelle 2007, Schrooyen et al. 2006, Fry and Lenert 2005, Muñoz et al. 2003), ultrasound (Mautz 2009) and the new Galileo system (Yang et al. 2007). Based on this we believe that indoor positioning will be available in the near future.

Although indoor positioning is not currently available apart from specific laboratory settings, we strongly believe that the work on cartography for indoor maps should be in advance and ready to meet the technological advances. This will inevitably make the acceptance and implementation of scientifically funded results easier when indoor positioning is mature and implemented. Additionally, indoor maps can successfully exist without the need for indoor positioning, as proven by today’s emergency maps.

There are several intriguing application areas for indoor maps. One of these is large hospitals. Large hospitals are complex buildings with a highly dynamic environment. A large number of patients, staff and equipment need to be coordinated and scheduled in order to make the process as fluid as possible. In addition, the different rooms have different facilities and schedules, such as operating rooms, emergency rooms and similar. Scheduling and planning in advance is often not feasible due to the rapid changing nature of a hospital. This is especially visible in emergency situations where for instance scheduled surgeries are postponed in favour of more emergent surgeries. This makes coordination work highly demanding. The location of all involved actors, equipment and rooms is believed to be an enabling factor supporting the coordination work (Marjamaa et al. 2006). For coordination workers, the location is especially important in order to get awareness and overview of the current situation. Situational awareness for non-coordinators is also believed to be enabling for the self-coordination of the regular staff at hospitals (Fry and Lenert 2005).

Traditional outdoor maps have proven to be highly successful at coordination and overview over large and complex environments. However, indoor environments open new issues with potentially very high information density and especially the added complexity of multiple floors. The latter adds a new dimension to the environment with the need to visually represent discreet floors in the third dimension.

In addition to the complexity of the environment, indoor maps for hospitals are faced with the issue of dealing with a large variety in potential users. There is a high probability that the regular staff is known to the geography and knows where the rooms and equipment is, or should be, situated. Patients and visitors on the other hand are unknown to the geography and should not have access to certain information, such as patient sensitive information. Indoor maps needs to not only visually represent the environment, but also consider the different user groups found in the environment.

Several usage scenarios can be elicited in the context of large hospitals. The following exemplifies two such scenarios, where the first exemplifies a situation where a map system is in place and the second illustrates a situation where such map system could be suitable. Both scenarios are artificial although based on real life experience and findings from health care researchers and workers.

Scenario 1: *John, a coordinator at the operating ward is in charge of coordinating and synchronizing the patients and the involved workers. The operating ward spans across 3 floors. John's office is located in the second floor. There are typically 20 patients assigned to the ward at any given time. A standard patients flow through the ward is; preparation, anaesthesia, surgery,* *post-operative. These activities are located at different rooms and different floors. Several different workers are involved in the patients flow, ranging from nurses to specialist surgeons. Several of them are not necessarily located or informed properly of their duties at any given time. John needs to make sure that everyone, including the patient, is coordinated at any given time. In order to get real time situational awareness and an overview of the operating ward, John frequently looks at the indoor real-time map (figure 1). The map shows all floors, the different workers as well as the patients. Before the map was implemented John used significantly more time paging and calling almost all the involved workers. John even admits that earlier he did not know where the patients were at several occasions.*

In this first scenario the map user is one single person. The person is highly familiar with the environment and has thorough understanding of the dynamic work situation he is monitoring and coordinating. Typical for his work is to not receive enough information explicitly and he must thus make his own investigations either by telephone or similar or physically go to the location in which he expects to get the information. A map system like indicated in the scenario would not necessarily be a primary tool for the worker but intended to primarily support his already existing routines and tools. It is natural to foresee that the map is displayed on separate standard size monitor (19-26”) and be used for “at a glance” usage. This means that the necessary interactivity is very limited. In addition the cartography should be very simple and intuitive allowing for near instant perception of the information. Since the user is familiar with the geographic environment the most prominent information in the map should be the real time information. This could be workers/patients location as well as their status/state. The background map should be visually dampened and include all relevant floors in one view to minimize the needed user interaction. Figure 1 is one example of such map which will be described further in later sections.

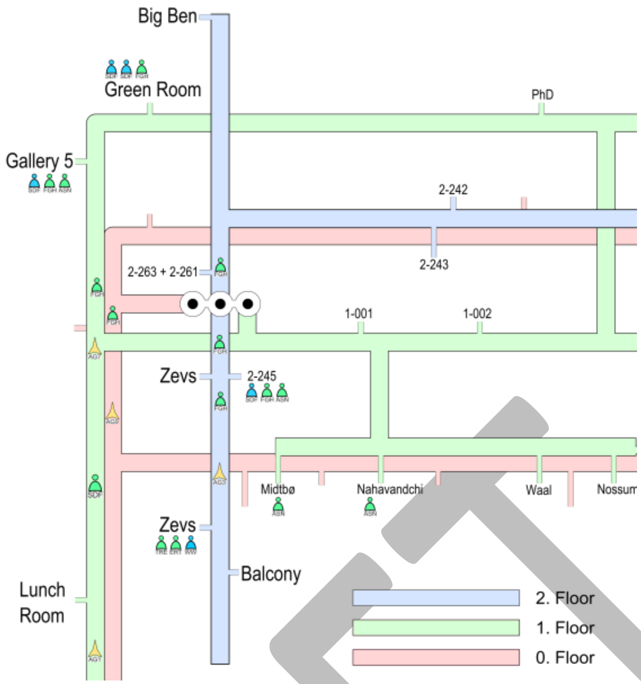

FIGURE 1: Indoor tube map with real time information overlaid. †

Scenario 2: *The post-operative section of the operating ward is waiting for patient J.D. The patient should have arrived from surgery 2 hours ago. Several of the workers have tried calling the coordinator as well as directly to the scheduled operating room. The coordinator has not received information about the surgery's process and is too busy to physically go and look. After one hour more of waiting it becomes clear that the surgery was cancelled due to an incoming emergency. The workers involved in the scheduled surgery were never present at the operating ward at all. Several of the workers are frustrated that they could have done something else if they only had known that the operating room was empty, the workers were not there and the patient still in preparation.*

The second scenario illustrates a need for easy situational awareness with emphasis on location information. Due to a lack of information transparency within the different co-workers as well as the different sections of the hospital the workers end up being sub-efficient. Implementing a map system capable of displaying easily what the overall situation is could minimize the confusion and

† Figures available at http://geomatikk.ntnu.no/projects/indoortubes

make the workers more efficient but maybe more important, make them more satisfied. In this context it is natural to foresee the map as an addition to the already successful whiteboards found in hospitals. Whiteboards have been successfully used in hospitals to provide situational awareness to the workers (Bardram and Bossen 2005, Bossen 2002). Adding an explicit and real time overview map of the situation to the traditional whiteboards could provide better tools for the workers to gain situational awareness as well as making correct decisions. Such map system could be implemented in large screens (>40”) and could also include interaction capabilities. Due to the large screen size individual workers could interact with a subset of the screen while coordinators or other “top-level” workers could interact with the larger map. In such a map the cartography should be very simple. The most prominent usage would probably be “at a glance” usage from users highly familiar with the environment. Taking this into account the map should require minimal interactivity to display the most needed information. From a cartographic perspective this is very similar to the first scenario – although with the differences of larger screen and potential individual interaction capabilities.

There are several other application areas that could benefit from an improved indoor map system. We would like to mention a few briefly to further explore the possibilities of indoor map systems.

Airports are often very large buildings covering large areas. Most of the users of airports want to minimize their time spent in the airports. As a consequence of this there is often little time to waste on getting the correct information and navigating to the correct places in the correct order. In order to get on a flight a traveller typically goes to several steps; check-in, baggage drop, passport and security check and boarding. All of these steps are often located on different positions in the airport and several of them have access restriction on them, for instance the area beyond security check is often very complicated to leave from. Information that guides the traveller through these steps is essential to avoid confusion and properly support the fluency of the steps. In addition travellers could be informed on what the different areas consisted of and provide information to plan ahead. Some examples are: “is there a way to get food inside the security area?”, “If I take this shuttle train – is it possible to get back? And what is on the other side?”, “I found my gate number at the screens, but where is E44? Can I walk there or do I need to take the shuttle train?” An indoor map system could answer these questions and additionally provide the user with a spatial orientation. We hypothesize that with this added spatial dimension would make the user more comfortable navigating and planning his journey inside the airport especially when time is limited.

Universities and large office buildings share more similarities with hospitals than airports. However the people using these buildings are not necessarily working as a large team. Universities have two distinct user groups; students and staff. Both share several similarities but are also different. Students typically are more eager for non-work situations such as; “where are my friends? Are they available for coffee or near the coffee shop?” However, students and staff are also interested in similar things such as: “Is meeting room R54 available now?”, “Where is the nearest meeting room available at 14:00-16:00 every day?”, “Where is room R65?” A social dimension is also of interest for staff with examples such as: “Is NN in his office now – and is he available?”

An indoor map supporting these user questions should be simple but also have the ability to overlay specific and real time information on demand. In addition the spatial dimensions should be very intuitive and easy to perceive. Traditional indoor maps fail at this with one map for each floor and a lot of excess information. This requires a lot of efforts from the user both in terms of cognitive load as well as interaction with the map. We suggest that the solution outlined in this article could better aid these types of non-critical real time maps.

A slightly different application area for indoor map systems is shopping environments. Large warehouses with several departments covering several floors are a common shopping environment for several brands. IKEA is one such example. IKEA has more or less standardized the design of their warehouses. The design of them is that the customer is guided through a path that is covering all sections of the store. Of course there are several "shortcuts" that allows the regular customer to quickly navigate to specific locations. The typical customer will follow the path and walk through the complete store. However, the level of frustration can be increasing due to this "endless" walking. In addition the customer can "miss" several items on the shopping list due to lack of knowledge of their location. A dynamic indoor map system could be designed for mobile devices to support the shopping experience better. The map system could provide the user with tools such as; "overview of sections", "fastest route covering all items on list", "spatial ordering of shopping list". In addition to this, and of interest to the store could be features such as spatial advertisement in combination with user profiles. User profiles could be built from items on shopping list, but also more sophisticated profiling such as the history of the users journey in the store. For instance if the user spends a significant amount of time near two similar types of sofas the system could recommend a third, give more information on the sofas and even give a "bargain price" to the customer. The advertisements could be included in the map making them more "natural" than regular advertisements.

The cartography for a warehouse map system would be fairly similar to the already mentioned application areas. However the map user and the incorporated advertisement/detailed information would be of high priority to the cartographic design. Simple and intuitive map design as well as a high degree of interaction would be essential for the success of such map system. The constraints of mobile devices affects the design but most importantly also requires good interaction possibilities. It is hypothesized that the core design proposed in this article would suit the kind of indoor map described here very well due to its simplistic design.

In the above we have presented several slightly different potential application areas for indoor map systems. The application areas are distinctly different. However there are several similarities among them. One prominent similarity is the added dimension of floors that do not exist as an issue in traditional outdoor cartography. We hypothesize that the floor dimension is a crucial aspect to the design of indoor maps. In addition we do believe that for indoor maps the topology is more important than the geometry in a similar way as for metro maps. Although we do also believe that the geometry plays a more important role for indoor maps than for metro maps. This means that the geometry can be deviated from slightly for the sake of aesthetics, however only to a certain threshold. These beliefs are taken into account when designing the proposed indoor maps later described.

The application areas described above illustrates well the differences in the map users. Both the type of users but also the tasks vary enormously. These map design should consider and reflect both of these differences. The users familiarity with the environment range from unknown to very well known. The user tasks can range from navigating from a to b, getting an overview of the building to looking up detailed information in the map. Users' familiarity will affect their use of the map. The map design should be easy to perceive this could suggest that the design should be closer to reality or closer to how users perceive the building and make a mental model of it.

In the different application areas we have suggested potential display devices ranging from small mobile devices to large wall mounted displays. This will inevitably affect the potential level of detail and the resolution of the map. In addition the type of device will also set constraints on the possible interaction capabilities. On the other hand, a map system should not only consider the possible interaction capabilities, but should emphasize more the needed interactivity. The needed, or optimal, degree of interactivity will largely depend on the task in question, the users' familiarity with the device as well as the needed interactivity due to screen size and viewing distance. We can foresee three different interactivity groups that could be suitable to distinguish between:

1. No interactivity: The map is view only
2. Little interactivity: Ability to manipulate the viewport (pan/zoom)
3. Full interactivity: Ability to manipulate viewport as well as rotating, looking up detailed information, step-by-step navigation, route manipulation, adding information to the map and similar.

We believe the proposed map design is able to include and support well not only the different application areas but also support the different levels of interactivity well. In the following we will look more detailed into the map design both conceptually but also relate the design to the potential application areas and reflect on the possibilities of interactivity and devices.

INDOOR TUBE MAPS

Harry Beck introduced a new way of portraying the London metro system in the 1930's. The most revolutionary aspect of Beck's tube map was the negligence of the geographic accuracy (Garland 1994). The topological ordering of the stations was however retained. This allowed for more freedom in the visual positioning of the stations and lines to make the map more visually pleasing and easier to perceive. Earlier tube maps were geographically correct making the lines and stations visually cluttered and seemingly unordered (Garland 1994). In addition to the visual layout of the lines the tube map consists of large amounts of information, as there are a lot of stations, each with a name, and a lot of overlapping and parallel lines, either physical or non-physical.

The map style developed by Beck was inspired by electrical diagrams. These kinds of diagrams are visually pleasing to look at due to their regularity. The bends of the curves are important in achieving this regularity. They are only bent at certain angles, a part from straight, where 45 and 60 degrees is the most common. Colour and texture is used to differentiate between the different lines. Stations occur in primarily three different fashions; small stations, large stations and connecting stations. Small stations are represented using a marker orthogonal to the line. Larger and connecting stations are represented using circles which are connected for connecting stations. In modern tube maps station names are included as text adjacent to the station. Combined this makes the information density quite high – especially when considering that there are several overlapping lines with potentially different stops.

The issues faced by mapping the metro system are similar challenges faced by mapping indoor environments. Rooms occur as both minor and major, such as private offices, meeting rooms and similar. All rooms are connected by corridors or other walking areas. Corridors are overlapping across floors, and each floor is connected through elevators and stairs. Combined this makes the information density similarly high, if not higher than a metro system. As mentioned earlier, for several of the envisaged usage scenarios the topological accuracy is hypothesized to be of greater importance than the geometrical accuracy. Although the users will probably not tolerate a large distortion in the geometrical accuracy due to the benefits of orientation and distance perception during, for instance, navigation.

Inspired by the similarities identified above, we propose a new map style for indoor maps; indoor tube maps. Indoor tube maps are directly inspired by modern maps for underground metro systems. The maps commonly used for portraying indoor environments are floor plans. Floor plans are typically extracted from the buildings blueprints where one map covers one floor. In addition floor plans typically include a lot of information clearly related to the architectural users of the map and not the users of the building. In the new design we simplify the traditional floor plan greatly by extracting only the absolutely necessary elements of the floor. We believe this to be the corridors and other "transfer" areas. Figure 2 illustrates the idea of extracting the corridors of three different floor plans and overlaying them. The results of the simplification are lines for each floor, very similar to metro lines in metro maps. These new floor maps are so graphically simple that they can easily be overlaid on top of each other. However, there will in most cases be conflict situations where one line covers another. This can be resolved by adjusting the line graphically since we expect the user to find the topology more supporting than the geometrical accuracy. However, the previously statements on the degree of distortion becomes evident in the example in figure YY. If the geometrical distortion was very high the similarity to the real-life building would probably be too low for the user to recognize, which would lead to very bad orientation but also the most certainly affect the comprehension of the map.

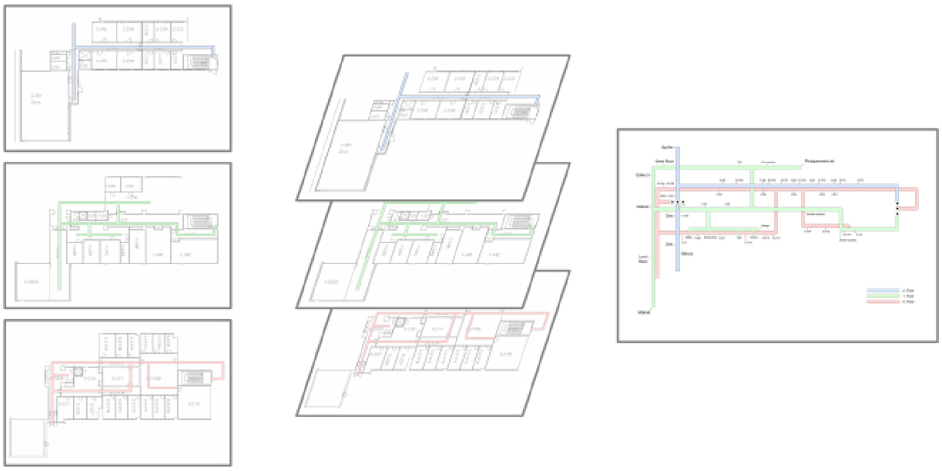

Figure 2: Illustration of the concept of simplifying traditional floor plans by extracting corridors and overlaying several floors into one map.

In addition to the displaying the corridors in the map, rooms, elevators and stairs are also included. Rooms are depicted similar to stations in a metro map with a small line and a text label is connected to the corridor. The size or importance of a room can be indicated by using a larger font size for the relevant labels. Elevators and stairs are conceptually share the function of acting as transfers between the different floors. Thus these are illustrated in a similar fashion as transfer stops in metro maps with small circles that are connected.

One of the major issues of indoor maps is the floor dimension. In order to prevent visual clutter the shape of each floor is the corridor lines. However, the different floors additionally need to be visually separated as well as provide information on the topological relationships between the different floors. To visually separate the floors from each other the design takes advantage of the fact that the corridor lines are overlapping and crossing. A contrasted outline of each floor as well as a small overlap on parallel lines provides good visual clues to the topological ordering of the floors. In order to visually separate the floors from each other, colour has been chosen as the primary variable. We have explored several different colour schemes with different qualities. Figure 3 illustrates the three most distinct of these. The first figure (figure 3a) implements contrasting and strong colours. This approach is similar to what is found in many metro maps. The scheme gives emphasis to the differences in the floors as well as the map as a whole clearly stands out. This type of map is hypothesized to be valuable for an overview of the buildings layout. It could be suitable for contexts where the map is viewed from a large distance and potentially also for visually impaired users. We do not believe this colour scheme to be adequate for dynamic maps due to the strong emphasis on the corridors which will in most cases visually be stronger than the overlaid information. Figure 3b is a more subtle version of the strong colour version. The colours are similarly qualitative and contrasting and function primarily as a means for separating the different floors. However the colours are more dampened and light making them stand out less. This colour scheme is believed to be more suitable for overlaying information as it allows for stronger emphasis on this information. Smaller screens as well as small viewing distances are believed to be very suitable for this scheme.

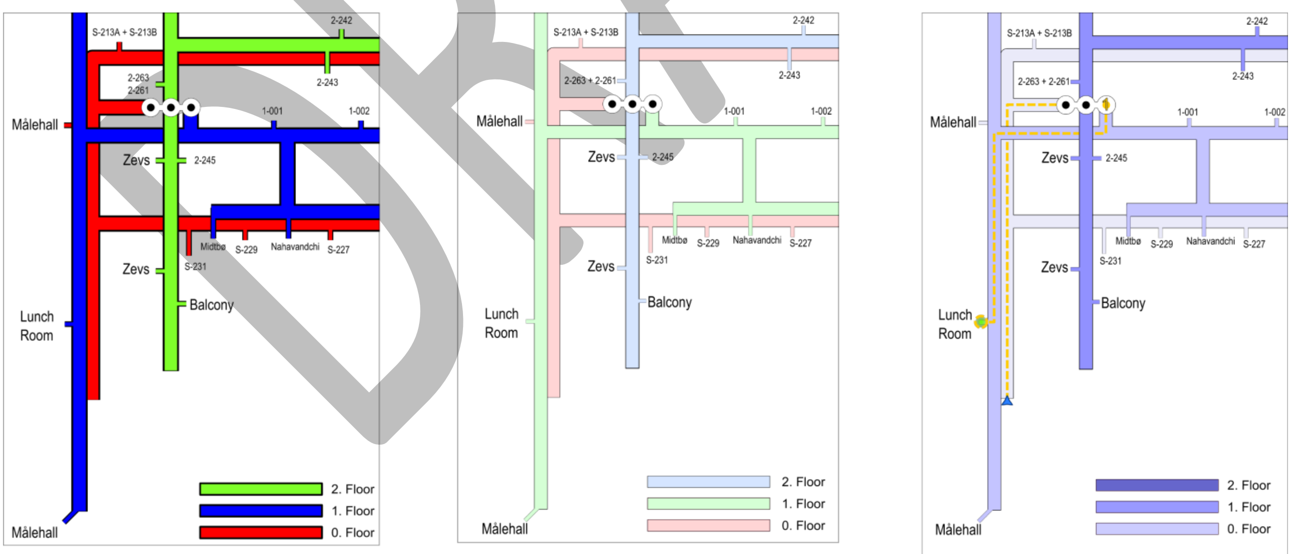

Figure 3, a, b and c: Three different colour schemes, a) qualitative and strong colours for easy visual separation, b) qualitative but lighter colours suitable for overlaying information, c) quantitative colour scheme for easy perception of floor topology.

The two colour schemes described above share the quality of emphasizing the separation between different floors. However, the colour scheme does not emphasize the differentiation in the floors topology. Although the floor topology is visualized using the queues mentioned above colour could further strengthen this. Figure 3c shows an example of such colour scheme. The colours are quantitative aiming at providing a sense of depth of the floors. Darker colours are “closer” to the viewer (i.e. higher in the building) and lighter colours are “further” away from the viewer (i.e. lower in the building). This type of colour scheme is believed to be especially useful for navigation tasks. The focus is on the overlaid navigation path, while the floors are visually dampened. The visual queue hopefully allows the user to more easily orient not only in the plane but also in the floor dimension easier than for the qualitative versions. However, the quantitative colour scheme is believed to be less suitable for differentiating between the different floors. This will be especially evident when the number of floors becomes higher as the distance between the colours will become less. In an attempt to overcome this problem it could be possible to use colour only on the *nearest* floors, for instance when navigating. This would allow for instance that only 2 floors above and below the current floor could be coloured, while the others where only outlined or similar.

The previously described scenarios indicate different contexts of usage. The usage scenarios can be divided into two general classes; public and individual maps. Public maps need to be more general and suit the different, potentially simultaneous users. Individual maps can focus on providing additional information specific to the particular user. This provides properties that affect the suitability of the map designs described above. The strong version in figure 3a is believed to be more suitable for public use without additional overlaid information. An overview map of a hospital building for patients and visitors is one example of usage where the strong version is believed to be suitable. On the other hand real-time airport maps could also fall in the public category. However, it is hypothesized that the overlaid information would, in any cases, need to be limited and fairly general to allow for rapid perception of both the geography as well as the overlaid information. For most public maps the viewing distance is large which the strong colours in figure 3a supports well. For individual maps both large and small viewing distances can be foreseen. Maps for hospital workers displayed on large screens could display real-time information about the patients under the responsibility of the workers. In addition the map could react on identification of the users to display only their responsibilities or even the particular user's preferences. This requires that the colours are subtle allowing for the overlaid information to attract the attention. However, the different floors need to be distinctly separated so the user can quickly perceive the different floors. However the users are most likely known to the geography and are primarily interested in the overlaid information. This separates the designs from the public maps where the user is primarily interested in the geography. The map design can thus be more subtle as the example in figure 3b illustrates.

Mobile devices are natural to consider as platforms for individual maps. Figure 4 illustrates one example of a real-time individual map on a mobile device. The map could display a student's friends and if their busy or not at a university, or the state of patients and workers at a hospital ward. In both situations the user wants to get the real-time information as easy as possible. This makes the subtle version of the qualitative maps suitable.

Figure 4: Illustration of real time indoor map on a mobile device with large touch screen.

Navigation is a very natural task to include in the discussion of indoor maps. This type of task typically falls within the individual maps, as the navigation path overlaid on the map is specific to the particular user. Thus, the task shares similarities with the above mentioned situations. However the subtle version is not believed to be the ideal colour scheme for navigation applications. When navigating, the user wants to know the path to follow. For outdoor navigation this typically includes telling the user which direction to turn. Indoor environments add the additional complexity of navigating in the floor dimension. The qualitative colour schemes do not include visual elements that indicate the order of the floors. We believe that quantitative colour schemes are better suited to visually portray the ordering of the floors. Figure 3c includes an example of a quantitative colour scheme with an overlaid navigation path. The quantitative colours of the floors visually order the floors according to their "depth" in the building. This provides the user with visual clues to whether he is going up or down in the building. However, as earlier mentioned the quantitative colour scheme has some issues associated with it. The number of floors included in the colour scheme is limited due since the different floors need to be visually separated. In addition small room lines that cross underneath a corridor line may be blurred and hard to visually separate.

In this section we have described the concept of the indoor tube maps. Simplifying and extracting corridors from traditional floor plans is the core of the idea. This enables the different floors to be overlaid on top of each other while avoiding the maps to be visually cluttered. The idea and the resulting maps are greatly influenced by traditional metro maps used for public transportation maps all over the world.

Several scenarios of potential usage situations for the map have been described. The different usage scenarios include different user types, different user tasks as well as different environments. All of these differences should affect the cartography of the maps used. We have primarily focused on different colour schemes. Their suitability for different scenarios and use has been discussed as well as their suitability on different devices with the primary focus on viewing distance. We believe that the most important scenario elements to consider in relation to the cartography of indoor maps are the user task and whether the focus is on overlaid information or not, the user's previous knowledge of the environment and the viewing distance.

It is evident that the designs are still on an early stage. We do believe the suggestions described in this paper to be very suitable for indoor maps in several situations. In addition we do also believe that the need and demand for high quality indoor maps will increase in the near future. However, in order to find answers to our hypotheses and explore the qualities and performance of the proposed designs further work is needed.

FURTHER WORK

In this paper we have motivated for new and innovative development and use of indoor maps in the field of cartography. The application of indoor maps in hospitals and large enterprises has been especially focused as an innovative and promising application area. Tasks like real-time maps for scheduling, overview and situational awareness are of particular interest.

The proposed indoor maps are in an early development phase. Refinement of the graphical style is most certainly needed in addition to further investigations into the applicability of the maps. In addition to the graphical style further work needs to investigate and explore the technological possibilities of these kinds of maps. Mobile devices are natural platforms to investigate further with the medium sized screens as well as good communication possibilities with wireless network and large storage capabilities. Screen size will inevitably affect the map design. Concerns have to be taken into both the information density as well as the graphical span of the map itself. Interactivity of indoor maps on mobile devices is also of concern. It is most surely needed some form of interactivity in order to navigate the maps, however what kind of interactivity suits the different users best is still unknown. Further efforts should focus not only on the application of traditional interactivity methods, but also include the recent multi-touch and tactual interfaces now possible on consumer products like smart-mobiles and tablet pc.

The successful application of whiteboards in hospitals (Bardram and Bossen 2005, Bossen 2002) briefly mentioned earlier suggests that large screens are appropriate to investigate within hospital contexts. Large screens can also enable interactivity with the users similar to what whiteboards do today. However, we believe that the successful interactive methods for mobile devices do not necessarily apply directly on large, fixed screens. Multi-touch interfaces for large screens are natural to investigate. However, non-physical interfaces are also of interest, such as pointers and similar. Further work will need to investigate and develop new knowledge of different interactivity possibilities of indoor maps for both medium and large screens.

In order to properly evaluate the quality and performance of the indoor map design proposed a range of methods is suggested. As indicated throughout the paper, users are in focus and essential to the performance and quality of the map design. Following this the evaluation methods should include the users tightly. Quantitative as well as qualitative user testing should be undertaken and guide the future development of the design. Evaluation methods from human-computer interaction can prove to be very useful to employ for this endeavour. As well, the future work should look further into the available work in the field of psychology; especially considering how mental maps are portrayed in different indoor environments (Lawton 1996).

We do also believe real-life experimental setups could be of great value to the evaluation of the design. The real-time maps are especially interesting for this kind of evaluation. We are currently working on the possibility of such an experiment in a hospital for eliciting the affect a real-time indoor map has on the workers situational awareness.

Both the demand and the need for indoor maps are strongly believed to be increasing both for personal as well as professional use. The design as well as the scenarios proposed and discussed in this article is one attempt at making indoor cartography in front of technological implementations in order to provide the best knowledge when the technology and users are ready.

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