Design of Human-Map System Interaction

Thomas Porathe
Malardalen University
SE-631 05 Eskilstuna, Sweden
thomas.porathe@mdh.se

Johannes Prison
Chalmers University of Technology
SE-412 96 Goteborg, Sweden
johannes.prison@chalmers.se

Abstract
In this work-in-progress we present some ideas and findings involving map design and human performance. Satellites has once and for all automated geographic positioning and resulted in a plethora of map applications, not only in professional transportation but also in the private sphere, in cars and even for street use in mobile phones. But many people have problems using the traditional bird's-eye view maps. The maze experiment presented here show that an egocentric ("out of the window") view of the map results in faster decision making and fewer errors. Can this also address some of the human-out-of-the-loop problems of navigation automation?

Keywords
Map design, 3-D nautical charts, maritime human factors

ACM Classification Keywords
H.5.4.Navigation. General term: Human Factors

Introduction
In 1999 the Norwegian high-speed ferry *Sleipner* crashed against a rock at full speed causing the death of 16 people. In spite of the fact that the vessel was equipped with all modern technical facilities the bridge crew lost their orientation for 23 fatal seconds. The system onboard was actually never lost, all the

instruments showed the right digits, but the humans interpreted the system wrong. So we may say that the interaction between the human and the systems failed.

When we showed a navy officer a new intuitive way of displaying nautical charts he said: "With such a system anyone can drive a ship". He meant that he was concern that some of his craftsmanship of navigation would be lost, but also that the systems made the task so simple so anyone could get the job done.

Today GPS supported electronic maps are everywhere. But a lot of people have difficulties reading maps. The problem with mental rotations [6] is well documented and effectively stops many persons from a simple use of electronic maps. Furthermore, it is well documented that spatial ability decline with age and favors male [3].

Navigation

Navigation is the aggregated task of wayfinding and motion [1]. Not long ago this was an extremely difficult task. Today, thanks to satellite based positioning systems this is all done automatically. Before the voyage the navigation officer enters the waypoints of the decided route into the navigation system. The track is then displayed on the electronic chart as a line together with a symbol showing the ships present position. The autopilot will then take care of course keeping. All the navigator has to do is to monitor the system. But sometime situations occur when the human is forced to take manual control. It may be incidents involving other ships, or bad weather which the autopilot cannot cope with (like in the *Sleiper* accident). It is then important that the electronic map system has kept the human in the loop to facilitate a switch to manual control.

Map design

Whenever an area is larger than one can overlook from a single position some kind of mental support is needed. Maps have been around for a long time (see Figure 1). The view has been that of a bird looking down on a world where the user has to imagine him or her as an object traveling over the map. Parallel to this, sailing descriptions have existed, later illustrated with egocentric view coastal views (see Figure 2).

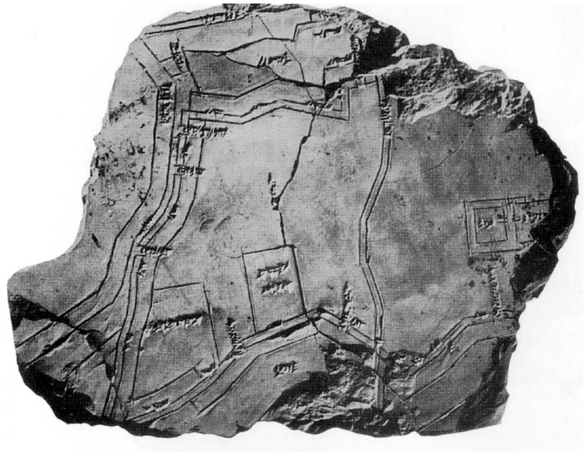


Figure 1. Early exocentric map. Clay tablet from Mesopotamia from the 16th century B.C. British Museum, London.

Figure 2. Early egocentric map. A coastal view incorporated in a sailing direction over the French west coast: *Ushant* is the English name for Île d'Ouessant at the western tip of Bretagne. A woodcut from Robert Normans 1590 *Safegarde of Saylers*.

However not until today the technical means of creating dynamic coastal views have existed. By creating a 3-D model of the map and letting the navigation system position the camera, a dynamic egocentric view can be created (see Figure 3).

The relevant question is then of course: does such an egocentric view really facilitate human understanding?

Maze experiment

To answer that question a laboratory experiment were conducted. On a 6 m by 6 m area in a studio a 10 by 10 invisible grid was created. In this grid four mazes were designed, each with an equally long track with an equal number of turns. Each track lead from a start position to a goal and for each design one traditional exocentric map and one 3-D map was prepared (see Figure 4).

In a first block 45 amateur navigators (students and university employees) and in a second block at a Maritime Academy 30 professionals (bridge officers) drove once through each of the four different tracks. Each time using one of four different map types. The order of the map types was randomized. The four types can be seen in Figure 5. An infrared tracking system mimed the GPS system and sent the position of the cart to a laptop computer fitted on the cart. The subjects were told to drive through the maze as fast as possible with as few “groundings” (entering into the red squares) as possible. The results were statistically significant and showed that the egocentric 3-D view

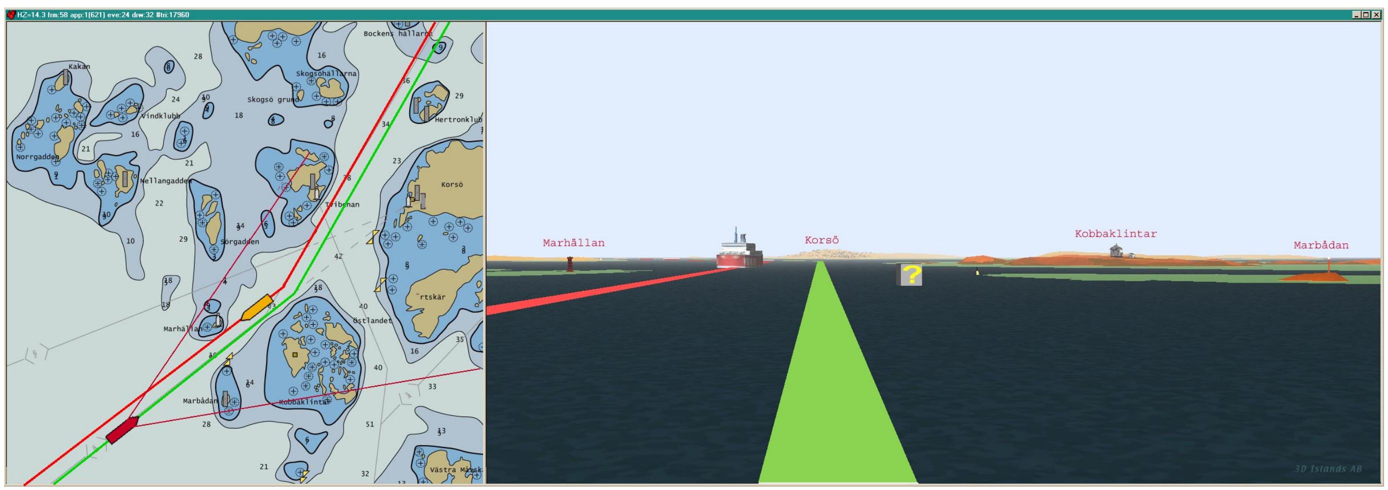
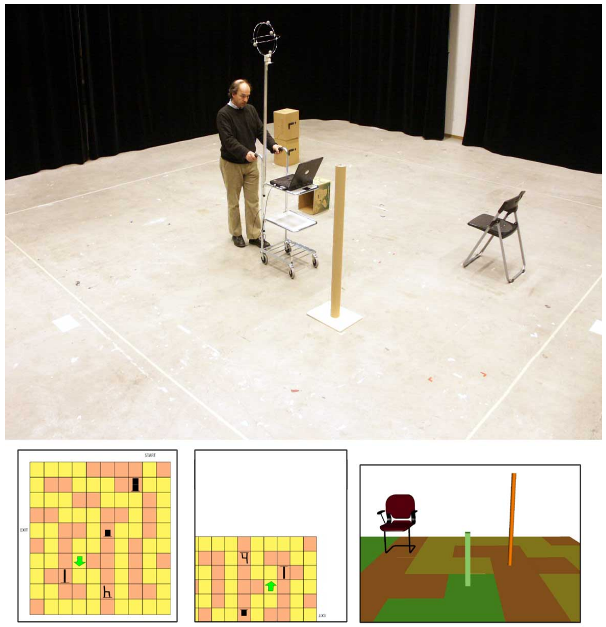


Figure 3. Two nautical chart displays. To the left the traditional exocentric north-up bird’s-eye view and to the right the new egocentric out-of-the-window view. (Screen dump from prototype application).



A B C

Figure 4. Top, the studio area acting as the maze with its landmarks (boxes, a tube and a chair). A cart was wheeled manually through the maze. Bottom left (A) the 2-D map in the north-up mode as it was shown on the screen of the lap top computer on the cart for the very position shown in the top picture. The middle (B) map is the 2-D map in course-up mode and right (C) is the 3-D map. The maps depict the cart's position in the large photo.

provided faster decision making and fewer errors than the traditional map types (see Figures 6 and 7). For more details of these experiments see [4] and [5]. After having done their four sessions with different maps each subject were asked to rank the user-friendliness of the four different map types on a scale between 1 and 4. The egocentric 3-D map was clearly ranked as the most user-friendly (see Figure 8).

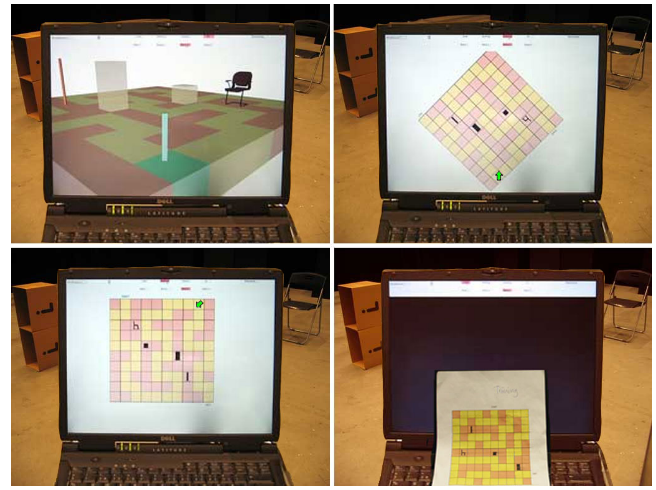


Figure 5. The four different map types: Top left the egocentric view 3-D map; top right the exocentric head-up map; bottom left the exocentric north-up map and bottom right the traditional exocentric paper map.

Discussion

In the first block the experiment was conducted on available students and staff at the university. They were all amateur navigators. The study clearly showed that maps supporting cognitive off-loading were more efficient: when the subjects needed to do fewer mental rotations they made faster decisions about the way through the maze and fewer errors. Next we wanted to test if these results would hold for professional navigators schooled in performing precisely these kinds of mental rotations. Much to our surprise they did. They had the same trend of higher efficiency with fewer

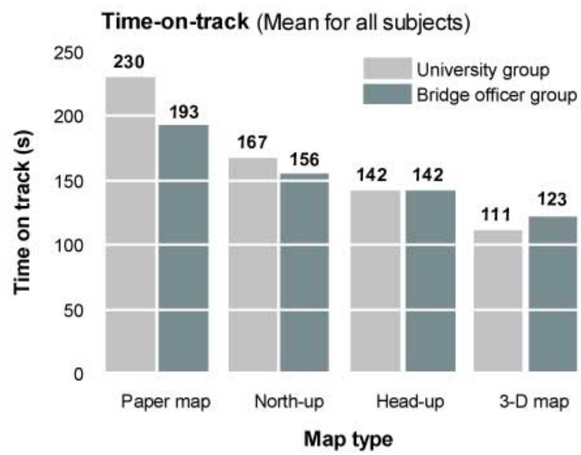


Figure 6. The time it took for subjects to pass through the maze.

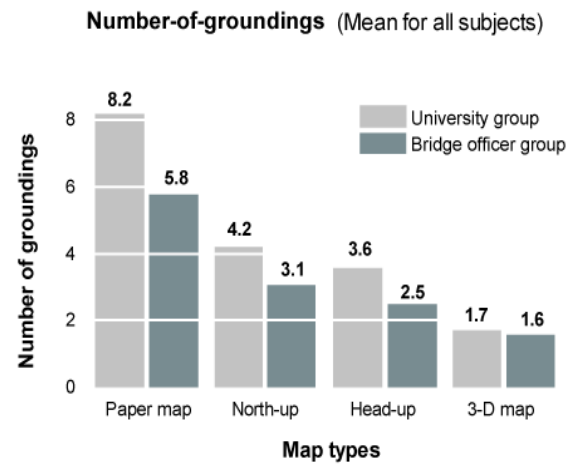


Figure 7. The number of groundings (cart entering a forbidden red square).

mental rotations. As expected they did better than amateurs when using exocentric maps in north-up, but surprisingly they did equally well as amateurs using head-up maps (an orientation mode seldom used by mariners), and worse than amateurs on the 3-D map. We did not ask the amateur group for computer gaming habits, but we did ask the professional group and found no significant correlation between gaming habits and results in the maze.

The professional group is doing over all better than the amateurs when it comes to errors. We interpret this as a result of the professionals' knowledge of the true consequences of a grounding. In a speed-accuracy trade-off they prioritize accuracy which may not be the case with the amateurs, which also has to be taken into account when looking at the speed results.

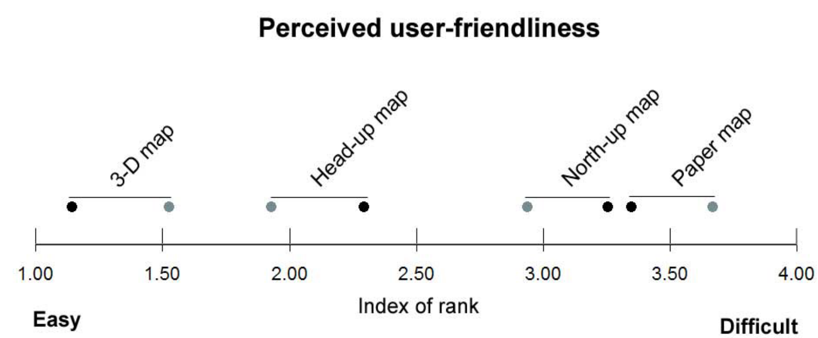


Figure 8. Results from the ranking of user-friendliness.

Never the less there is a stable trend that the differences in navigation performance between the schooled and the unschooled group is equalized when using displays modes that remove the need of making mental rotations.

Conclusion

By removing the need of performing mental rotations the 3-D egocentric map display lessens the cognitive workload of the user. A known problem in automation is that operator tasks changes from manual control to monitoring [7] [2]. This in turn leads to what has become known as out-of-the loop performance problems, meaning that if something goes wrong forcing the human to retake control, she often lacks in situation awareness and valuable time is then lost trying to regain situation awareness and control which might lead to a potentially disastrous situation. When vehicles navigate on autopilot and a monitoring crew members need to retake immediate control, for example to make an evasive maneuver for another ship, the time to realign the map with the real world through a number of mental rotations, might be just too much. A cognitively less demanding display system might save those valuable seconds.

Map applications in cars and mobile phones become more and more frequent. So called "3-D modes" are today standard in most applications. Very little research is presented on the human-machine interaction of these map systems; we hope that these findings may add to the knowledge in this field.

Future work

The laboratory experiment concluded the first phase of this project. For the coming year sea trials are planned in the Goteborg archipelago in Sweden. Ecologically valid tests are important as unforeseen contextual factors might play a role. However in a field experiment redundancy and safety issues is anticipated to cause less clear results. The overall aim of the project is to produce knowledge for a new generation of 3-D nautical charts as a foundation for safer navigation.

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