Exploring Multi-touch Gestures for Map Interaction in Mass Casualty Incidents

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Abstract: In mass casualty incidents a common operation picture, which gives an overview about the current situation is critical information for managing the emergency. In order to support the collaboration between different incident commanders a multi-touch table, placed in the incident command post, is used to present the current operation picture on a map. To place as little additional mental load as possible on the users, any interaction with this map interface should be natural and intuitive. Therefore we investigated in a user study several alternative multi-touch gestures, combined to five sets for the tasks of modifying the map view and selecting map objects in an emergency management scenario. The gesture sets contained widely known as well as new promising gestures.

1   INTRODUCTION

In mass casualty incidents (MCIs) the rescue service is confronted with a huge number of patients. More injured people have to be treated then the local Emergency medical service (EMS) is able to handle. Within the project SpeedUp[1] we create a collaborative infrastructure for management and coordination of an MCI on a multi-touch table and several other devices.

During an MCI, the incident management officials like the medical incident officer and the ambulance incident officer together with their supporting personnel has to plan and coordinate a suitable reaction to safe as many injured as possible. To be able to manage the situation it is essential to have a common operation picture giving an overview about the current situation.

Accurate information about the number, location and medical condition of patients as well as of the available rescue workers in the field is critical for MCIs. We provide this overview

on a map on the digital table, which is placed in the incident command post (ICP), shown in figure 1(a). All information about the incident is collected here, in the centerpiece of the medical incident management.

Everyone working in the ICP has to work effectively and in close collaboration. To manage an MCI, it is already common to create a map of the affected area. We see a multi-touch table as an ideal user interface for this map. A table is very convenient for discussions with a common content like the map. The digital table offers additional advantages. The map can be updated continuously. Details of the map can be enlarged through zooming. Additionally all users can interact at the same time with the device.

To place as little additional mental load as possible on the users, any interaction with this map interface should be natural and intuitive. Gestural commands, particularly those which are based on real-world metaphors, are therefore a promising mode of interaction.

Gestural interfaces which have already been presented rely mostly on a small set of gestures such as pinch-to-zoom, popularized in 2005 by Han [Han05]. However, one question remains - are these common gestures for the EMS personnel really the best way to interact with a virtual map? We have addressed this question by assembling five sets of potential gestures from various sources. Each of these sets contains gestures for the four operations of panning, zooming, rotating and selecting. In figure 1(b) a zooming gesture is shown. Figure 1(a) shows a part of the map with icons, indicating the position of the patients, the EMS personnel as well as some vehicles. In a user study, we have evaluated these sets with users from various backgrounds: user interface experts from our research group, domain experts from the university's fire department and inexperienced randomly selected students. The subjective impressions and opinions of the users offer valuable insight into potential improvements.
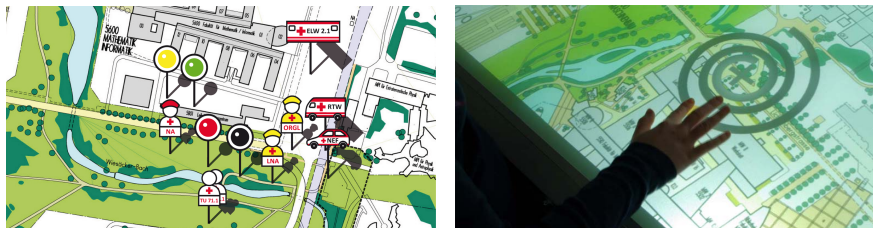
(a) A screenshot of the map application on the multitouch table. It gives an overview of the patients, the EMS personnel and the EMS vehicles.

(b) Map interaction with an alternative gesture set: zooming through a spiral gesture.

Figure 1: Two map figures.

2 RELATED WORK

Several research projects investigated the usage of mulit-touch devices in emergency situations. The table developed by Stasch et al. [SDW$^+$09] is part of the larger Soknos project

[DPZM09]. It aims to provide a general framework for management and visualization of data relating to catastrophic emergencies.

Other applications of interactive surfaces in the area of geospatial rescue management focus on single specific tasks. For example, Zibuschka et al. [ZLE10] show a system which supports the planning of large-scale events with the goal to avoid potentially catastrophic accidents through appropriate placement of rescue units, escape routes etc. Nobrega et al. [NSRC08] present an interactive flood visualization system which uses terrain data and physical simulations to predict the course of catastrophic flood events. Micire et al. [MDC+09] use an interactive table to plan routes for and steer remote-controlled search-and-rescue robots in a disaster area.

In all of the aforementioned projects the user interacts with a mulit-touch table. Most of them use well known gestures, which are also used by commercial multi-touch devices like the iPhone[2] or Microsoft Surface[3]. However little research is done in exploring new alternative gestures for map interaction in detail in order to find the best suitable gestures for the EMS personnel working under severe time-pressure.

3 ALTERNATIVE GESTURE SETS

We explain in this section the background as well as the design of the gestures and the corresponding sets.

3.1 Design Strategies

Good gestural interfaces have very similar characteristics to any other well designed system [Saf08]. Gestures for map interaction should fulfill the same requirements as any other good user interface. Ben Shneiderman has defined eight golden rules of user interfaces [SP10] and Don Norman describes several important design principles [Nor02]. If we transfer those rules and principles for general user interfaces to gesture based user interfaces, then gestures must be simple, straightforward, easy to remember, consistent and distinguishable. Gestures should be based on knowledge in the world and in the user's head. Natural mappings and metaphors simplify the recollection how gestures and actions are connected.

We used the following strategies for defining the gestures:

Gestures based on related research results: Good gestures for tabletop interaction were found already by several researchers. Some of these gestures are suitable for map interaction as well. Jeff Han presented gestures for panning, zooming and rotating. He used two fingers pinching to shrink and spreading to enlarge. Rotation is done using two finger as well, where the pivot point is between the fingers [Han05].

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[2]http://www.apple.com/de/iphone/
[3]http://www.microsoft.com/surface

Wu et al. present different gestures for interacting with a prototype room furniture layout application, called RoomPlanner. Objects are rotated with two fingers. One finger defines the center of rotation, while the second specifies the angle [WB03].

Other results are given by a user centered evaluation about gestures for tabletop interaction. It shows that users don't mind how many fingers are touching the table [WMW09]. Thus, the number of fingers are an inappropriate feature for the differentiation of actions. Considering that, those gestures are more promising, which can be performed with an arbitrary number of fingers.

Metaphors and natural mappings: User interfaces are often based on the idea of metaphors. An example of a well known metaphor in PCs is the trash-bin. Files are deleted like trash, as soon as they are moved into it. Metaphors connect the well-known with the new - they create a connection between the real and the virtual world. However, metaphors have to be selected carefully, as cultural differences can lead to different interpretations. A natural mapping sets a proper relation between controls and movement. Therefore metaphors and natural mappings reduce the mental load to perform a task [SP10].

In our application we use a spiral as a natural mapping for zooming. Going along a spiral is like zooming through space. If the spiral is traced inwards the map is zoomed in and vice versa.

Transfer of desktop concepts: We assume that all of our users have experience in using a Desktop PC with a mouse. Based on this knowledge, interaction techniques are transferred from the Desktop PC to the tabletop interface.

To select multiple items on a desktop one method is to hold the Control key and to click on one item after the other. We transfer this "hold and tap" method to the table. The first item to select has to be held with one finger, while further items can be selected by tapping one after the other with another finger on the other hand.

Another selection method for several items is to draw a rubber band rectangle around the items. One edge of the rubber band rectangle sticks to the mouse cursor while the user holds the mouse button, making it possible to adjust the rectangle's dimension. This method is a common technique to select files on the desktop or in the file explorer. On the table objects are selected by drawing a semi-transparent rectangle around the objects.

Transfer of software concepts: Other popular interaction techniques are derived from well-known Software applications like Adobe Photoshop. Knowledge from this application is transferred to the tabletop interface.

Adobe Photoshop has a zoom function where a rubber band rectangle specifies the area, which has to be enlarged. Everything inside the defined rectangle is scaled up to fit the size of the Photoshop window. Zooming out is realized by pressing the Control key in the zoom mode and clicking to the image. On every click the image is then stepwise zoomed out.

On the multi-touch table the area which should be enlarged is defined similar to the zoom-in in Photoshop. As there is no Control key on the tabletop zooming-out is done by double clicking, or rather double tapping.

3.2 Individual gestures

We created a pool of individual gestures for four operations of panning, zooming, rotating and selecting based on the aforementioned design strategies.

3.2.1 Gestures for panning

Moving the map is probably the most frequently used feature of a map application. Consequently, the gesture, which triggers the translation, should be simple and easy to remember.

Sticky finger: One or more fingers move the map. The finger sticks to the map and drags it along when it is moved.

Flick: The *Flick* gesture is a slight modification of the *Sticky Finger*. When the finger is removed from the surface the map continues sliding in the direction it was moved. It might become more difficult to accurately position the map. But on the other hand moving from one side of the map to another is much easier and faster than with *Sticky finger*, because the map moves automatically in the desired direction.

3.2.2 Gestures for zooming

Zooming is one of the big advantages of a digital map over a paper map, which is not scalable. Zooming is, after panning, a task which is done very frequently.

Pinch: The pinch-to-zoom is often found on recent multi-touch devices, like the iPhone or some Android devices. This gesture can be performed with two fingers using either one hand or two. One or two hand manipulation is a matter of personal preference and size of hardware. The action for zooming-out consists of two fingers coming closer to each other. Zooming-in is done by the reverse pinch gesture: two fingers spreading.

Free pinch: This gesture is a modification of the pinch gesture. *Free pinch* is executed using an arbitrary number of fingers (2-5 per hand), which breaks the limitation of the fingers of the original pinch gesture.

Spiral: The *Spiral* is triggered by moving one finger on the surface. Moving inwards along the spiral zooms in, moving outwards zooms out. The spiral can be seen in figure 1(b)

Window and double tap: To zoom-in the user draws a rubber band rectangle onto the screen. The frame is drawn like the translucent rubber band rectangle used in desktops and file managers to select items. As soon as the user has selected the area of interest the map is zoomed so that the area fills the screen. This can be done so often until the maximum zoom level of the map is reached. Zooming out is stepwise possible. The user can double tap onto the screen to revert the last scale operation. A history of scale operations is recorded so that successive double-taps can be handled.

Contrary to the aforementioned gestures continuous scaling is not possible, making small adjustments to the scale factor infeasible.

3.2.3   Gestures for rotating

Rotating a map is especially important on a multi-touch table, when not only one person is using the map. People standing around the map might want to see it correctly aligned.

Around center rotation: This gesture is very similar to the already mentioned pinch-to-zoom gesture and was also shown by Jeff Han. Two fingers are moved clockwise or counterclockwise while the map changes the orientation. During the movement the map rotates around the center of rotation, which lies between the fingers.

Pivot point rotation: This gesture is slightly different to the first one. The center of rotation is not between the fingers, but it is specified by the position of the first finger, which touches the tabletop. According to Guiard [Gui87] the non-dominant hand sets the reference frame and is the first which starts the action. In our case it sets the pivot point for the rotation and holds it, while the dominant hand defines the degree of rotation.

Circle rotation: The last rotation gesture presented here is based on a one finger circling motion. As soon as one finger starts dragging the map is rotated around a fixed point close to the finger. For as long as the gesture is in progress the center of rotation stays fixed.

3.2.4   Gestures for selecting

Selecting and highlighting items is another core feature, which is implemented in our application.

Rectangle: A rubber band rectangle, similar to the one described in the *Window and double tap* gesture for zooming, can be used for selection as well. In the selection mode every object inside of the rectangle is selected. This method is derived from the rubber band selection on a desktop or file manager. We think that it is an easy way to perform and to remember the gesture. However, one of the main drawbacks of this function is, that it is not possible to draw a rectangle around the desired objects. An unwanted object may be positioned in-between and might be selected accidentally.

Lasso: This type of selection is common in graphic programs like Adobe Photoshop. In contrast to the rubber band, this method allows the user to be more accurate with the selection area. Though there are two disadvantages, when using the *Lasso* selection. At the beginning it might feel a little slower and more difficult, because it takes longer to select the same amount of items compared to the *Rectangle*. So this describes a trade off between accurate area selection with the *Lasso* and the more comfortable, faster selection with a rubber band rectangle.

Hold and tap: We transferred another desktop interaction technique for selection. A common way to select items on the desktop is to hold the Control key while clicking on one item after the other. This "hold and tap" method is performed in a similar manner on the table. The first item is selected with one hand and then held while further items can be selected by tapping one after the other with the second hand. *Hold and tap* is a good method to select a couple of items, but if the number of items increases, the time to execute the selection rises as well.

3.3 Gesture Sets

We combined the aforementioned gestures to five different gesture sets for evaluation and testing purposes. However, some gestures can not be combined with other gestures. The interpretation of the gesture takes place during the execution. Due to that fact, the system has to know right from the beginning what gesture is performed to respond correctly. We have to consider that only those gestures are put in one set, which can be detected immediately through unique characteristics, like the numbers of fingers or the position of the fingers to each other. Gesture sets are shown in figure 2.

3.4 Visual Feedback

Our application gives immediate visual feedback during the interaction. The instant response of the system provides the user with an indication of the system state. It makes the outcome of actions apparent. When designing the feedback icons it has to be considered that the feedback visualization should be recognizable regardless of the user's point of view. As a result, symmetric and simple graphics are designed to fulfill this requirement. The feedback graphics can be seen in figure 2.

Touchblobs Feedback is given in form of orange semitransparent circles when touching the surface of the table. This information makes the user aware of the number of detected touches. The user can notice if the system is responding correctly or not.

Translate: A cross sticks to the finger when the map is translated.

Zoom: The symbol for zooming is often a magnifying glass. We reduced it to a circle with a plus or minus sign inside. This design ensures that the graphical appearance
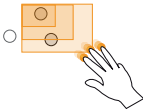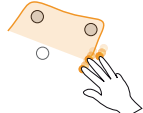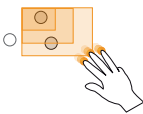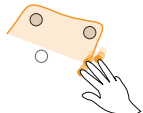
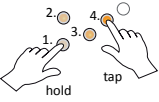|	Pan	Zoom	Rotate	Select
Default	Sticky finger / Flick 1 Finger	Pinch 2 Fingers	Around center rotation 2 Fingers	Rectangle 3 Fingers
Circle	Sticky finger / Flick 2 Fingers	Pinch 2 Fingers	Circle rotation 1 Finger	Lasso 3 Fingers
Spiral	Sticky finger / Flick 2 Fingers	Spiral 2 Fingers	Around center rotation 1 Finger	Rectangle 3 Fingers
Fly	Sticky finger / Flick 2 Fingers	Window and double tap 1 Finger	Pivot point rotation 2 Fingers	Lasso 3 Fingers
Free	Sticky finger / Flick 1-5 Fingers	Free pinch 2-5 Fingers	Free pinch 2-5 Fingers	Hold and tap 2 Fingers

Figure 2: Five different gesture sets with support for translation, scaling, rotation and selection. The icons are also used as help graphics. The visual feedback associated with every gesture is also illustrated.

is consistent from every side of the table. Arrows indicate the direction of the finger movement.

Rotate: We have designed three slightly different rotation illustrations. All of them consist of a circle and at least one arrow showing the direction of the rotation. A circle with two arrows is used for the *Around center rotation* with the center of rotation in between and only one arrow for the *Circle rotation*. An orange point marks the pivot point in the *Pivot point rotation* surrounded by a circle with one arrow.

Select: The selected area of the *Rectangle* method is visualized with a semitransparent rectangle. A polygon is drawn with the *Lasso* method. A semitransparent overlay is shown between the end and the start point. Selected objects are highlighted.

3.5 Help

Don Norman [Nor02] stated that a user interface has to bridge the gulf of execution and evaluation. The gulf of execution is the difference between the intentions of the users and what the system allows them to do or how well the system supports those actions. We developed a help functionality, which visualizes available actions, so people are aware of possible actions and their execution.

Furthermore one of Shneiderman's eight golden rules of interface design is to *"Reduce short term memory load"* [SP10]. The help system reduces the memory load as well as it bridges the gulf mentioned before. The user can always rely on the help system if the recall of the gestures is not correctly or not possible at all. The help can be called with a five finger tap on the table. Tapping again hides it.

All available gestures are illustrated with icons depicting hands that perform the gesture including the resulting visual feedback. The help for the *Fly* set can be seen in figure 3(b). Apart from assisting the user, the help functionality has advantages for the developer as well. The frequency and the duration of the user's need for help can be tracked. Therefore, the call of the help gives an indication about the memorability of the gestures.
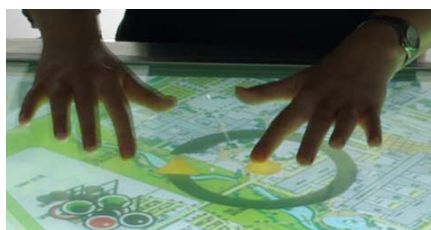
(a) Feedback during *Pivot point rotation*.

(b) Help system for the *Fly* set. Illustrations indicate how to perform each gesture for panning, zooming, selecting and rotating the map (from left to right.)

Figure 3: Feedback and help functionality

4   EXPLORATIVE USER STUDY

In order to compare the gesture sets, we conducted a user study to find answers to the following questions:

- Is the application self-explanatory and intuitive?

- How difficult are the gestures to learn, to perform and to remember?

- Are the icons of the help menu easy to understand?

- Are the gestures suitable for left as well as right-handed people?

- What is the best suited interaction technique?

4.1   Participants

Nielson has shown that a small sampling size is enough to identify the most critical usability problems in an early stage [NL93]. Additionally Schwerdtfeger states that a small and diverse test group consisting of user interface experts, domain experts and inexperienced random users enhances the problem finding as well [Sch10]. Hence, we selected six participants for the study: Two user interface experts, two inexperienced students and two domain experts. The two domain experts are from the fire department of the Technische Universitaet Muenchen (Feuerwehr TUM), who are working in the emergency medical service.

The subjects' age ranges from 21 to 49, one female and five males, two left-handed and four right-handed. All Participants are familiar with Desktop PCs. Four participants have used an iPhone or an iPod Touch, one of them used an Android based smartphone. Two users have experience with multi-touch tables. Another two participants are using touch interfaces daily, like phones or touch displays, the other four once a month or less. Five participants know Google Maps and two are familiar with Open Street Map.

4.2   Procedure

Participants had to execute realistic tasks, which are very common and are often performed with a map in an emergency scenario. These nine tasks included panning, scaling and rotating the map. Another task was also the selection of single and multiple items, in our case patients. The patients were illustrated as pins.

At the beginning all participants had to fill in a questionnaire concerning demographic data and their experience with touch. Afterwards each participant had to complete all nine tasks in a fixed order using each of the five gesture sets, one after the other. That means by the end every user had done all nine tasks five times. We used a within-subject
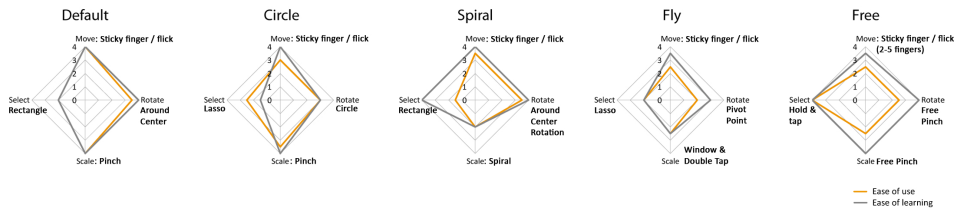
Figure 4: Net Graphs showing the ease of learning and ease of use. The higher the value the better.

design and changed the order of the gesture sets randomly for each user. The system was not introduced to the test persons, because one of our goals was to see how self-explanatory and intuitive the application is. Participants were asked to think aloud during the evaluation.

After solving the nine tasks with one gesture set a questionnaire had to be filled out. Three questions were asked concerning the ease of learning, ease of use as well as the ease of remembering of each set, using a five point-likert scale. Furthermore users could give comments on their preferred gestures of each set.

Each session lasted between one and two hours. Video and audio recordings were made in all sessions.

The hardware on which our study was conducted is a rear-projected FTIR-based [Han05] multitouch table with a screen diagonal of about 1.30 m. As the interaction surface is situated at a height of approximately 0.9 m, the system can be comfortably operated by one or more persons standing beside the table.

5 RESULTS

This section described our experimental results and gives a detailed discussion of the findings.

5.1 Ease of learning and ease of use

We asked users to vote for their favorite gestures after working with all sets. The results are presented in figure 4 and are described in the following:

5.1.1 Panning

For moving the map only three gestures were available. They only differed in the number of fingers that are used to perform the gesture. In the end the sticky finger as found in the *Default* set and the move gesture found in the *Free* set were the clear favorites.

5.1.2 Zooming

The pinch-to-zoom gesture in the *Default* and *Circle* set were rated both in terms of learning and using very high. The *Fly* gesture was rated better than Spiral for zooming. The *Free pinch* gestures with 2-5 fingers was easy to learn, however not so easy to perform.

5.1.3 Rotating

The *Circle rotation* gesture, together with the *Around center rotation* are rated as the best gestures for rotation.

5.1.4 Selecting

Hold and tap is clearly the favorite for selecting patients. However *Lasso* and *Rectangle* gestures are also very valuable, if it comes to a more comprehensive selection.

5.1.5 Ease of remembering

Generally, *Default* and *Free* are voted easier to remember than *Fly*, *Spiral* and *Circle*. The latter three are all rated the same.

We tracked users who called the help function for different gestures. The results show that the *Spiral* and *Fly* sets had been called eight and nine times respectively, for all user tests. This shows that the *Spiral* and *Fly* sets require most support to use them. Therefore, this confirms and supports our finding from the results presented above.

6 DISCUSSION

6.1 User feedback

Users had the option to comment freely on the application and the gestures. From our observation, we noticed that users accidentally activated gestures that they did not intend to perform, and in some cases users interrupted their experimental tasks with an accidental gesture. For example, in the process of selecting items using any of the three finger gestures it frequently happened that users accidentally rotated or moved the map, because not all 3 fingers were detected by the system.

The majority users reported that using three fingers for *Lasso* or rubber band rectangle selection is impractical. The *Hold and tap* gesture received a lot more positive comments. Users suggested that the selection gestures should be activated using three fingers and continued using only a single finger. However, this was actually already possible yet unknown to the user because the help icon did not explicitly show this feature.

The last thing to note is that the widget received very mixed comments. It was characterized as being "very easy to use" and "very clear" but it was also reported that it is "slow to use".

6.2 Recommendations for gestural interaction

Based on our quantitative and qualitative data as well as our observations during the evaluation we have some recommendations for future gestural interfaces.

6.2.1 Don't differentiate by the number of fingers

As shown also by Wobbrock et al. [WMW09] the number of fingers is not the best choice to distinguish between triggered actions. Gestures which could be performed with any number of fingers like *Free* are best. From our test observations EMS personnel tends to use the whole hand for interaction like they are used to do in their daily work, when treating patients. To place as little mental load as possible on the users, gestures should work with any number of fingers.

6.2.2 Provide help functionality

To reduce memory load well-known gestures should be used. A help system, which can be easily accessed and understood in a second, helps the user to remember gestures.

6.2.3 Continue triggered actions

As soon as an action is triggered, it should not be switched during the execution of the gesture, even if the system is no longer detecting the same number of fingers. Users tend to take their finger off when starting a new interaction. Thus, new actions can be started as soon as the user removes all fingers and touches the surface again.

6.2.4 Offer multiple gestures for the same action

The system should offer multiple alternative gestures for one action. For example there could be different gestures for selecting a huge group of objects or only some of them. *Lasso* is a good tool to select a lot of items whereas *Hold and Tap* is better for a few items. The same applies to zooming. Depending on the required accuracy of zooming different methods are best.

6.2.5 Give fallback options

Our application should be used in very critical situations - during mass casualty incidents. Hence we need a system with high reliability. If for some reasons the gestural interaction does not work as expected, fallback options are needed. A button widget could be one of these options, other inputs could be a digital pen or a conventional mouse.

6.2.6 Provide shortcuts

Shortcuts allow the user to perform specific actions faster. A very valuable shortcut are buttons, which allow to jump to a certain position. In our application arrows on the edges of the map were hints for patients which are not visible on the current part of the map. Some users tried to tap them in the hope that the application moves to that patient automatically.

Another example where shortcuts would be useful is the *Spiral* gesture. The *Spiral* does not give the possibility to "jump" to a certain zoom level by tapping somewhere onto the *Spiral*. Shortcuts are a useful feature, which save time.

7 CONCLUSION AND FUTURE WORK

Our work explores a variety of gesture sets, which go beyond the widely used pinch-to-zoom gestures, for the interaction with a map application. The application is designed to be used in emergency situations. It gives incident commanders an overview in mass casualty incidents (MCIs). An MCI is a very time-critical situation. Therefore, the user interface needs good usability in order to support and not to distract incident commanders. In order to find the most appropriate gestures for our target group, we designed five different gesture sets. Each of these sets contains gestures for the four operations of panning, rotating, zooming and selecting. "Traditional" gestures like pinch-to-zoom are compared to new and promising gestures in a user study. Our study shows that an improved "traditional" gesture set is the best solution for emergency commanders. Additionally this set should allow any number of fingers to perform gestures. Our future application will also use the *Hold and tap* gesture for selection, extended by the *Lasso*. The latter is a preferable gesture for selecting many objects precisely.

Our work represents a first step in bringing interactive surfaces closer to a new target audience, which has to solve serious problems.

8 ACKNOWLEDGMENTS

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