Fovea-Tablett®: A New Paradigm for the Interaction with Large Screens

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Abstract. Today's desktop computers can be regarded as evolution of the typewriter. They are well suited for office applications but far from optimal for e. g. mechanical design, traditionally conducted on large drawing tables. Large screens are nowadays widely available for table-like computer workplaces. But their resolution is still too poor. To overcome this drawback the »fovea-approach« has been developed. A slim tablet PC (the so called Fovea-Tablett®) can be put deliberately on top of a large table screen. The position of the tablet in relation to the table screen is tracked and the screen content of the table display just below the tablet is displayed on the Fovea-Tablett®: just as if one would look through the tablet onto the table but with higher resolution. Whereas the table display is still good for overview, the Fovea-Tablett® brings highest resolution to the region, one is just focusing on.

1 Introduction

One basic idea of ubiquitous computing and ambient intelligence is to bring computer-based tools back to that, what already Aristoteles found roughly 2400 years ago: that »*every instrument is best made when intended for one and not for many uses*« [1]. The widespread desktop as well as the notebook computers can be regarded as the evolution of the typewriter: from an ergonomic point of view well suited for editing letters, setting up spread-sheets or preparing presentation slides, but in between overloaded by a vast amount of very different applications. So the classical drawing table nearly vanished as design workplace for engineers and became replaced by a desktop computer with one or two moderately large screens. But today's CAD[1] workbenches do not reach the ergonomically optimized size of the drawing table that allowed over the span, comfortably reachable by the two hands of the designer, a coherent view over the whole design object as well as a high resolved look onto that detail, the designer is currently working on (see Fig. 1, right hand). Nowadays the designer must either steadily fiddle with the zoom factor if he wants to change between overview and detail. Or he loads the overview on a separate screen what

[1] Computer Aided Design.

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dismembers the coherence of the object and causes additional cognitive workload to fit together the two views mentally. The same goes for the work with geographical maps for e. g. navigation planning (Fig. 1, left hand), planning of military operations or management of natural disaster relief activity. Before computers offered a rich functionality for map display and GIS[2]-supported geospatial reasoning, maps were laid out on a rather large table with a team of specialists grouped around it, performing their job by communication among each other logically *and* physically over the map. Today the teamwork is done mostly in front of the projection of a computer generated map: with the advantage of common view, but restricted possibility of common interaction with the geospatial information. And the detail work is conducted by single specialists in front of a common desktop workplace with the same problems as described above for the CAD.

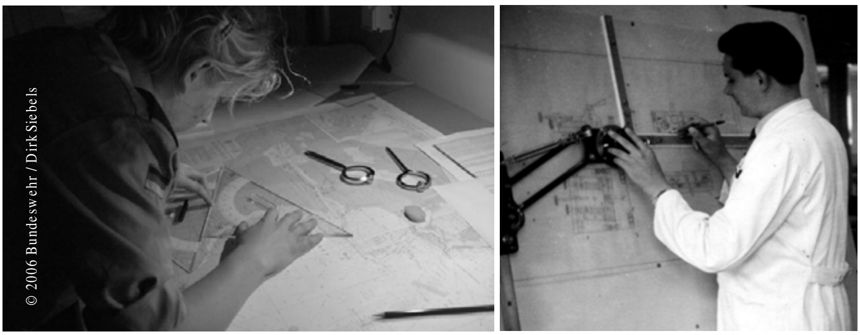

Fig. 1. Traditional work places for navigation planning (left hand) and mechanical design

Technical limitation in the production of wide-area computer screens to an affordable price retarded the construction of ergonomically optimized large screen computer-based workplaces for applications as discussed above. But in the most recent years one could observe a breakthrough of large flat panel displays based on LCD technology (Liquid Crystal Display), the most common computer display technology in between. Reaching a diagonal width of 50 inches and above they offer a much higher pixel density than the also large and since many years established plasma screens. The main driver for those large LCD screens is home television/cinema that opens a worldwide and highly attractive market. But are they also well suited for the future computer-based drawing or mapping table?

From Fig. 2 we can see, that for a viewing distance of 3 m (assumed as reasonable for home television) a resolution of more than 30 ppi (pixel per inch) is required to make the pixel lattice unperceivable. If we assume a 50 inch screen with 16:9 ratio and a common image size of 1.280 x 720 pixels (video standard HD 720), a resolution of 30 ppi will be achieved. This is sufficient for watching TV from the sofa in your living room. But even the image size of 1.920 x 1.080 (HD 1080) of a high end screen would only yield a resolution of 44 ppi. And this is still much less than enough if you take such a screen as drawing table and work on it from a distance of lets say 60 cm.

[2] Geographical Information System.

On that distance a resolution of at least 150 ppi is required in order to perceive sufficient detail and not to become distracted by the pixel lattice (see Fig. 2). To achieve this resolution a hypothetical image size of at least 6.600 x 3.700 would be necessary for a 50 inch 16:9 screen.

If we assume, that large flat panel displays with this image size will not be produced to a price affordable for the mass market in the near future, we see two choices. The first one is to assemble a large screen from a couple of smaller and higher resolving ones[3]. This »tile approach« is straightforward and, for vertical display walls and with rear projection instead of flat panel already realized with e. g. the HEyeWall [2]. Its drawbacks are the high technical effort to assemble the panels seamlessly and to provide a satisfying radiometric continuity over the whole display.

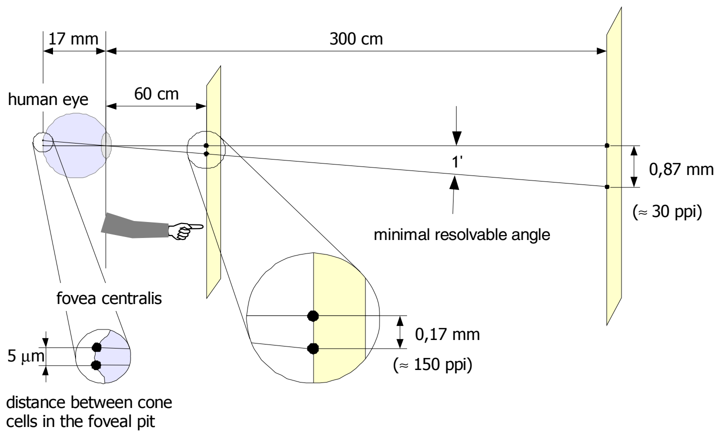

Fig. 2. Required ppi (pixel per inch) on a display derived from the least resolvable angle based on the distance of cone cells in the small foveal pit of the human eye; the distance of 60 cm is suited for touchable screens, the distance of 300 cm for e. g. home cinema

The second approach starts with remembering how the human (and other mammal) eye is designed. The so called fovea is the small area of the retina for sharp and detailed visual perception. The foveal pit (see also Fig. 2) covers only 1 ° of the visual angle but carries the highest density of the colour receipting cone cells (roughly 140.000 cells/mm^2). Outside the fovea this density falls quickly down to about 10 000 cones/mm^2. The eyes are steadily moving in order to focus sequentially small spots of interest whereas the retinal periphery is only taking care for the overview. Having in mind this very economic design of nature, we can combine a large flat panel LCD or a similar rear projection device with its poor resolution as display for the overview, and put a smaller, but much higher resolving display device, e. g. a tablet PC, on top of it for the detail view. The first step towards this idea has been undertaken by Baudisch ([3]) who fit a LCD screen into a large whiteboard, serving as screen for a front projection. While the large projected image showed the whole scene, e. g. a map, the

[3] E. g. 3 x 3 14" screens, each with an image size of 1 600 x 900 and a resulting resolution of 130 ppi, would be a big step towards the requirement for a drawing table.

LCD in the middle showed the respective cutout with higher resolution. With [4] a similar method was published but with two differently resolving projections instead of the combination of projection and flat panel. The disadvantage of those solutions is the fixed relation between the focus and the context view.

The »fovea approach«, described in this paper, overcomes the drawbacks of the fixed installation mentioned above, and allows by the use of mobile devices for the high resolution a deliberate shift of the point of interest, similar to the biological fovea, roaming across the scene to observe. The basic lines of this patented approach have first been published with [5], and, with emphasis on situation analysis as application area, in [6]. A similar solution is published with [7], with some differences explained later. The following sections describe the underlying method, and give an outlook for future research and development.

2 The »Fovea-Tablett®«

The equivalent of the foveal pit on a large screen workplace we do call »Fovea-Tablett®« (FT). An FT is a small, portable display unit, e. g. a tablet PC, with a rather high pixel density. It is simply placed on top of a much larger screen, here called the »overview table«. A measuring device determines its position and orientation with regard to the overview table. The measured position and rotation angle are wirelessly transmitted to the FT, which displays the graphics of the application (maps, technical drawings etc.) in such a way that the observer has the impression of looking through the FT onto the underlying image, but with a much higher resolution. Fig. 3 shows this arrangement with the so called »digital map table« of Fraunhofer IITB, the experimental system of a future workbench for the processing of geo-information. Fig. 4 gives an impression of the gain in visual acuity by the FT in relation to the overview table. Here the overview table, realized as a rear projection, shows a resolution of 22 ppi whereas the FT reaches 120 ppi.

2.1 Measurement of Position and Orientation

Measuring position and rotation of the FTs with respect to the overview table is carried out optically with a video camera. Therefore the FTs are equipped with a special visual marker, the so called MC-MXT (Multi-Cursor-MarkerXtrackT, see Fig. 5). Originally developed by Fraunhofer IITB for the purpose of high precision tracking of crash test dummies, those markers have an inner part of five points that determine the markers position. They are surrounded by a circular bar code giving each marker an identity and a defined rotary orientation. The so called Multi-Cursor-MarkerXtrackT image processing algorithm (MC-MXT tracker) detects and identifies the markers of the various FTs and calculates their position and rotation angle in real-time [8]. This kind of measurement distinguishes the FT approach from the ubiquitous graphics, published with [7], where an ultrasonic direction finder is used that can for one single device only determine the position but not the orientation.

Fig. 3. The »digital map table« of Fraunhofer IITB with its horizontal table for scene overview, two Fovea-Tabletts on top of this table illustrating scene details, and a vertical board displaying additional information.

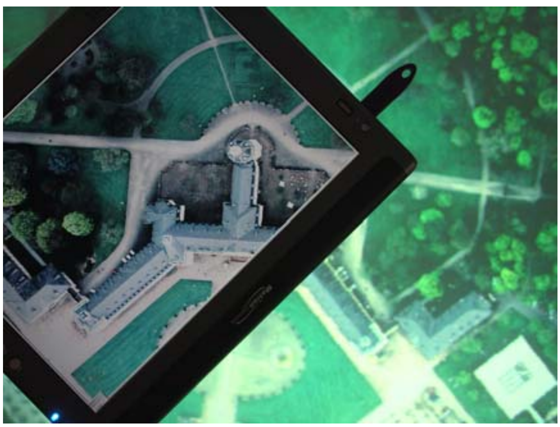

Fig. 4. Gain of visual acuity with the Fovea-Tablett compared to the underlying overview table

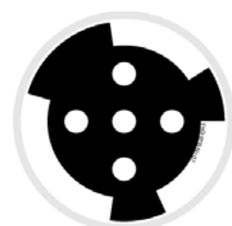

Fig. 5. The coded MCT-MXT marker

Those coded markers can be slotted into one corner of the FT screen on a rather small area, e. g. 5 x 5 cm^2. But for our current experimental system as shown with Fig. 3 we went another way: while the frosted glass, where the overview image is projected on, is sufficiently transparent for objects laying directly on the glass, we fix a marker on the bottom of the FT and observe it with a video camera from below. In order to avoid interference with the projected image onto the overview table, the measuring camera operates at near infrared (0.78 – 1.5 µm) and we provide additional lighting in this spectral band from underneath. Fig. 6 shows the image taken by the IR camera positioned under the overview table with recognition results. The higher wavelength of infrared light and its diffusion through the frosted glass force to select a bigger marker in order to achieve sufficient measuring accuracy. The markers can get stuck deliberately underneath the FTs, e. g. as a self adhesive and easily removable tape. The measurement accuracy of the FT position is about ± 1 mm for the current arrangement and the orientation accuracy is better than ± 1 °. Measurements are taken with a frequency of approximately 20 Hz.

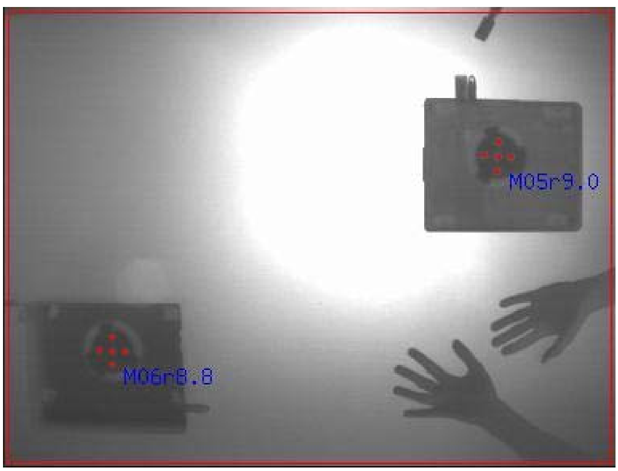

Fig. 6. Image taken by the IR-camera from underneath the table display

2.2 System Architecture

Fig. 7 gives a coarse view over the system architecture of the digital map table. The tracking camera is mounted above the overview table (or underneath it if rear projection is used). It is connected to the MC-MXT tracking server which detects the markers, determines their identity, position, and rotation angle from the camera image. The MC-MXT tracking server with the camera work independent from the application server as an embedded system with a TCP/IP socket interface using XML protocol.

The tracking information is passed over to the application server. Based on the data from the tracking server the application software calculates the coordinates of the views for the FTs. These data are passed to the FTs in dependency of their identities.

While tracking server and application server are connected by a wired LAN, the FTs and the application server communicate wirelessly, actually via Bluetooth. Bluetooth has been selected, because we decided for the current experimental system to run the application software not only on the server but also on the FTs (see, chapter 2.3). Therefore only position and orientation have to be transmitted for which a small bandwidth is sufficient. In the future the communication will move to wireless LAN.

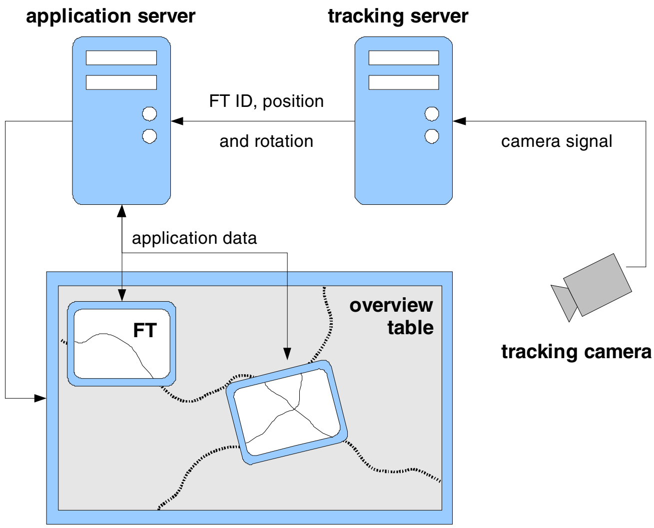

Fig. 7. System architecture of the digital map table

For reference calculation between work table and FTs the MC-MXT tracker must be calibrated. During the calibration process the coordinate transformation between the tracking camera images, which are the input for the MC-MXT tracker, and the viewer of the work table is calculated. In a first step, that has to be carried out only once for the whole table arrangement, the camera image gets referenced to the overview table. Therefore an calibration image with four defined cross points is projected onto the table. Each cross point is identified by its own colour. Four special MC-MXT calibration markers, only used within the calibration process, are marked with the same colors and laid on the projected cross points. So the camera »knows« the size of the overview table and the size of the markers. The second step has to be carried out for every Fovea-Tablett separately. For an FT calibration two images of the FT with the fixed identity marker are taken, whereby the FT has to be positioned on two defined regions of the work table. These regions are also indicated by the calibration image.

2.3 Interaction

At our experimental system, the digital map table, a GIS system as application software is running on the application server as well as on the FTs. So every tablet offers the full functionality of the application software at the user's hand. Various users can generate concurrently different logical views on their respective FT, e. g. showing different GIS layers, without interference between the users. It is also possible to take the FT away and work for a moment besides the table on a specific detail. Back at the table the FT will get instantly synchronized again with the overview image and will feed back the intermediate results to the application server.

Using regular tablet PCs, interaction with the FT is conducted with a digital pen, as Fig. 8 illustrates. A dedicated extra toolbar is overlaid that offers some functionality specific for the FT. The display can get decoupled from the overview so that the user can zoom or pan the image deliberately if he is for himself just diving into a specific detail. Afterwards he can quickly couple to the table with one pen click. All functionality that changes the view like zooming, panning or selection of map layers can also get activated from the FT including the overview. While the fovea approach is designed to working in teams, a clear management between those functionalities that affect the whole view has to be provided. If every team member could deliberately change the overview, confusion would be unavoidable. We decided that all manipulation concerning the overview is only allowed by one master FT, handled by the team leader. Other solutions are also thinkable but demand a higher discipline among the team members.

3 Discussion and Future Work

We have shown, that the fovea approach of combining large but low resolving with small, very mobile, and high resolving displays is a promising step towards ergonomic optimized work places that deal with extended objects like maps or technical drawings. While we have already gained experience with the first application area with our digital map table (for more detail see [6]), work for the area of future drawing tables is just in the beginning.

Fig. 9 illustrates the application of the digital map table for electronic circuit design. In the right part of Fig. 9 one can recognize, that the circuit details, like the

Fig. 8. Tool selection by pen

inscriptions are easily readable inside the FT but never on the overview table. Our first steps towards this electronic and mechanical design confirmed, that the interaction concept depends heavily on the selected application area. We see two general directions. The one is to use the Fovea-Tablett as a more or less simple detail viewer that shows exactly the underlying image but with high pixel density. Then the interaction with the pen offers the same but not more functionality as one would work with the mouse cursor in the respective area of the overview image. This direction has the advantage of being application independent and the demands on the device taken as Fovea-Tablett are rather low. But the space of interactions over the FT then is limited. - The second direction makes the Fovea-Tablett to an interaction device of its own that offers all of the functions the application software has, and is able to control the overview as well as its own detail view. This solution (the one we presented here with the digital map table) is much richer in the possibilities to interact and to use the specific advantages of the fovea approach. But it is also more specific with respect to the application software and demands separate installations on the fovea devices. Both directions have their own benefits and drawbacks and have both their own chance for a future use.

Finally it is necessary to allow also interactions directly on the overview table in order not to be forced to use the FT in every case. Beneath the usage of regular pen interfaces (as they are offered for writing on digital blackboard) we actually survey the chances of hand gestures, recognized by the same tracking camera as we use for the tablets. This is working already very well for simple image manipulation. The future research will concentrate on building an integrated architecture that harmonizes the interaction over the Fovea-Tabletts with those by hand gestures and others in order to come to a conclusive concept for the future work on large computer displays.

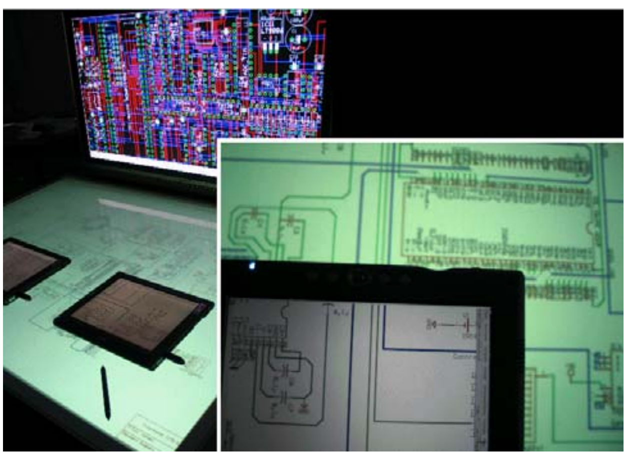

Fig. 9. Electronic circuit design: printed circuit board layout on the vertical screen, schematic diagram on the overview table with Fovea-Tabletts (detail view: right hand image)

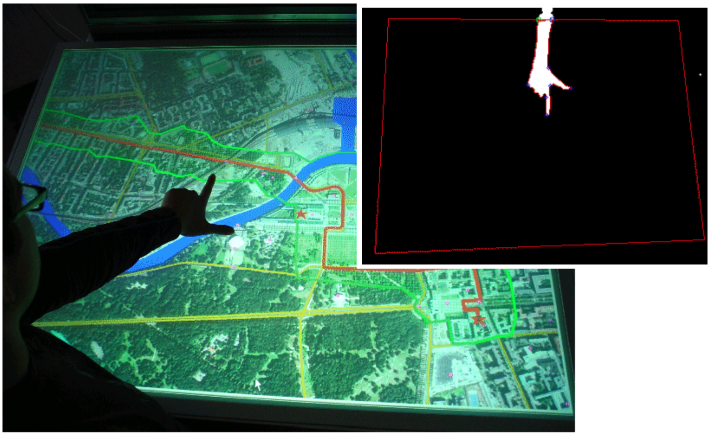

Fig. 10. Manipulation of the overview image with camera tracked hand gestures (small image)

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