Visualizing Physical Space on Small Screens for a First Responders' Safety System

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Abstract : *PDA's have opened up a new world o f functionality. Far beyond their original capacity as digital organizers, today's PDA's can run advanced software and communicate via satellite. As such, there is a wealth of new applications being developed to take advantage of the mobile capabilities.*

Along with the portability that small size affords come many visualization issues. The limited number of pixels on the screen demand that we rethink our current methods and develop new strategies for representing data. This paper introduces the ResQ Firs t Responders' Safety System. as an example application. In this particular application, maintaining context at all times and preserving spatial relations is vital. To satisfy those needs, we describe a collection of techniques that provide a new method for visualizing physical spaces on small screens.

Introduction

Many techniques have been developed to facilitate the visualization of physical space. Bringing those techniques to the small screens of portable electronic devices introduces unique challeng es. For the user to effectively navigate a space, some notion of context + overview must be maintained, even while the user is zoomed in on a small part of the space. This research takes that one step further, making context a critical requirement. At the same time, the presentation of context information cannot take up too much of the screen space since pixel real estate is so valuable.

As an inspiration and example, we describe a system to help first responders in search and rescue operations. A mobile device with communication abilities perfectly suits the technical requirements of such a system. The purpose introduces several visualization requirements as well, essentially requiring an accurate representation of the entire physical space. After a care ful analysis of the needs for such a system, we describe several techniques that, when combined, form an effective solution to the visualization problem.

The issue of maintaining context with limited screen space is one of the largest challenges here. Using a technique that indicates the position of points off screen, users can zoom in without losing the context of points outside the focal area. All of this is accomplished with an eight -pixel border around the edge of the screen, maximizing the space available for visualizing the focal area.

Figure 1: The PDA interface

Example Application: The ResQ First Responders' System

This visualization system is inspired by its use in a first responders' safety system. Below, we describe the background of this application, and the interesting visualization issues that it raises.

In our background interviews for this project, one mantra kept coming up: "Firefighting: Two hundred years unimpeded by progress." While technology has found its way into parts of the service, the management of lives and safety remains untouched by technology.

Background: How a fire scene currently operates

When a fire alarm goes out, trucks, engines and ambulances head toward the scene. A commanding officer remains stationed at his vehicle and is in charge of managing each firefighter. There are several objectives he must keep in mind. First is the "two in two out" rule. This rule actually contains two directives. First, no firefighter enters alone. He must always be part of at least a pair. Second, no two firefighters are sent into a fire until two others are pulled out. The officer must also manage time. Firefighters are required to wear and use SCBA (self contained breathing apparatus) air tanks at all times in a fire. These tanks contain about fifteen minutes of air. If the air were to run out, the life of the firefighter is put in serious risk.

To keep track of the numbers, names, and timings of everyone, a commanding officer currently uses a very low-tech system. As firefighters enter a building, each leaves a nametag with the commanding officer. Nametags are maintained on a clipboard and time is managed with a stopwatch.

Because firefighters are tracked manually, there is a lot of room for error. First, the officer must be watching his stopwatch and doing the mental math to know when a pair of firefighters are nearing their time limit, all while he is trying to direct and strategize an attack on the fire. Oversight is a real possibility in such a system.

Secondly, there no way to know if a firefighter is injured or has run out of air unless someone notices that he is unreachable via radio communication.

In the case that such an emergency arises, it is nearly impossible to locate a firefighter in a loud, dark, smoky, unstable building—particularly if he is unconscious. To make themselves more visually and audibly discoverable, firefighters wear a PASS (Personal Alarm Safety System) Device that emits a loud alarm and flashing light to help other rescue workers locate him. This device automatically activates if the wearer is immobile for more than 30 seconds, and it can also be manually activated in case of an emergency.

Once it is discovered that a firefighter needs to be rescued, a small team of individuals is sent in to rescue a downed firefighter (sometimes called a RIT – Rapid Intervention Team). This team has the singular task of rescuing other firefighters. They are directed toward the victim's last known location where they search him out.

An Improved System

From a safety perspective, it is apparent that technology could be used to keep better track of the health and location of firefighters or other rescue workers. There have been many tragic instances where firefighters became trapped and died because they were not located in time. Our system is the result of nearly fifty interviews with active firefighters, and has three goals that are addressed by new technology.

1. Monitoring - Use a computer to manage the names firefighters along with any other information. Indicate which individuals are in the fire and which are not. Connect digital timers to each individual as he entered a building, and automatically alert the commanding officer as time gets low. This step alone could prevent any oversights that may occur in a manual system
2. Know the location of everyone at all times – This is essentially impossible in the current system, but very important. By incorporating an Indoor GPS© system into the standard PASS device, the precise location of each firefighter, as well as the direction in which he is moving, can be transmitted to the commanding officer.
3. Indicate the status of a firefighter's PASS Device – Just knowing whether or not a device is activated or not activated lets a commander know immediately if any firefighter is in danger.

All of this new data is designed to prevent serious oversights and accidents. If a problem does arise, it is important to include a method for actually rescuing a firefighter in trouble.

With the new information available to us, it is possible to know the precise location of a victim. This means that a RIT commander outside the scene can precisely direct her team toward the victim. To do so, this commander must have a device with her own interface to show the victim and her team inside the building. While the scene commander is stationed at one place, the RIT commander should be able to move freely while providing radio assistance. She should also have the ability to monitor several teams and several victims if required.

In interviews with many firefighters, we found that to be successful in the field, such a device must be small, mobile, robust, easy to use in emergency situations, and simple. Another clear requirement is that the officer must be able to see the status of every individual at all times – even when they move off-screen. A modern PDA fits these requirements well. We envision a system where the RIT commander has a PDA to monitor and direct firefighters.

Desirable Features

After reviewing the goals and requirements of the PDA system described above, we have established the main goal of a PDA system is that the user should be able to see all points at all times, and quickly focus on any point if necessary. As such, we describe several features that are necessary in an implemented interface.

Maintain context: Users must be able to know the physical location of every data point at all times. Since connectivity between points is not as important as their location in physical space, the context should just give an indication of position off-screen and distance from the focus.

Provide uniform scaling at focus: Uniform scaling preserves angles, proportionality in distances, and parallelism between lines. Physical information essentially becomes useless if this is not preserved.

Avoid distortion: Following from the previous point, we should avoid distorting physical space in the context as well as at the focus. Preserving the overall shape of the layout allows users to maintain a correct mental model of the space. Eades, Lai, Misue and Sugiyama [3], mention two properties relevant to this application that should be preserved by transformations to achieve this: orthogonal ordering and clusters.

Orthogonal ordering can be simply thought of as the bearing between two points. Consider points p and q. If p is northeast of q in the undistorted view, the transformed view should preserve this relationship. Clustering requires that points that are close together in the normal view should also be close together in the transformed view [7].

Prevent occlusion: All of our other desirable features have focused on ensuring that the user has a constant view of all data points at all times. Any features to preserve that view are lost if detail information covers part of the view. It is important to devise a strategy for preventing any occlusion.

Allow panning and centering: Because this is a physical space, the user should be able to pan across the visible entire space or easily choose a point to snap to the center. Incorporating these functions is also important to the overall goal of allowing the user to quickly focus on any individual or group.

Related Research

Many problems exist when visualizing large amounts of data on small screens. While our task only has a few dozen data points sparsely distributed over a space, the amount of data is actually quite dense. Since the physical relationships between points and clusters are important to the understanding of this system, every point in the space becomes a data point to be shown on the screen. As a result, the task of visualizing physical space actually shows thousands of well-ordered data points.

Some earlier strategies for visualizing a lot of data on small screens simply provided zoom and pan functions. Unfortunately, this does not give the user any sense of context when the view is zoomed, so it is easy to get lost.

To alleviate this problem, various methods add a small overview window to show the entire space and indicate the users current position. However, this technique is not well suited to smaller screens. The overview window either occludes part of the zoomed window or forces the visualization area to be significantly smaller. The user also has an added cognitive load to integrate his current position with the overview.

Because of these drawbacks, one of the more widely studied visualization strategies is distortion. This compresses parts of the view to allow other parts to expand. Several methods of distortion have been developed for or applied to the small screen problem.

One of these is Furnas' fisheye lens which attempts to maximize the display available to the user. A photographic fisheye lens is a wide-angled lens. Regions close to the focal point can be seen in extreme detail while elements far away from the focal point are not shown in so much detail. The fisheye technique borrows from this. It extends on the focus and context idea. In this technique, the user can have two disjoint areas of interest that are displayed at the same time. The display is maximized to show the areas of interest while providing minimal resources to the other areas of the screen. Additionally, the user can define a defined "degree of interest (DOI)" for each element. The display can be configured to show complete detail close to the focal point and, as the distance increases, elements with higher priority can be seen at a "global context."

Sakar, Manojit, Snibbe, and. Tversky introduce the "rubber sheet". The idea is based on stretching a sheet over an area to get as much detail from the stretched area as possible. Users can employ "handles" to increase an area to get more detail. The more the sheet is stretched the more detail is shown. This technique presents two different sub-techniques: orthogonal and polygonal.

With orthogonal stretching there are four handles: two vertical and two longitudinal. There is an associated stretch factor for both vertical and horizontal handles. The horizontal stretch factor is the stretches the width relative to the original width. Vertical stretching works the same way. Each original point is mapped to its stretched point relative to the scaling factor [7].

The manipulation of space is only one of the issues we need to address for this visualization. Preventing occlusion is another. With such a small screen size, presenting the data to the user in a clear concise way becomes extremely important. Translucency allows multiple sets of information to be presented to the user without cluttering the visual space or causing distortion [6]. Applying the translucent technique to any widgets that enter the space, such as tool tips, menus, and alerts, prevents the problem of data being hidden from the user.

Implementation

After reviewing previous research and experimenting with various techniques for visualizing physical space, we developed a technique to implement the desirable features of a physical visualization system on a PDA. The examples presented here were designed for a 240 X 320 screen, but the technique could be generalized to any other size. The entire screen is used as the focus area.

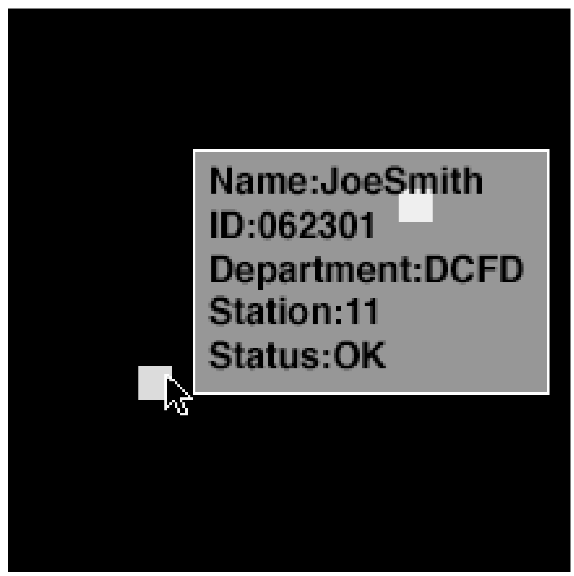

Figure 2: Transparent details window to prevent occlusion

Zooming in this system always zooms in on the center. The user can click on a point or cluster of points to center them, or pan across the screen to bring them into the zoomed view. Zooming is done with uniform scaling to preserve the positions of each point relative to others and the cluster and relative to those off screen. To preserve screen space for the visualization, zooming uses hardware controls provided by the PDA. In the Compaq iPAQ used here, going up and down on the large center button controls zooming. Panning and centering also do not use on-screen controls, but rely on mouse clicking and dragging.

We prevent occlusion by providing details on demand with a transparent window. The user can put her mouse over an individual or group and get a small window to show the relevant information. This window does not fully occlude the area behind it, allowing the user to maintain a view of the full physical area.

Figure 3: The zoomed view. Note the thinner vertical line along the left border compared with the thicker line along the bottom border.

The main feature of our visualization is the technique for maintaining context. As points move out of the window space, they are replaced with a line along the border of the window. The line indicates the linear position of the point off screen. If a point moves off the screen horizontally, the line will appear in the correct vertical position along the correct edge. Similarly, if a point moves beyond the top or bottom of the screen, a horizontal line indicates it's correct horizontal position. If a point moves off-screen in both a horizontal and vertical position, the corner shows a shorter vertical and horizontal line to represent it.

To make context views clearer, points are clustered. An entire cluster is represented by a single line that is approximately the size of its diameter.

The thickness of each line indicates its distance from the focus area. The thickness of a line is determined by how far a point is from the focal area vs. how far it could possibly be. A point closer to the focus area has a thicker line, and as the point moves away, the line grows thinner. In corners, the horizontal and vertical lines are independent. Thus, a corner could have a thick vertical line and a thin horizontal line if the point is very far from the center on the horizontal axis, and very nearly within range on the vertical axis.

Color is reserved for application specific indications. In our example application, color indicates the status of individuals.

Applicability to Future Systems

The speed at which technology is evolving cannot be ignored. While most new PDA screens today may have resolution of 240 X 320, there is little doubt that the standard resolution will be much higher a year from now. With that being the case, it is natural to wonder how useful a system such as that described here will be. If we eventually have 600 X 800 resolution on screen, will there be a need for this visualization?

In some respects, visualizing data on a PDA screen will become much easier as technology evolves. Smaller fonts will be readable making browsers and other text based applications more usable. Higher quality graphics will also be easier to see. However, while our application is visual, it is not reliant on either text or graphic quality.

The physical size of screens is more of a limitation in this application. The idea is similar in large settings. Consider a wall-size poster. The resolution at which text can be printed on that poster eventually becomes irrelevant. Readers will never be able to make out clear 6 -point text from a reasonable distance. There is a lower limit to how small text can get before it becomes unreadable from a distance, and at that point, resolution is not much of an issue.

In the example described here, we have a screen with resolution of 240 X 320. At that size, we have chosen the smallest representation of a point on the screen to be a 4 pixel X 4 pixel square. The amount of space we could visualize would increase sixteen times if each point we represented by one single pixel. The single pixel is simply too small to be easily seen in this application, and indeed in many others.

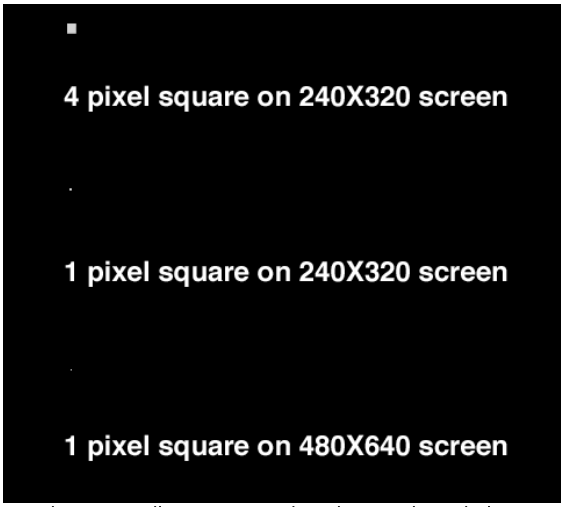

Figure 4: Indicators at varying sizes and resolutions

Consider figure 4. In that figure we show the current 4 pixel representation of a data point, a one pixel representation, and a one pixel representation on a theorized future screen with 480 X 640 resolution.

Clearly, in an application where the user wants to have a quick view of sparse points in physical space, the single pixel on a screen with higher resolution is simply not big enough. In fact, even at the current resolution of 240X320, this application does not take full advantage of the smallest point on the screen. Usability requires a larger representation of the smallest visible unit.

While the physical size of screens may also increase, their role in portable handheld devices ultimately limits how large they can get. At some point, when a screen gets too large, the device is no longer easily portable. Thus, for handhelds, the physical dimensions of the screen will never be so large that visualization becomes a non-issue.

While the evolution of technology will certainly allow further development of features of this system, the technology will not progress to a point where the techniques described here become obsolete on handheld devices.

Future Work

Scalability is one issue we would like to explore further. While this technique seems well suited to our example application, the number of visualized points is limited. In all but the most catastrophic situations, it is unlikely that there would be any need to visualize over one-hundred points. This application has the further advantage that points are automatically clustered as an effect of the team organization of the fire scene. In other applications that also require a visualization of physical space, there may be thousands of points. Further study is required to address clustering algorithms and adaptations that may be necessary for the technique to scale.

Broader applicability of this system is another goal. This research started with the specific task of discovering methods for effectively visualizing data in the example application described here. We would like to take this one step further and investigate the applicability of these techniques to a larger set of tasks. Modifications that present themselves in the process of applying this to other problems may help to improve the system for the entire range of applications.

We believe this system has an advantage over many other visualization techniques that introduce distortion. To confirm this, we would like to conduct a usability study to see if there is a significant improvement in user performance.

Conclusions

In this paper, we demonstrate a set of techniques for effectively visualizing physical space on a small PDA screen. We introduce a new technique that maintains context on the borders of the screen. Other techniques include zooming, panning and translucency. This allows the user to be continually presented with the information by preventing occlusion.

For the example application of a first responders' safety system, this series of techniques effectively fulfills all of the desirable qualities. The user is able to maintain a contextual view of the entire space without the complications of distortion or an added cognitive load of other techniques.

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