

# Is it possible to interact with a handheld device while holding it in both hands?

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**Abstract:** Intuitiveness, attractiveness and efficiency are in general important characteristics of high quality User Interfaces (UI). In the case of a Mass Casualty Incident (MCI) and other life threatening situations good user interfaces are essential as every second counts in these time-critical situations. Finding the best way to interact with the system is a challenge with many open issues. Therefore, it is essential to test different UI alternatives to determine important usability issues as those mentioned before. This paper focuses on the research question how patients can be selected on a map application which runs on a rugged tablet PC. A rugged tablet PC is in general heavy because of its robustness, which introduces a new special requirement in addition to the existing UI requirements. Consequently, since the users are forced to hold the tablet PC with two hands because of its heaviness, they have to perform all UI interaction with the thumbs. This implies that the users are not able to reach every item on the screen of the tablet PC. Therefore all UI elements have to be either on the left or on the right hand-side of the screen. The implementation and the evaluation of the UI alternatives presented in this paper were performed within the scope of the SpeedUp project<sup>1</sup>.

## 1 Motivation - Usability brings order in the chaos?

A Mass Casualty Incident (MCI) is an incident which generates more patients than the locally available rescue workers can manage simultaneously. The medical rescue teams have to face a vehement organizational challenge in such disasters. Since there are too many injured people to handle at once, they need to be categorized. This categorization is done by the relief units executing a triage algorithm such as the Simple Triage and Rapid Treatment START during the first triage [MKC96]. This is a deterministic way to define the priority and the need of each patient to benefit from medical care. There is already an ongoing research which digitizes the triage approach using PDAs [NK07]. Using PDAs equipped with GPS sensors has the advantage to track the position of the patients. The PDAs are supposed to be used by the relief units in the field. The tracking positions are

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transferred from the distributed PDAs in the field to the tablet PC used for this work. The positions of the patients are visualized in an overview map on the tablet PC in the scope of this work.

This paper focusses on the second triage. It is done by the Emergency Medical Chief (EMC) or an emergency doctor appointed by the EMC. During this second step the patients are more precisely re-categorized if necessary and the succession of patients' transportation to the nearest hospital will be determined by the EMC. Currently, the EMC is getting this information from the rescue units verbally. The number of injured people and their classification are written down by the relief units on paper. So this information can be incomplete, redundant and/or wrong. Obviously, using an IT solution can improve and introduce order in the chaotic situation in such incidents. This is why we propose that the EMC should use the tablet PC to acquire the required information about the patients. However, because of the users' tendency to resist or even reject new technologies with inadequate user interfaces or bad usability, all conceivable improvements can be useless. It is therefore essential to develop the user interface closely with the user to find out which UI alternative is the most intuitive, efficient and attractive. To achieve that, we investigate first touch user interfaces, because of the fact that the UI has to fulfill the UI requirements coming from touchscreen devices. This is described in section 2. Additionally, more special requirements on the user interface suitable for an MCI situation have to be considered and explored. This paper focuses on designing a usable UI to select items (patients or relief units for instance) fulfilling these special UI requirements. Those special requirements are going to be mentioned in section 3.2.

## 2 Touchscreens

An advantage of touch screens in general is that the user can directly interact with the interface making it more intuitive and natural. Furthermore, there is no need for additional input devices like keyboards or mice, allowing a more compact interaction method since the UI and the hardware share the same space. Consequently, a higher mobility can be achieved with touchscreen devices such as tablet PCs. Another advantage is that the soft UI elements are movable, changable and can be hidden if not needed, whereas hardware UI do not support this. These kinds of context dependent buttons can also be obtained by dynamic hard buttons but users are often confused by them, since their performed actions are changing, but their label is not. With touchscreens all buttons can be labeled with visual symbols which makes their actions easier to understand and therefore more intuitive.

Nevertheless, there are also disadvantages coming with touchscreens. If the user for example presses a soft button, its label will be occluded by his finger. Another disadvantage is that nowadays users are used to the "mouse-over" effects and many applications are using them for different features like displaying information about a button. This is not possible with touchscreens controlled with the fingers. Last but not least people are not as precise with their fingers as with the usual mouse cursor. The resolution of a finger tip is low [AZ03]. But, an accuracy of 99% can be reached if the button size is larger than 22mm

[Lew93], [LP98]. There are known techniques to reduce the button size like “first-contact” and “take-off” for small devices like mobile phones. As an illustration, the size of a soft button can be reduced to 6.8mm with the take-off strategy without losing accuracy [SS91]. Since our User Interface will be developed and evaluated on a tablet PC size reduction methods are not needed because enough space is available. A relevant requirement in an MCI situation is to enable the user to use the application without distracting his concentration more than necessary due to the nature of the life threatening situation. Therefore, it is reasonable to make the button size even larger than proposed for home or office applications. Another important criterion is the feedback of an interaction item. The visual feedback can be similar to the visual feedback on common desktop user interfaces. The only difference is the lack of the “mouse-over” effect and the occlusion of the item by the finger of the user. Those missing features have to be taken into consideration in the UI.

### **3 Requirements for the tablet PC application**

The requirements in general can be split into hardware and software requirements. The first subsection (3.1) describes some important hardware requirements, the second subsection (3.2) presents the software requirements. They are again subdivided into common and special requirements.

#### **3.1 Hardware Requirements**

In an MCI situation, time is very critical. Thus high-performance hardware is a basic requirement, to reduce the computational delay. Loading times will reduce the intended speed up of the rescue process and the risk that the application will not be accepted by the target group will increase. Second, the hardware needs to have a GPS receiver to get the information about the current location. With the GPS built in the tablet PC it is possible to track the EMC’s position as well. All off the rescue units will each carry a PDA which has a GPS receiver too. So all rescue unit’s positions will be available and transferred to the tablet PC where they can be visualized. The tablet PC has to be equipped with a WLAN card to be able to connect to a nearby server and get the PDAs GPS positions. As fall back strategy, other possibilities to submit the data like GPRS, EDGE and UMTS should also be available. However, this is not the scope of this work. Another relevant hardware requirement is the battery life that should be at least lasts four hours. Additionally, a car docking station for the tablet pc should be available to be able to recharge the battery during the trip. Due to the nature of an MCI, the environment in which the tablet PC will be used can be unstable. The used hardware has to endure those environments in which fire, water or dust exist. There are known standards which define the degree of protection for those devices. To conform with these requirements the device should accord at least to IP55 defined in DIN EN 60529. That means that the device offers a full protection against contact and interior injurious dust deposits and it is protected against water (out of a nozzle) from all directions.

### 3.2 Software (UI) Requirements

There are some common requirements which every user interface should fulfill. Some of them are especially important in the case of an MCI while others are incited by the hardware. We will differentiate between common and special requirements in the following.

**Common Requirements** The first common requirement is the intuitiveness of the user interface. In fact this requirement is very important for all user interfaces, especially in an MCI situation. The reason behind that is the fact that a special training for every EMC would cost money and time. Another reason is that the user should be able to immediately understand the information presented by the UI and perform the basic interaction with the application. Last but not least the target group; the EMC in our case will not accept a new application if they have to spend a lot of time in the learning phase. Another common requirement is the possibility to undo actions or decisions to avoid mistakes and frustration. In fact restarting the application is not an option due to the time sensitivity of the MCI situation. The last common requirement relevant for touchscreen UIs is that all interactions elements may not be smaller than 22mm [Lew93].

**Special Requirements** To date, the information in an MCI situation is mainly captured on paper. Since this method provides an easy, familiar, intuitive and flexible way to realize the information capture task, the first requirement is to achieve a comparable performance with the tablet PC UI as compared to paper. Another special requirement from the fire department of the Technische Universitaet Muenchen (Feuerwehr TUM) is to use just the thumbs for all interaction tasks while holding the tablet PC with both hands. The fire department staff is using a heavy ruggedized tablet PC during their daily work. The model of the used tablet pc is xplora iX104. Because the interaction with the tablet PC is done through a stylus, the staff complained about the fact that holding it with one arm causes their arm fatigue. The usage of the stylus is imposed by the fact that the existing UIs for the tablet PC are not suitable for the usage of the finger, since the UI elements are too small and not adapted to the low resolution of a human's finger. With a stylus people can achieve a higher resolution but they must mentally focus on the UI elements. Therefore, to solve this problem, the users should be able to interact with the application while holding the tablet PC with two hands. This leads to the fact that only the user's thumbs are able to reach the screen. As a consequence the application must provide all interaction elements on the left and/or the right edge of the tablet PC screen as shown in figure 1.

For the first evaluation of this concept it was assumed that the user can reach an area of a rectangle in both sides. The edges of the hardware are not symmetrical on the "xplora iX104", which makes the interaction rectangles not symmetrical as well. The left side of the screen was reserved for interaction elements with a width of 19mm which is smaller than the recommended 22mm. For that reason, only elements not requiring high precision during interacting will be available on the left side. The right edge frame of the hardware is much smaller; i.e. more screen space is available, so larger UI elements with a width of 44mm are considered on the right side of the edge. These values are only estimations and

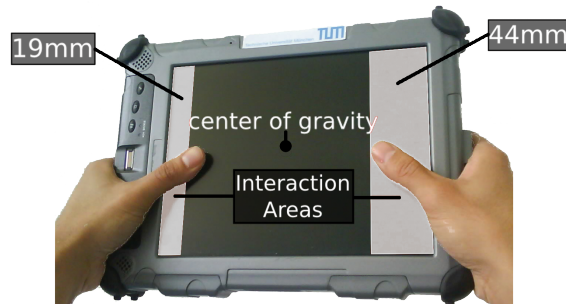


Figure 1: Tablet PC xplora iX104 holding in both hands

further evaluation with the test users will define the right size for the interaction areas and hence will give a better input to design an element with a specific shape in that area like a semi circle or other shapes. We expect that the optimal position for the user interface elements will be at the horizontal line going through the tablet PC center of gravity.

#### 4 Concepts to select patients

The UI of the map application will be developed gradually to increase the chance of its acceptance by the target group (EMC). The goal of this paper is to find an answer to the question: **How can patients be selected?** There will be different items like vehicles, special places, relief units or patients in the final application. Since the UI has to be completely controllable from the edge of the screen, items cannot be selected by just touching them. Three different UI concepts which fulfill this main requirement are introduced in this section. All of them will create special UI elements (buttons) at the edge of the tablet PC screen which can be reached with the thumb while holding the tablet PC in both hands. And since the space on the edge is limited, only a subset of all visible patients can be selectable at once. Therefore, how to determine this subset is the main topic of this section. To be able to compare the three selections methods with each other, all three should use the same buttons to finally select one patient among the determined subset. Those buttons are of type FishEye described at the end of this section. The three investigated selection methods are: Horizontal Line (SE1), Selection Quad (SE2) and Automatic Mapping (SE3).

**Horizontal Line (SE1)** One approach to select patients which are not reachable with the thumb is to draw a horizontal line from the user's right thumb position to the left hand-side of the screen (see figure 2). This line disappears when the display is not touched anymore. If the user slides his right thumb up or down the horizontal line will follow it. The speed of the line's movement is one-to-one mapped to the thumb's speed in order to make the movement more intuitive. Each patient intersected by the line will be a member of the

subset described before, and is therefore selectable through pressing the buttons on the left-hand side of the screen. This means that the patient is selected when the user presses the corresponding button with the left thumb. This way every patient which is visible on the current segment of the map can become selectable by moving the horizontal line.

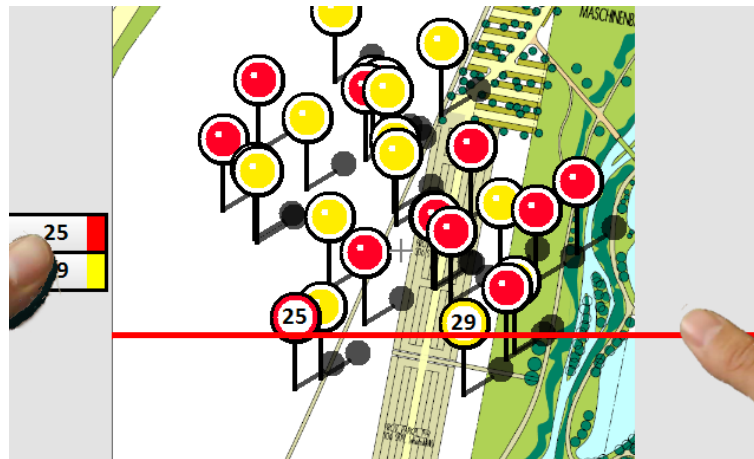


Figure 2: Horizontal Line (SE1)

**Selection Quad (SE2)** The approach here is to render a square on the tablet PC screen as shown in figure 3. Each patient who is inside this square is mapped to a member on the left side of the tablet PC and thus selectable by the left thumb. The user is able to move this square by a graphical joystick. In the contrary to the selection with the horizontal line there is a risk that there are too many patients inside the square, so there has to be a possibility to resize it. For this issue the joystick is extended with a plus and a minus button to control the size of the square. Even though this will increase the complexity of this selection method compared to the horizontal line, it also provides more flexibility to the user. Another advantage of this method is that the square can be used to scroll the map as well, if the screen's edge is reached, by holding the joystick in the desired direction. With this technique the users can even zoom or centre the map to the current square. In this first step only the selection feature of the square will be evaluated. Extending this method to allow zooming, centering and moving will be investigated in future work.

**Automatic Mapping (SE3)** Our last approach is to map all of the visible items to both edges of the screen. On the one hand an obvious advantage is that the user can select an item without the step of determining a subset (see figure 4). This alternative provides a button to toggle the selection on and off which makes it easier and faster compared to the horizontal line (SE1) and the selection quad (SE2). On the other hand this method introduces some undesirable effects. Since each patient can be selectable, every patient

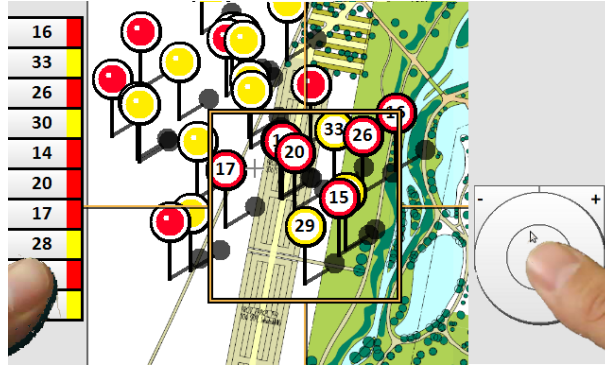


Figure 3: Selection Quad (SE2)

needs a correspondent button on the edge which requires more space from the limited interaction space. If the number of visible patients is moderately high, other solutions have to be researched, such as zooming the map automatically, or introducing a way to scroll the buttons up and down. To avoid the confusion of the user by introducing those extra steps, those solutions will be integrated if this last selection method of automatic mapping appears to give acceptable results in the first evaluation by the test person.

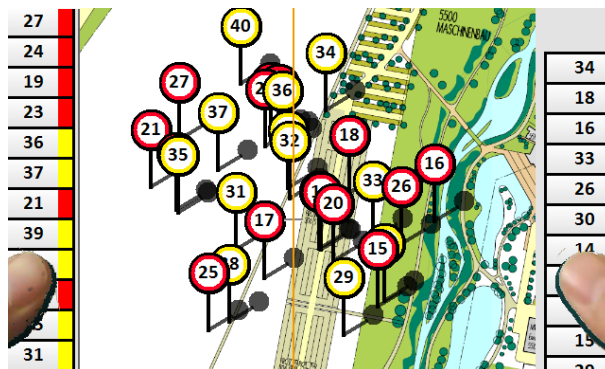


Figure 4: Automatic Mapping (SE3)

**FishEye Buttons** As previously mentioned the limited space for the interaction at the edge of the screen limits the number of buttons to be placed there. Additionally special attention should be paid to the general requirement that buttons should not be smaller than 22mm in width and should be even larger for the scope of our work. We decided to use buttons with a bifocal technique described in [Spe07]. In this technique the focus is set to a special point and a particular size of the space around this point becomes stretched. This is illustrated in figure 5. In our case the position of the user's thumb will be the focus point

when it hits the desired button. The other buttons which are at a certain distance from this focus point are rendered a lot smaller. This is not reducing the accuracy because the buttons at this focus point is immediately larger when touched. So the limited available space will be used more efficient. In the scope of this work we are not evaluating the FishEye buttons, we just want to evaluate different selection alternatives to determine the subset of selectable patients.

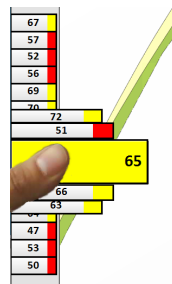


Figure 5: FishEye buttons

## 5 Evaluation

To develop intuitive, practical and powerful user interfaces it is essential to work together with potential users of the system. The users themselves need something to obtain a realistic feeling about the application and its features. Therefore, the first step is to gather the users' initial requirements. After this step, we are able to develop different UI alternatives which satisfy those initial requirements. Therefore we can have an initial evaluation of the UI by the users. The first part of this section explains the participants of this evaluation, followed by a subsection describing the procedure to be performed by the users. After that the results are presented and discussed.

### 5.1 Participants

According to literature we will learn the most from our first few test users. It is recommended to have between three to five test users, since more users will not necessarily improve the results of the evaluation [Nie94]. Therefore, the system was evaluated by five test users. In this first approach those test users were not from the rescue service. This decision was made because the **initial** usability issues are the same for most of the people during the **first** evaluation of an UI, whether they are from the rescue service or not. Actually, it is more important to choose people with low experience in the field of human computer interaction in this first step. People from different fields were randomly chosen for that reason: Two biologists, a political scientist, a sociologist and a jurist. The results



of this evaluation will highly improve the presented UI elements and may lead to filtering out of some elements. The remaining enhanced and optimized UI elements will **then** be evaluated with the rescue service team (EMC) in future work. All of the five test users (two females and three males) have low to average experience with computer interaction in general and with touchscreens in particular according to their own estimation. All of them were between 25 and 28 years old. To find out usability issues and to be able to rate the different UI alternatives, the test users have to use and experience the UI elements. Therefore, it makes sense to define the same task in all three alternatives to be performed by the users. The time duration it takes to finish a task, is measured for all users for each alternative. For each of the interface elements the users fill out two questionnaires: SUS (System Usability Scale) [Bro96] and AttrakDiff [HBK03]. After that a short interview is held with each of the test users. In this interview the test users are asked how they feel and think about the different UI techniques. This is important to find out the reasons for the scores of SUS and AttrakDiff and to be able to determine specific difficulties using these UI techniques.

## 5.2 Procedure

During the execution of each task the test user is observed to detect some usability issues and clarify potential ambiguities faced by the test users. To avoid the learning effects, the sequence of the different alternatives are randomized. During the interview phase, the test users give their feedback and experience multiple UI alternatives. Finally, the test users are asked to choose and argue about the preferred UI alternative for selecting patients. Concerning the task description, there are 26 patients at the beginning displayed at the center of the map, and the ability to move or zoom the map is disabled. The patients' locations and triage states will be the same for each alternative. The test users are first asked to select every red categorized patient, then every yellow one with each alternative. Every selected patient will disappear immediately in this test scenario from the map. The task is completed when no patient to select is left on the map.

## 6 Results

In this section the results are presented for each UI selection alternative and discussed. In the first paragraph the results of AttrakDiff are recapitulated, while the next paragraph summarizes the results from SUS. Finally the outcome of the test users' feedback during the interview will be summed up and discussed.

**AttrakDiff** The results of AttrakDiff are divided into four dimensions (see figure 6 (a)). The first two dimensions describe the hedonic quality of the UI and enclose stimulation and identity. For the stimulation part the selection quad (SE2) shows the best results while the automatic mapping has the highest score in the remaining three dimensions. The dif-

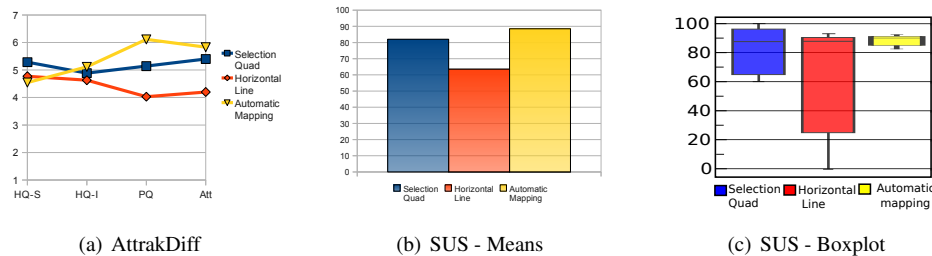


Figure 6: Results for AttrakDiff and SUS

ferences between UI alternatives are higher for the pragmatic quality (PQ) and the attractiveness (Att). Moreover, the order of the scores for the identity quality, pragmatic quality and the attractiveness respectively are the same. That means, the automatic mapping (SE3) has scored the best results in all three qualities followed by the selection quad and finally the horizontal line. Nevertheless, the results are good for all alternatives since the score is never below four, but there are evident tendencies for the automatic mapping alternative.

**SUS** The results for the system usability scale support the results from AttrakDiff (see figure 6 (b)). Actually, the usability of the automatic mapping alternative obtained as well the highest score of 88.5 among the three alternatives. Figure 5 (c) shows clearly that the results of the automatic mapping alternative are very decisive since all test users rated this alternative in an interval between [82.5 ; 92.5]. Even though, the selection quad alternative obtained the second best score with a mean of 82.0, the test users rating was spread over a bit larger interval of [60.0 ; 100.0] compared to the automatic mapping alternative. The reasons for those scores become clearer after the interview and the feedback of the test users.

**Interview** The interview shows that the reason for the low score of the horizontal Line (SE1) is that the line was too thin to intersect the patients easily. That is even more disadvantageous for the specific task performed by the test users during the evaluation where they had to select all patients. However, if the specific task is to select one patient among a huge number of patients geographically, the horizontal Line (SE1) might score the best among the three UI alternatives. This has been also confirmed by one of the test users. The selection quad is not immediately understood from all the test users which make this alternative not as intuitive and practical as the automatic mapping. A better visualization of the functionality and the usage of the selection quad could improve its usability and practicality. Even though the complexity of the selection quad is higher than the automatic mapping, it provides also more flexibility to the user since scrolling and zooming can be integrated in a very compact way with no extra UI element. This benefit could not be seen by the test users during this evaluation because the scrolling and zooming feature of the selection quad was disabled for this evaluation.

## 7 Conclusion and Future Work

During this evaluation, the automatic mapping was clearly rated as the best selection technique. But this result has to be regarded carefully, since this was an initial evaluation with a predefined task. This task is not representative for all possible real tasks in a real MCI, in our case the result of the evaluation is strongly bounded to this task. Nevertheless the evaluation points out important issues for all three alternatives. Investigating those issues and learning from the test users' feedback, improve greatly the proposed selection technique. Within the SpeedUp project there is ongoing work researching the best UI scrolling and zooming alternatives based on the same requirements presented in section 3. So the next step is to combine the alternatives for these three basic map features (selecting, scrolling and zooming) which was rated with the highest scores and integrate them to a compact system. Additionally, a new UI alternative with all basic map features has to be introduced for the purpose of evaluation. Finally, defining new tasks is also needed to heavily evaluate the UI alternatives; those tasks should make the user employ all provided UI alternatives features.

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