TOUCHPAD AS INTERACTION INPUT CONTROL FOR USE OF IN-VEHICLE INFOTAINMENT SYSTEMS

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ABSTRACT
There is evidence that In-Vehicle Infotainment Systems (IVIS) with complex interactivity can distract the driver and that new interaction methods are needed. We report on and assess the suitability of a multi-touch touchpad controlled IVIS from an interaction design perspective. In summary the results show that a rich multi-touch controlled interface can be developed that users accept and like, regardless of previous personal preference of touchpad usage. The results indicate that a bi-modal feedback system, either visual-audio or visual-haptic is necessary to facilitate necessary driver control with regard to road safety.

KEYWORDS
HMI (Human Machine Interaction), Touchpad, IVIS (In Vehicle Infotainment Systems), automotive, interface design, multi-touch, gestures, usability, multi-modal

INTRODUCTION
In recent years the car industry has taken steps towards a more centralised interaction model for the IVIS functions. This measure aims to reduce clutter in the driving environment while maintaining safety and at the same time increasing the IVIS functionality [7]. This has typically been done with some kind of rotary control or touch-screen [6], with or without multi-modal feedback. When using a rotary controller the driver typically has to convert circular input movements to unintuitive linear cursor movements on the screen [7]. Contrary, interfaces made for touch-screens are usually very tangible and intuitive, but can instead suffer from a slightly unfavourable display position, since the display has to be easy to reach for the driver. Research shows that display position has an impact on driver efficiency; if the display is placed far from the drivers normal forward field of view, the driver's peripheral vision cannot be effectively used to detect unexpected events in front of the vehicle, which is the case for some touch-screens [6].

However, using a touchpad, which is a pointing device (commonly found at e.g. laptop computers) that can translate the motion and position of a user's fingers to a relative position on a screen, as input device offers several advantages. Firstly, menu items and other interaction elements can be displayed with a good natural mapping [4], that makes the system intuitive to use. Secondly, the display can be mounted in a high position with the touchpad separated from
the proximity of the display, as the driver can operate the touchpad with feedback from the screen without looking directly at the touchpad. A high display position has a smaller distance in degrees from the drivers forward field of view, and less implications on refocusing the eyes compared to a lower display position [5]. Thirdly, with a touchpad, cursor movement can be controlled in two dimensions by moving the finger in the desired horizontal or vertical direction [7].

The main purpose of this study was to investigate the potential of a touchpad as the main interaction principle for IVIS and perform a subjective evaluation to investigate the user acceptance towards the technology. A conceptual design solution with multi-touch gestures was developed and evaluated to establish how well the concept could handle the challenges that comes with the next generation of infotainment systems.

Figure 1 - Detailed overview of prototype set-up

METHOD

Process
The work was divided into three iterations with each consisting of a number of steps and a series of questions that needed to be answered. A brief overview of the agenda is listed below and the results from the third iteration will be presented in this paper:

• First iteration
  • Gather knowledge about the problem
  • Create a concept sketch to be implemented and tested
• Second iteration
  • Implement a concept
  • Test the concept in test vehicle
  • Test the concept in simulator
• Observe users and gather opinions from experts
• Third iteration
  • Create a graphic identity for the concept
  • Improve implementation after observations
  • Conduct user testing with experts and regular users
  • Identify further studies

**Technology**

Four basic parts were needed to build the concept:

• Capture program
• Touchpad
• Laptop
• Driving simulator/test vehicle

The capture programme handles gesture recognition and runs on the touchpad, which is an iPod touch. The touchpad sends the interpreted multi-touch gestures wireless as input to the interface simulation program that runs on the laptop. The laptop is connected to the IVIS display, that displays the interface simulation in the simulator or car (see Figure 1 for an overview of how the different components were connected).

**Test vehicle**

Volvo Cars Corporation in Gothenburg has a specially equipped Volvo XC90 dedicated for use in clinics and user tests of driver environment and IVIS functionality. All controls, except those necessary for driving, is connected to a laptop that can use the controls in the car as inputs to an interface simulation. The car is equipped with an IVIS display (approx. 7”) in the centre of the dashboard, that can be used to test graphics, interfaces and other visualisations under real driving conditions.

**Driving simulator**

The driving simulator was a fixed base simulator with the interior from a volvo car similar to the XC90, assembled in a room in front of projector screen. The IVIS display set-up in the simulator is very similar to the one in the test vehicle with the same display size. The simulator can display a number of scenarios, but during the tests in the second iteration a rural driving scenario with little to medium traffic was used to test the expert group. The scenario was selected to be easily managed by any driver in a normal driving situation.

Simulator driving has been shown to affect the judgement of the test subjects, which causes them to overestimate their driving capabilities, compared to a real driving situation [2]. However, this should not have affected the outcome of the experiments conducted, since the user tests were focused on user experience and not on task performance.
Concept

The tested concept consisted of a visual interface and a touchpad mounted between the front seats in the testing environment, behind the gear stick (driving simulator and test vehicle). The interface and was built to have a very wide menu hierarchy, as research shows that menu width is preferred over depth by users without negative impact on performance [3], [1]. The wide hierarchy was also an effort to reduce the number of choices imposed on the driver and give access to fewer functions of higher importance. At the same time an effort was made to create a logical grouping that would make the interface as shallow as possible. A result of a wider hierarchy is a higher information density in each screen which is preferred by users over lower information density (see Figure 2) [1].

![Figure 2 - Interface with wide hierarchy](image)

Higg’s law and Fitt’s law was used to make the pointer actions easier for the drivers, and the selection on the screen was always active (the cursor could not “just disappear” as it sometimes does on a PC) in order for the driver to maintain control at all times (see Figure 3).
The prototype was built to use three different gestures to control the functions in the IVIS. These forms the foundation for interacting with almost any imaginable application in the system on a standardised way.

A 1-finger gesture, i.e. regular pointing on a touchpad, was used to move the selection and to input alpha-numeric data by drawing the characters with the fingertip on the touchpad surface. A 2-finger gesture was used to move and pan the different screens in the interface and a 3-finger gesture was used to zoom in- and out in the interface, including on the map in the navigation view (see Figure 4).
The touchpad was equipped with a special “home-button” that took the user directly to the start screen, which provided an exit at all times and prevented the user from getting lost in the interface. There was also a favourites bar that contained shortcuts to different functions e.g. waypoints to “the store”, “the office”, “Radio station 1 - 107,3 MHz” so fourth (see Figures 2 and 3) by which frequently used functions could be easily accessed, customised for the particular user.

Evaluation

User tests

The goal with the evaluation was to measure user acceptance and capture thoughts about multi-touch interaction with a touchpad in an in-vehicle environment. The technical performance of the concept was sufficient to conduct these test, but not enough to measure task performance in any meaningful way. However, the conceptual performance was very good, with many interesting concepts available as described above. The participants in the evaluation consisted of 15 persons in two groups, one with experts and one with novice and they had these characteristics:

- Expert group
  - 9 participants
  - Expertise in interaction design or a field related to car industry
  - Education was on average a master degree
  - Age ranging from 20-60 years old
- Novice group
  - 7 participants
  - No particular correlation in background e.g. one person was a teacher, one a fashion designer, one a project manager
  - Education ranged from college to master degree
  - Age ranging from 20-30 years old

The evaluation was divided into five parts and took approximately 90 minutes for each of the groups:

- Presentation of concept with screen-shots and explanations of the interaction model
- Questionnaire where the test participants filled in their background information and their touchpad experience and attitude towards touchpads (e.g. like or dislike touchpad usage on a laptop)
- Concept evaluation in in-vehicle environment (no real driving or driving simulation); however simulator tests were conducted with the expert group during the second iteration of the project - the findings of those tests were used to design the interface as presented in this article.
- Questions that served as subject for group discussions among the participants
- Another questionnaire part where the participants individually rated the different features of the interface prototype (e.g. rate what you think of using the 2-finger gestures for panning the map, see Figure 5)
The results from this evaluation consisted of comments from the participants and the data from the questionnaire. Figure 6 shows the average rating for the different parts of the concept. The coefficient of variation has been added to display the quote of the standard deviation to the mean, as a measure of how much the answers differed among the participants (see Figure 7). A low number indicates that the participants have a agreed on a particular rating and a high number indicates that the participants have given different ratings on a particular property. I.e. 0% means that all participants gave the same rating (1, 1, 1, etc...) and a higher percentage will be generated by a more varied set of ratings, for example (1, 2, 3, 4, 4, 4 etc.).

Figure 8 shows a plot of the relation between the concept average rating and the touchpad average rating for each participant in the evaluation. The concept average rating was calculated from the prototype assessment answers in the questionnaire and the touchpad average rating was calculated from the touchpad assessment answers from the questionnaire. The questions where of the type shown in Figure 5, asked individually to the participants via the questionnaire.

1. Do you think the way to select an element in the display works well?
   Not at all | Very much | Don’t know

Comment:

*Figure 5 - Example of question in questionnaire*

The questions concerned all aspects of the interaction model (1-finger select, 2-finger pan, use of home button, etc.) proposed in this paper. Each bar in Figure 6 and 7 corresponds to one question, each of similar character shown in Figure 5.

The solid line in Figure 8 shows that the slope of the concept average rating (y-axis) is very gentle as a function of the touchpad average rating (x-axis), which means that on average all users like the concept regardless of their attitude toward working with a touchpad as input device. The rating would be on average at least 3.69/5 and at most 4.16/5 if the user disliked touchpad or liked touchpad respectively. The character input method was disliked by novice users, probably because it was implemented with a relative pointing style, which made it hard to use. I.e. to move the cursor you have to drag your finger relative to the cursor position on the display; dragging left moves the cursor to the left, regardless of where on the touchpad the dragging motion is initiated. To make the character input work well with the finger as stylus, the touchpad should operate with absolute pointing style. I.e. the whole surface of the touchpad directly maps to the whole display area, point in the left corner of the touchpad and the cursor immediately appears in the left corner on the display. This is the natural way for humans to write with paper and pen. Another comment from novice users were the lack of support to spell words. Some of the novice participants explained that they used the keyboard (e.g. on a computer) as a tool to remember how to spell certain words, and that the lack of this made it hard to recall the spelling. This problem can be solved by adding a context aware spelling support, that shows word alternatives in a list, from which the user can choose an appropriate word. The experts
liked the input method better than the novice, probably because they had previous knowledge of other input methods and saw an advantage in using the finger as a stylus.

**Figure 6** - Concept average with coefficient of variation (n=15)

**Figure 7** - Concept average with coefficient of variation (n=15)
Driving test

This part was performed by the author as only participant and therefore it does not provide any statistical significance. However, the results were nevertheless interesting and worth mentioning for future studies.

The test vehicle was used for a driving test, to evaluate how the prototype handled in a real driving situation, compared to the more controlled environment in the simulator. The prototype was in the same state that previously had been tested in the simulator and the test consisted of a 30 minute driving session within the gates of Volvo's Torslanda facilities. The driving conditions can be compared to driving in a small city centre on a weekday with little traffic. There were some stretches of oncoming traffic, at speeds lower than 50 km/h and yielding to cars in some situations. Compared to the simulator tests performed in iteration two, this environment was more demanding and that made it harder to control the simulation with the touchpad.

The previous results from the simulator in iteration two indicated that the system worked fairly good, but the driving test turned out to be really interesting, as the experience differed a lot from the driving in the simulator. When driving a real car the impressions are much more vivid and the sense of danger is more real compared to the artificial danger in the simulator. It is easier to become overconfident in a simulator than in a real car, and overconfident driver behaviour has been observed in simulator studies [2]. Unfortunately, due to security regulations only the author could perform this testing, but it would certainly had proven to be a very useful test if more participants had been able to participate. However, the findings indicate that final user-testing ultimately should take place under real conditions, in the test vehicle, to get the best results, but unfortunately that was not possible.
The most important observations from the driving test:

- Cursor speed is very important to give the user control over the interface
- There is a large leap from testing in a simulator to actually using the prototype in a vehicle

**DISCUSSION AND CONCLUSION**

Driving is a very physical experience with levels, buttons and forces acting on the driver, in this context that is a challenge for using the touchpad as an input device, as it has to provide feedback and enable the driver to stay in control. The results in this paper suggest that the use of a touchpad as interaction input device for an IVIS system is possible if the system has been designed with the advantages and disadvantages of using a touchpad in mind. At first the touchpad appears to be a bit hard to operate compared to other techniques, mainly because of the lack of physical properties. This can be compensated for by making a more dull control in the interface, which is possible since the cursor sensitivity of a touchpad can be tweaked in a full spectrum from simple push button to a high resolution control with multiple dimensions available through the use of gestures. Necessary haptic or auditory feedback can be added to give the system a more tangible impression and better performance. A study investigating the effects of bi- and tri-modal haptic and auditory feedback in a touchpad controlled IVIS system concludes that bi-modal feedback was the most efficient, with auditory ranking slightly higher than haptic [7]. However, this might be a result of the participants being more used to auditory feedback and hence they responded better to that [7].

The use of a touchpad with multi-touch gestures gives access to many degrees of freedom in a natural way of interaction. How many depends on the number of gestures used. Three gestures have been proposed in this paper, which provides the basic interactions necessary for a complete IVIS system including unrestricted Internet navigation.

Some observations regarding ergonomics indicate that the touchpad surface texture has to be a bit rough to decrease finger to surface friction, which otherwise prevents the driver from controlling the system. The pad should be mounted in an angle with the front edge placed a bit lower than the back edge as it gives the user a consistent feeling of resistance, when swiping the fingers in the back and forward direction of the pad. A good armrest and wrist support has to be in place behind the pad to give the user proper control of their finger-movements.

The touchpad is not as solid as a physical control which results in more fragile interaction, which can be compensated for by adjusting the resolution and pointing style depending on application and driving situation. The lack of multi-modal feedback affects the interaction and demands very good graphic design to make the interface easy to use. A solution to this is to use two modes of selection, one coarse driving mode that strips the system of functionality and allows the driver to perform basic actions, and one finer mode that allows detailed manipulation e.g. dragging and placing a destination on the map when traffic situations allows that.
The trend to put more functions into the IVIS system without investigating the user requirements and the actual use of these functions should be considered to be revised. Very simple observation based studies can be performed to gather information, which can be used as a starting point for this work towards a more user-centred design process. Statistical data about user patterns should be collected to better design the system for the drivers. For example, mounting a small video camera in the ceiling of the car interior could be used to capture user activity and when the video is fast-forwarded the user patterns will emerge. This information can be used to reduce the amount of levels in the interface and information relevant for the context can make the system easier and less demanding to use. The favourites bar proposed in this paper works as a way to avoid complex menu navigation in a number of cases. This could possibly increase performance statistically over time, since functions often used can be accessed without entering any menu at all. In combination with the home button this makes navigation backwards in menus obsolete in the cases where a favourite is used. Character input should be reduced to a minimum as it is resource consuming. Spelling support and word suggestions should be provided to simplify the action.

The age of the novice participants could have been spread in a wider range that 20-30 years old to possibly get a more varied result. The implications of their comparatively low age, might be that they are more susceptible to new technology and therefore gave the prototype a better rating in the evaluation, than an older group would have done.

The driving test performed in the real car gave a very good perspective on how different a real driving situation is from an office environment. It is recommended that system- and interaction designers try out their prototypes in a real car during a prototype stage, to get an understanding of how one is affected by the system and what properties are important. The results are not trivial, for example, small animations can be very disturbing when driving, though they seem very subtle and informative and well designed in the office. Another example is colours, they might seem perfectly fine on a computer screen in the office, but in sunlight on a display made for a car they may be too washed out to be useful. Yet another example is the effect of input controls, what sensitivity they have, how you operate them, etc. The control and the distractions you are exposed to, greatly affects the perception of a systems capabilities and weaknesses. In a real driving situation these are perceived much different from an office or simulator environment.

In summary the results show that a rich multi-touch controlled interface can be developed that users accept and like regardless of previous personal preference of touchpad usage, but it should to be equipped with feedback in one more modality than visual to give the users proper control.
REFERENCES


