

SCROLL THE SPACE AND DRILL-DOWN THE INFORMATION

Liqu Meng

Technical University of Munich

Arcisstr.21 / 80333 München / Germany

Fax: 0049-89-2809573

Email: meng@bv.tum.de

<http://www.carto-tum.de>

Abstract

Since predigital era, cartographic models have been the most popular tools that support our understanding of the reality. However, an effective and efficient interaction with a scrollable and scalable digital earth is not possible unless the mismatches between the system designer and his users are considerably narrowed or removed. Based on an analysis of the characteristics of direct and indirect human-reality interaction, the paper addresses general behaviors of map users during interactive map reading. The author believes that popularization and personalization of mapmaking do not exclude from each other. Analyzing general behaviors of map users and providing them with desired interactive tools are necessary steps toward the individualization of cartographic systems.

Characteristics of human-reality interaction

Human-reality interaction is a never-ending process as long as our sensomotor organs do not cease to function. The perception of our surroundings is primarily performed by our sense organs that work in a cooperating and complementing manner, although we cannot tell how much contribution each sense exactly makes. The movements of our motor organs (limbs, head or the whole body) are guided by the sensorial perception, which in turn is enhanced by motor perception. The gravity force of the earth helps us to stand upright when we halt and keep balance when we move, thus we never care about the vertical orientation. We are able to locate and orient ourselves by integrating signals of translational and rotational position changes caused by various motions such as walking, biking, boating, driving and flying.

A relative orientation and navigation is efficient enough for the interaction with our near surroundings. This egocentric perception takes place automatically and creates correspondingly an egocentric mental image, which is characterized by its special geometry - a mixture of perspective, hyperbolic, Euclidean, and other unknown geometries. Distances along the view direction are, for instance, shortened in comparison with those lying perpendicular to the view direction. Most objects in the surroundings have been rescaled and deformed in the memory. However, such distortions do not disturb our positioning efficiency. While sensomotor organs support the human-reality interaction in a bottom-up fashion, the mental image does it in top-down direction. The impacts of our actions and other external forces on the surroundings stimulate further perceptions, hence modifications of the mental image. As a result of our intensively repeating perception and cognition, "your body is in the world, the world is in your head". Our mental image enables us to "see" invisible things behind us or beyond a wall. Similarly, we can locate soundless and scentless things in the darkness and walk without vision.

For the interaction with remote regions, egocentric sensorimotor perception alone is not sufficient, complicated and effortful cognition based on both egocentric and geocentric perception must be activated (*May 2000*). In the absence of any external tools, many bottom-up and top-down processes run simultaneously in order to perform tasks such as positioning the current location, remembering preceding locations, planning a route, estimating distances and homing etc. The efficiency of human-reality interaction is mainly influenced by our personal ability to integrate a large number of perceptive and cognitive processes, adjust their discrepancies, sew the separately perceived fragments together and map the result onto a mental image free of conflicts. We protect ourselves amazingly well from the over flooding information by ignoring the majority of the signals coming to us and inserting only those that are both new and relevant into our memory. Moreover, we effectively refresh our short-term memory so that it is always ready for new input. Nevertheless, we get disoriented quite often. Many people have difficulties to quickly determine a consistent reference system, thus do not know how to perform the conversion between egocentric and geocentric geometries.

Characteristics of human-model interaction

The reality is unique to us, although we perceive it in different ways. However, the modeling of the reality is neither unique nor complete. One single person can have access to many different models and many people can share the same model. In addition to traditional paper maps, digital models ranging from off-net models (e.g. databases or maps on CD-ROM), on-net models (e.g. distributive databases or web maps) to wirelessly networked models (e.g. databases or maps that can be accessed by mobile devices) are increasingly entering into our daily life. Each model cuts us from our reality, thus makes the human-reality interaction indirect. We have to understand the contents in the model at first and then associate them with their counterparts in the reality. Such a detour is necessary for many reasons: (1) In spite of its incompleteness, a digital model holds much more information than what we can acquire through direct sensorimotor perception. In particular, details about places beyond our physical reach are available. In case of a wirelessly networked model, the world and its dynamic happenings can be mirrored in our palms. This allows a direction comparison with the real world. (2) Unnecessary details have been filtered away in a digital model. This helps us to focus on the essentials. (3) A digital model represents a scaled down reality. It is able to bring large regions together. Two correlated regions that are spatially or temporally far from each other may dramatically reduce their distance to only one single mouse click. (4) The interaction with a digital model can take place indoors or outdoors in a convenient way. Instead of moving our bodies toward real objects, we “require” virtual objects to move toward us and render us their closer look. In addition, a digital model is based on a consistent geocentric system, which allows different users to share the information and communicate with each other without conversion artifacts. (5) A seamless and layered digital earth makes it possible for us to browse it in an arbitrary direction, dive into its depths, turn it inside out, locate special facts and connect our traces into routes etc.

In spite of the spectacular technical progresses, however, there are still many open questions concerned with human-model interaction. Ironically, the more the

technologies offer, the more new expectations they bring about. User demands are always an edge over the technical possibilities. Following statements are by no means exhaustive, but they give us some hints at what must be improved:

- By talking to satellites, I receive everything except what I really want.
- The information is so distracting that I forget what I am looking for.
- I cannot tell what is going on in a web map because too much is going on.
- I am trapped in a deadlock.
- The security holes on firewalls are not less frightful than ozone holes.
- Time is over before I see something.
- The interface is obsolete again before I get to know the majority of its old functions.
- I gave a system everything it required from me, but it gives me nothing in return.
- It's horrible that I am observed and tracked.
- I feel dizzy after a few minutes of scrolling.
- My damned mouse arm is aching again.

For a better analysis of the problems, it is necessary to divide the available models of our reality into two fundamental types: digital object models and cartographic models.

Digital object models

They are objective reflections of the reality and its alphanumeric representations. The objectivity is primarily characterized by their task-neutral contents, impersonal description and geocentric reference systems. A digital object model extends our memory substantially. For the sake of interaction, the geometry of the recorded objects is often converted into a graphic format that functions as an interface through which the object contents and associated analytical services can be accessed. Among the essential quality issues for the creation of digital object models are e.g. actuality, geometric precision, semantic accuracy, completeness, topological consistency, homogeneity, access speed, availability, security etc. Most of them are actual research topics in the realm of GIS.

Cartographic models

They are subjective reflections of the reality and its elaborately designed graphic presentation. In a digital context, maps are usually derived from an object database. The subjectivity is characterized by the effortful cognitive processes involved in the map design procedure. It is this subjectivity that allows a map to magically extend our vision. A map keeps the visibility of intrinsically visible things in different ways. It brings invisible things (covered or hidden objects) into view. It even makes intangible things visible. The interaction with cartographic models is centered on the map, its symbols, place names and many other graphic or multimedia artifacts. The map understanding is often enhanced by an underlying database that delivers additional information upon request. Since predigital era cartographic models have been the most popular and favorite tools that support our understanding of the reality. However, to judge whether a map is good or not is far more complicated than the quality assurance of an object model.

One of the demanding quality issues deals with the personalization of cartographic models, which requires a careful study of user profiles and context of map use. Similar to the risky business of promoting individual e-commerce, personalization of a map incl.

its user interface is a dream that can be realized only to the extent of mutual understanding between the designer and his user. Anyone who has tried his hand at design knows that it is not so easy to capture a fickle user's attention. The result of personalization could very well be an odd design that the public turns head away. In fact, popularization and personalization do not exclude from each other. Analyzing behaviors of map reading by general public and providing users with the desired tools to create their own maps is a reasonable strategy to start with.

General human behaviors by reading interactive maps

Humans are curious. Many people are keen explorers of unknown regions. The curiosity lasts longer if an unknown region is presented by different maps or paramaps with varying geometries, display dimensions, scales, viewing angles and symbolization styles. According to the motto "you do not understand anything until you understand it in more than one way", multiple presentations make it possible for a user to obtain a robust and complete impression of a mapped region by noticing its invariance. While maps with their geocentric geometries render a relatively unbiased view of the reality including its semantic attributes, paramaps with their egocentric geometries and interactive steering functions (e.g. flying-through, dynamic magnifier etc.) allow a personalized or immersive view, therefore hold our curiosity longer. Sometimes, our curiosity is driven by "Jones syndrome" (*Ormeling 1996*). Instead of exploring unknown regions, we are eager to find out what our neighbors or competitors are thinking and doing, what their past and future looked or will look like and how different they are from us. We require an easy access to interactive atlas information systems that display the regions to be compared in the same style and scale. Meanwhile, we need steering functions to "pick and drop" the relevant maps, link them together, decompose them into layers, arrange them adjacent to each other or above each other.

Perceiving and understanding new things are effortful processes. If new facts are successively accumulated on the reference of some known facts, our cognition will less likely be overloaded or disoriented, as a result, our attention lasts longer. That is why many people like to have an overview of a region at first and then drill down to its details step by step with help of zooming and generalization functions. Similarly, animated objects against a static background tend to be better focused than if the background changes simultaneously.

Users are honest in front of a screen display. They do not pretend to know what they do not or vice versa. There is no such thing that users answer questions deceitfully, but quite often they are puzzled by dubiously formulated questions or lengthy questionnaires. Patterns of eye movements during map reading can reveal to certain extent users' personal interest and the design quality of a cartographic system.

Screen reading is strenuous and uncomfortable because our eyes are looking at a light source instead of receiving reflected light as in case of paper reading. Reading text on screen is 25-30% slower than the reading on paper (*Thissen 2000*). We are less concentrated and get more easily fatigued due to relatively coarse resolutions and flicker effects of monitors. Moreover, we tend to take a rather stiff sitting posture, which often causes pains in shoulder and neck. Many people complain that they have sore eyes

because staring at screen reduces the frequency of batting eyelid required to moisture eyes.

Users' tolerance is limited in getting along with interactive maps. 1/10 second is the limit beyond which a system is believed to be unable to process text input simultaneously. 1 second is the limit beyond which users begin to feel slightly disturbed by the interaction. If a mapping system delays its reaction longer than 2 seconds, certain signals are necessary to convince users of errorless system performance. The display of an hourglass, a progression bar or a message that tells how much time is left for the completion of a function proves to be very helpful. 10 seconds mark the limit beyond which it is hard to hold the attention of a user. Therefore, it would be wise to provide the user with a possibility to break a time-consuming process.

Visual perception is selective. Many users do not read screen contents at all. Instead, they let their sight fly over the whole display, hunting for a place to halt and focus on. Potential eye catchers are visually conspicuous signs, such as a blinking sign, a word amongst graphic signs or a sign that looks like a human face. Every eye catcher, be it a point, a line, an area or a volume, serves as an orientation cue and forms together with its surrounding signs an information unit (chunk). Regardless chunk sizes our short-term memory is able to accommodate up to 7 chunks for ca.15 seconds. A chunk will not be transferred from short-term memory to long-term memory unless it contains something new and relevant. Therefore, a screen map should not contain too many eye catchers or meaningless "flaunting" signs.

Many users avoid scrolling a screen unless they are given sufficient orientation and navigational support. For a better perception, we often introduce artificial seams into a seamless large space by defining windows, polygons or separating lines in addition to the frame bordered by display size. A seamless digital earth is fantastic not in the sense that we can now freely move within the virtual space, but it allows us to create our personal seams wherever we want. This is why interactive atlas information systems will never be replaced by a single scrollable presentation of the seamless space. Artificial seams help to mark a boundary between inside and outside, between this side and other side or "between an intimate part and an open space" (*Müller* 2000). They enhance our selective perception by automatically directing our sight to a windowed area. As a consequence of focusing, we tend to see more details within the window. Moreover, we usually attend to a window longer, trying to see it through.

If a display is relatively empty, our eyes tend to see something that is otherwise not noticeable, e.g., we can even discover the small stains or dust grains of an empty screen. This behavior may well be traced back to survival instinct of animals to watch out for potential dangers. Screen design should follow the principle of "less is more" (Fig.1). Users prefer an apparent visibility to the just noticeable visibility. A symbol that blinks less than once a second or has disappearance duration of longer than 1/2 second will likely be overlooked. On the other hand, a symbol that blinks more than 5 times a second will be perceived as flicker. Good blinking relations (blink duration / disappearance duration) lie 1:1 by graphic signs and ca. 1/3 to 2/3 by texts. Users appreciate concise screen displays that are effective even when it is not clicked on. A

concise screen display that primarily contains conspicuous hyperlinks is irritating. Most users do not tolerate more than three futile mouse clicks. Although a mouse click takes only about 1/3 second, it is an effortful process to decide whether it is worthwhile to click on a hyperlink. Some typical questions users go through are: What kind of information is connected to it? How long is the rendering time? Is it a deadlock? Is the hyperlink available? For this reason, web maps that explicitly provide metadata (e.g. by mouse-over function) about its hyperlinks would considerably reduce users' cognitive effort.



Fig.1 Screen design according to the principle “less is more”
© Hermann Lechner

If a display is full of small and homogeneously looking signs, our eyes tend to see far less than we believe. In case that the small signs blink or move simultaneously, we may see nothing at all. This reminds us of the biological protecting mechanism of small fish that swim in swarms. They will not be swallowed up by a bigger hungry fish that gazes at them because the latter is visually overloaded (*Thissen 2000*). A topographic map that is one-to-one converted from paper to screen is boring due to its homogeneous and overcrowded appearance (Fig.2a in comparison to Fig.2b), while a screen map with more than two simultaneously animated objects is disturbing.



Fig.2 (a) One-to-one conversion from paper to screen (b) Improved screen design

Human thinking process is sequential, although with ramifications. We see graphic symbols in a parallel mode, but we process what we see and communicate it to others in a sequential mode. We break a seamless space into small chunks at first, and then chain them together. A sequential presentation of information (e.g. rendering symbols in a chunk one after another) is more efficiently perceived by users than parallel presentation

because the former takes over part of our cognitive effort (*Weidenmann 2000*).

Many users do not bother to consult a map legend that is separately located. Instead they tend to search for sensitive symbols by flying over the mouse at first. If embedded legend and info-graphics are not available, they will try to encode the graphic signs by relying on their association ability and their knowledge of graphic convention. Only when even this strategy fails, will they begin to read legend, activate on-line help. Turning over a thick printed user manual seems to be their last choice.

Mobile users expect a wireless mobile map to be able to scale its contents and adapt its orientation incl. text placement on the basis of users' actual moving speed and direction. Without this rudimentary flexibility, a wireless map is not superior to a paper map. The smaller the screen size or the display device, the stronger the user wishes to have access to personalized map and time-critical services. Ideally, PCs, PDAs and mobile phones could display personal information to their owners. It may be wasting resources to marketing our geodata services to mobile users by simply squeezing a watered-down version of web maps onto smaller wireless devices.

The majority of users have become conditioned to menu-driven interface. Most interface buttons are thought for the right-handed users. This makes left-handed users feel inconvenient, while right-handed users frequently suffer from mouse-arm syndrome. Therefore, both types of users require ergonomically interactive modalities that can motivate both arms in a balanced way.

Map symbols and their information depth

Maps are syntactically dense systems. The dominance of visual presentation will probably never be changed by multimedia possibilities. Each graphic sign has at least one explicit meaning defined by the legend. Very often the explicit meaning is associated with one or many implicit meanings. The empty space between graphic signs is also meaningful as regards spatiotemporal relations. The inadequacy and context-dependency of visual literacy makes the understanding of a map less straightforward, hence, more effortful than the interpretation of textual instructions.

There are no firm rules for symbol construction. Whether a map symbol is successful or not depends largely on whether an intended user can quickly and intuitively discover the right relationship between the symbol and its referent. Cartographers have been trying hard to relate a symbol to its referent by creating certain kind of resemblance. The resemblance is certainly not limited to the superficial aspects because symbols in an interactive cartographic system have to represent, in addition to visible objects, non-visible attributes, abstract concepts, spatiotemporal relationships and interactive functions. Although successfully designed symbols for certain topographic map features have been well accepted as conventions worldwide, symbolization of the most geographic phenomena and design of graphic user interface remain a free choice. Obviously, it is neither possible nor necessary to find a symbol that duplicates its referent, but users do expect a symbol to (1) highlight the prototypical or distinct characteristics of a tangible referent, (2) hint at the fitness of a tool for its task, or (3) utilize metaphoric cues to stimulate association of an intangible referent. Most users

prefer self-explaining symbols to abstract symbols, although the latter are less likely to be misunderstood. A pictograph of “leopard” representing a zoo is more attractive than a dot. A falling leaf arouses our association of autumn. However, self-explaining symbols often explain too much and are culture dependent. Identifying something may be just a trigger for the understanding of further meanings. For instance, no one would deny that the symbols in Fig.3a stand for "fork" and "knife" respectively. The frame around them stimulates us to associate the fitness of fork and knife, i.e. as tools to eat with. A further cognition brings us to the meaning “restaurant”, the place where fork and knife are used. However, Asian people who eat with chopsticks will probably have difficulties to catch this final meaning. Likewise, the symbol in Fig.3b may be identified as a hand and a pen, a handheld pen or a writing hand. This may or may not trigger the deeper meaning “drawing” or “editing” intended by designer. What may make a symbol like something is not the fact that the two are indistinguishable from each other, rather the similarity between the mental activities both can arouse. In fact, map users understand symbols as a result of discovering similarity, or they discover similarity as a result of understanding symbols.



Fig.3 Symbols and their multiple meanings

Concluding remarks

A digital earth that is scrollable and scalable in all directions is merely a technical prerequisite for the creation of interactive cartographic models. Further requirements must be satisfied for the design of a successful interactive map that should be able to (1) immediately draw the attention of its intended users by means of eye-catchers; (2) keep and enhance the interest of the attending users by rendering their wanted information in their languages; (3) invoke users' desire to have more information by providing the necessary extension and depth of the key information; and finally (4) stimulate its users to make decision or take action based on their understanding.

References

- M. May 2000: Kognition im Umraum. Deutscher Universitäts-Verlag, 2000.
- A. Müller 2000: Altertis Fenster - Gestaltwandel einer ikonischen Metapher. In: *Bild - Bildwahrnehmung - Bildverarbeitung* Sachs-Homback / Rehkämper (ed.), DUV, 173-183
- F. Ormeling 1996: Konzeptionelle Konsequenz für die Bearbeitung elektronischer Atlanten. In: *Wiener Schriften zur Geographie und Kartographie*, Band 8. Mayer / Kriz (ed.), 109-116
- F. Thissen (2000): *Screen Design*. Springer Verlag

B. Weidenmann 2000: Psychologische Ansätze zur Optimierung des Wissenserwerbs mit Bildern. In: *Bild - Bildwahrnehmung - Bildverarbeitung* Sachs-Hornback / Rehkämper (ed.), DUV, 243-253