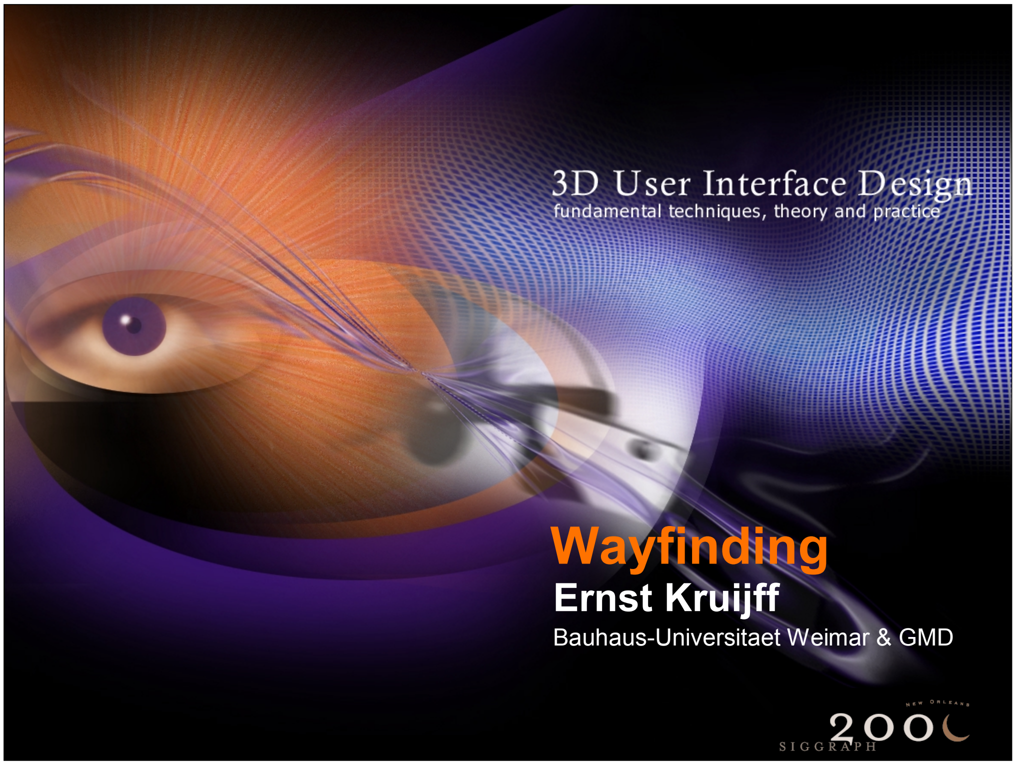

Wayfinding

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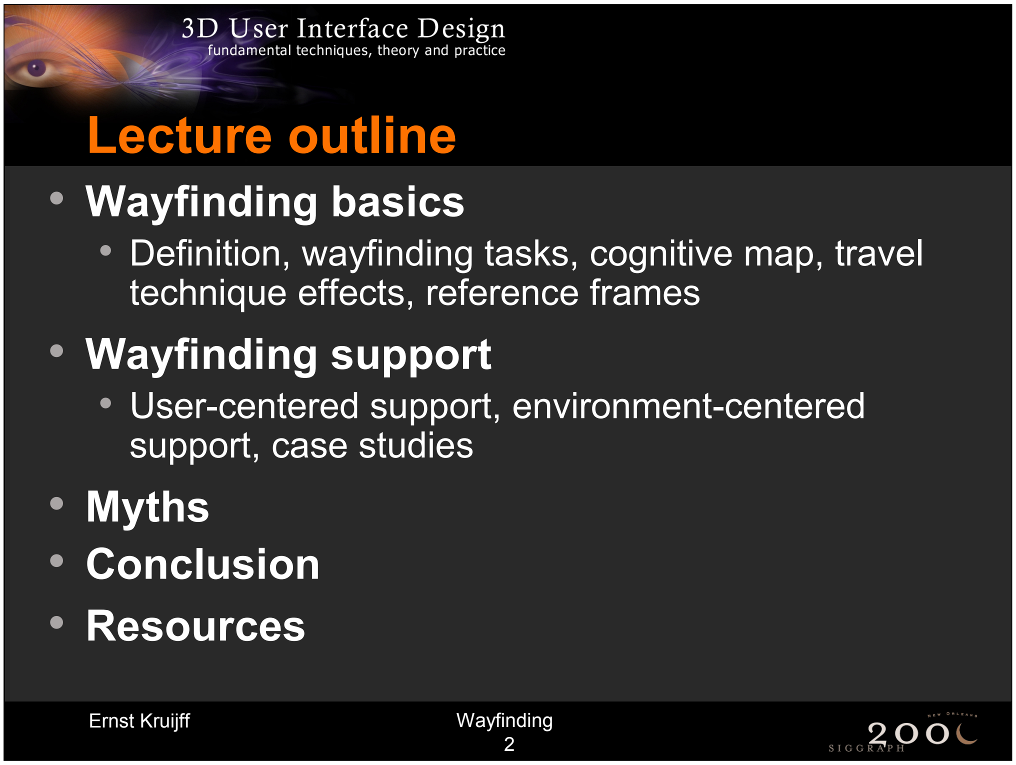
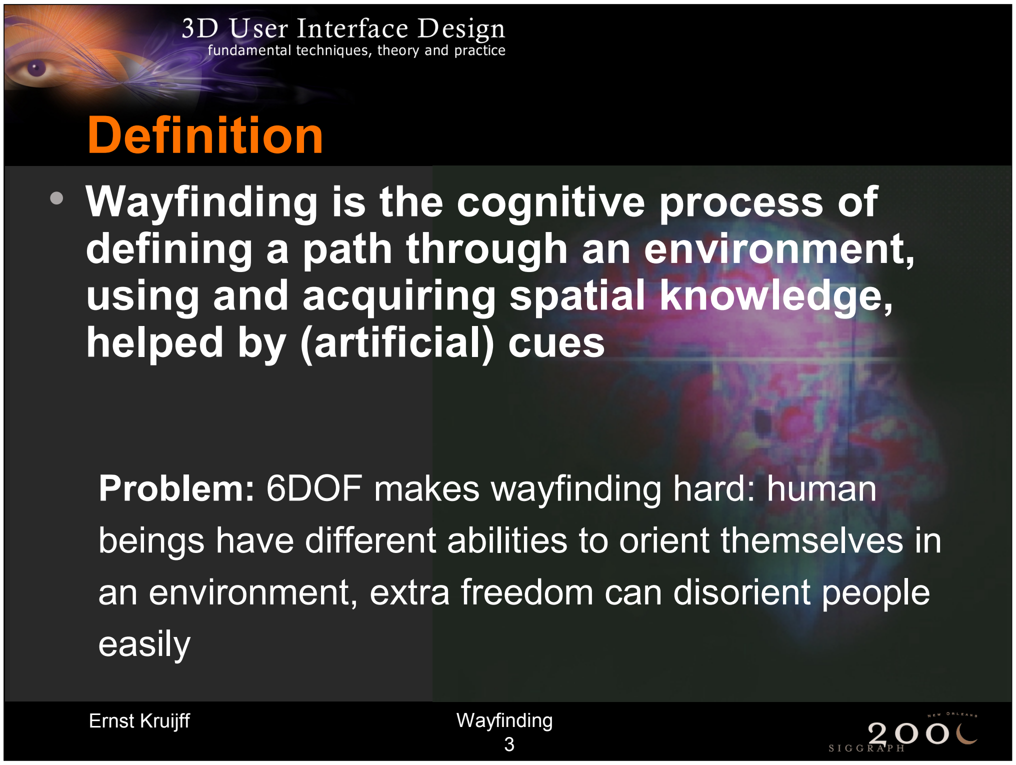


Why a lecture on wayfinding?

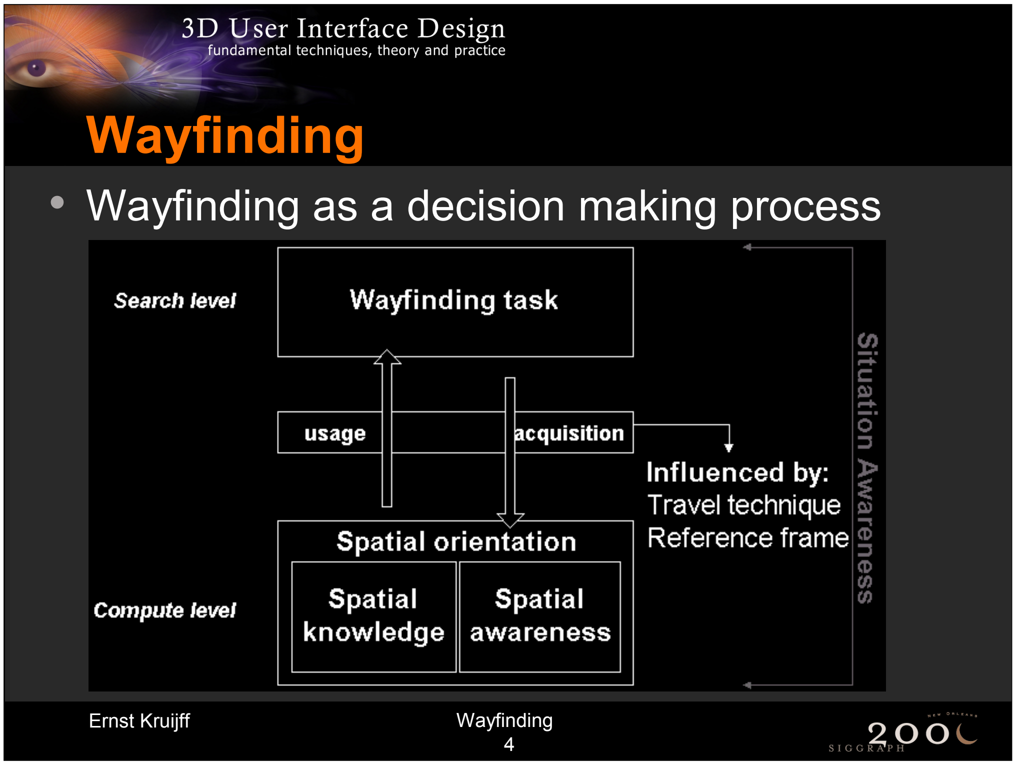
Wayfinding is one of the two pillars we built on when navigating through an environment. Without wayfinding, we are unable to make predictions for movement through an environment. Wayfinding support is needed to assist both wayfinding in a virtual environment, and the usage of a virtual environment to strengthen wayfinding in the real world.

How is wayfinding explained in the lecture?

The lecture basically consists of three basic parts. In the first part, the basic mechanisms behind wayfinding are explained, which includes several references to the travel lecture. The second part explores methods of supporting wayfinding in a virtual environment, both user and environment centered. In this part, several case studies illuminate the topic of the lecture. In the final part, several myths will be demystified, plus conclusions and directions for further research. At the end, sources for further reading are given to broaden the scope of this lecture.



When we observe wayfinding as a cognitive process of defining a path through an environment, we can state several particular differences between real-world wayfinding and wayfinding in a virtual world. Foremost, the added degrees of freedom make it harder for human beings to find their way through a virtual environment: whereas we are normally used to being constrained in our actions (i.e. gravity, walking on floors), we can often freely fly through a virtual environment. The unconstrained behavior does not match with how we move through a real environment. This feeling is strengthened by the lack of of real-motion cues we obtain during virtual movement.



When we observe wayfinding as a decision making process, we can identify several major building blocks and factors which influence this process. We can identify different wayfinding tasks, which will either

•make use of spatial knowledge

•build up spatial knowledge

•both use and build up spatial knowledge

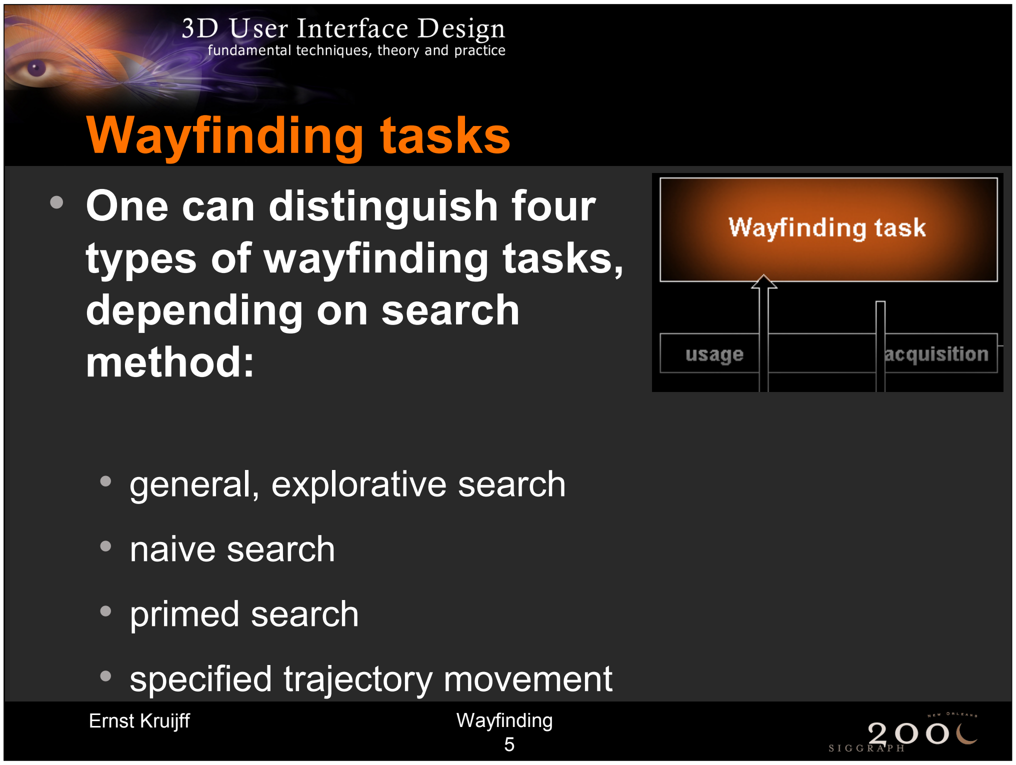
During wayfinding tasks, the position of the user within the cognitive structure built up of spatial knowledge (the cognitive map) plays an important role. We can also name the position of the user in the context *spatial awareness.* The combination of a cognitive map, and the user's position and orientation within the cognitive map we call spatial orientation.

On a decision process level, we can compare wayfinding strongly with *situation awareness*. Situation awareness needs are information requirements to make decisions, on the premise of understanding the problem which needs to be solved. It involves:

•Extraction of information (also non-visual)

•Integration information into coherent cognitive structure

•Usage of cognitive structure in the future for making predictions

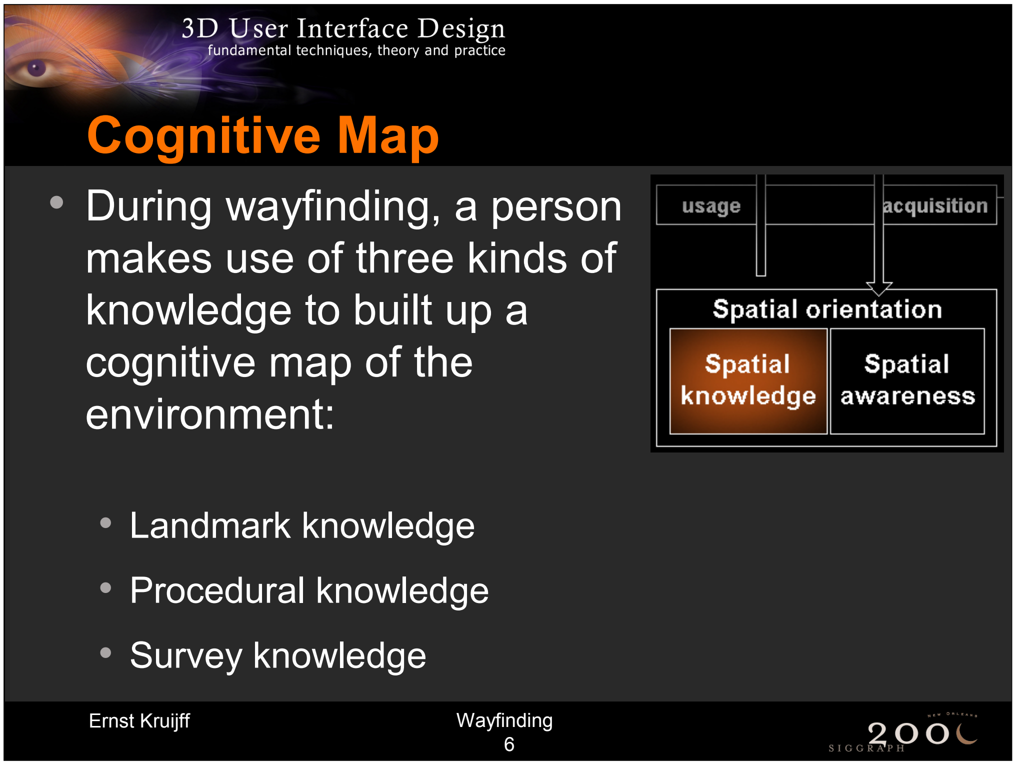


The four defined wayfinding tasks are directly connected to the acquisition and / or usage of spatial knowledge, as described on the previous page. A general, explorative search is a search without target. The naive search is a search without knowing the position of the target, whereas with a primed search, the position of the target is known.

The specified trajectory search has a special influence on wayfinding. Since the user is *not* able to freely walk through the environment, he/she can not obtain infinite viewpoints, like is possible in the other three wayfinding tasks. So, although one can obtain spatial knowledge from an environment with a predefined path, it is likely that a cognitive map is harder to build up than in the other three wayfinding tasks. In any case, the predefined path is rather meant for getting an (quick) overview of an environment, possibly for transferring knowledge to the real world - one is obtaining spatial knowledge rather than using spatial knowledge like in the other three tasks, which have a search characteristic.

Finally, the wayfinding task is heavily dependent on search methods - different search tasks may require different search techniques.

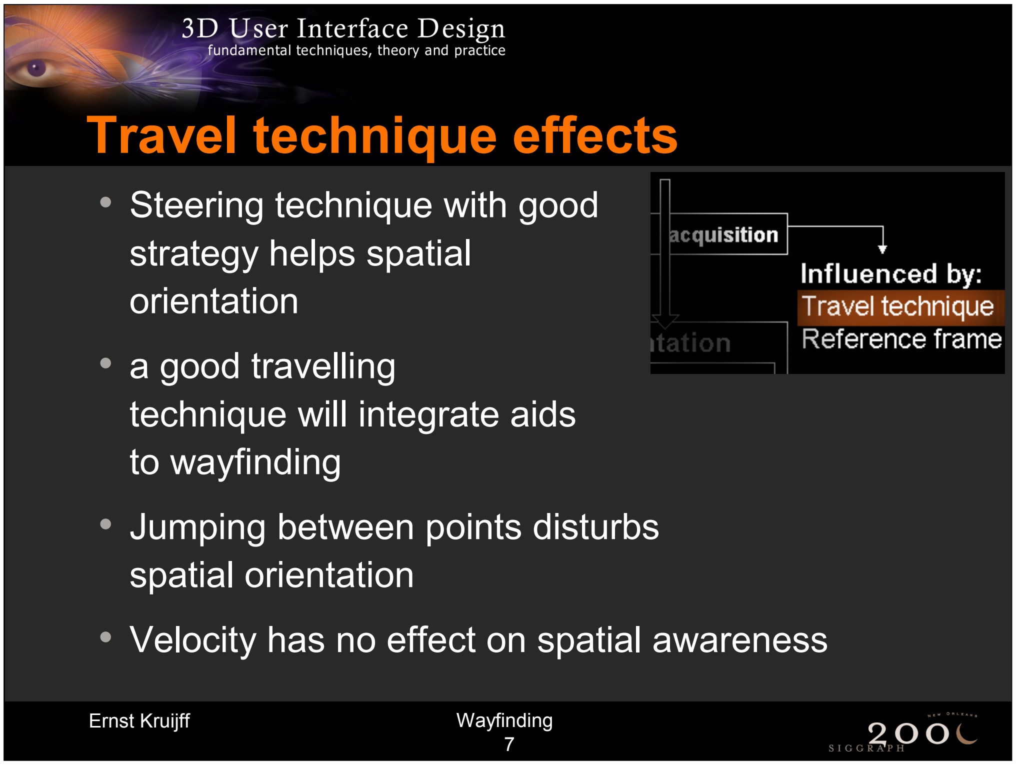
Reference: (Elvins 1997)



Three different kinds of spatial knowledge can be identified, namely landmark, procedural and survey knowledge. Landmark knowledge consists of visual attributes of an environment, including shape, size and texture. Procedural knowledge describes the sequences of actions required to follow a certain path, or to traverse paths between different locations. Survey knowledge can be described as the configurational or topological knowledge of an environment, consisting of object locations, inter-object distances and object orientations. This kind of knowledge is map-like and can be directly obtained from a map, although this tends to be orientation specific. Survey knowledge represents the highest level of spatial knowledge and has a hierarchical nature. It also takes the longest time to build up survey knowledge. The subdivision of spatial knowledge types is based on (Thorndyke and Hayes-Roth 1982), please refer to this article for more details. And, please note that this framework on spatial knowledge is just one of many, but hopefully a powerful one - a large body of hierarchical models form the primary theories.

A major problem can be that perceptual judgments are biased within a virtual environment. Several tests have shown that users wearing a head mounted display underestimate dimensions of space, which might be caused by limited field of view. Biases in perception of orientation was found less in egocentric situations as in exocentric situations. In exocentric situations, so it is thought, both the location of the user itself and the target of a search action will be misjudged.

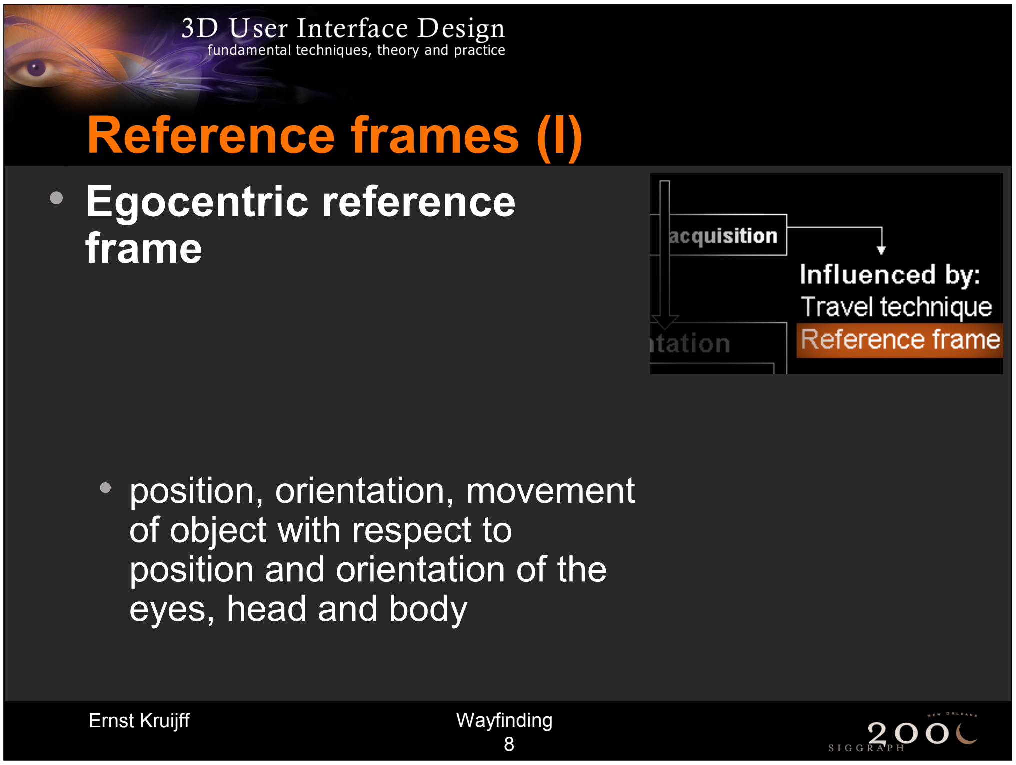
In addition, “chunking” of survey knowledge at a certain level in a cognitive map might occur, in which only knowledge of a specific location is remembered, and not the context around this location, although the context is regularly traveled through.



As has been stated in the introduction of the course, navigation consists of a motor component (traveling) and a cognitive component (wayfinding). It can be clearly stated that both components are strongly interconnected. Above, several particular connections between traveling and wayfinding are stated. Also, a strong relationship exists with real-motion (e.g. motion platforms) for supporting real-motion cues during traveling. For further details, please refer to the travel part of the navigation lecture, by Doug A. Bowman, and work by Ruddle and Iwata.

Reference:

(Bowman *et al* 1997)



During travelling, humans feel as if they're in the center of space (*egomotion*). In order to effectively navigate through an environment, a person needs to associate his egocentric perspective with the information stored in the cognitive map. Survey knowledge, however, has an exocentric character.

An egocentric task is a task in which judgments are made according to the sub-frames of the egocentric reference frame. More detailed, egocentric tasks include stationpoint centric, retinocentric, headcentric, bodycentric and proprioceptive tasks. The proprioceptive task can be seen as a special bodycentric task. Proprioceptive cues include non-visual (sense of body parts), visual (visual location of bodyparts) and intersensory (combination of visual and non-visual stimuli) cues.

The exocentric reference frame is also referred to as the *geocentric* reference frame, in which objects are observed as the center of space.

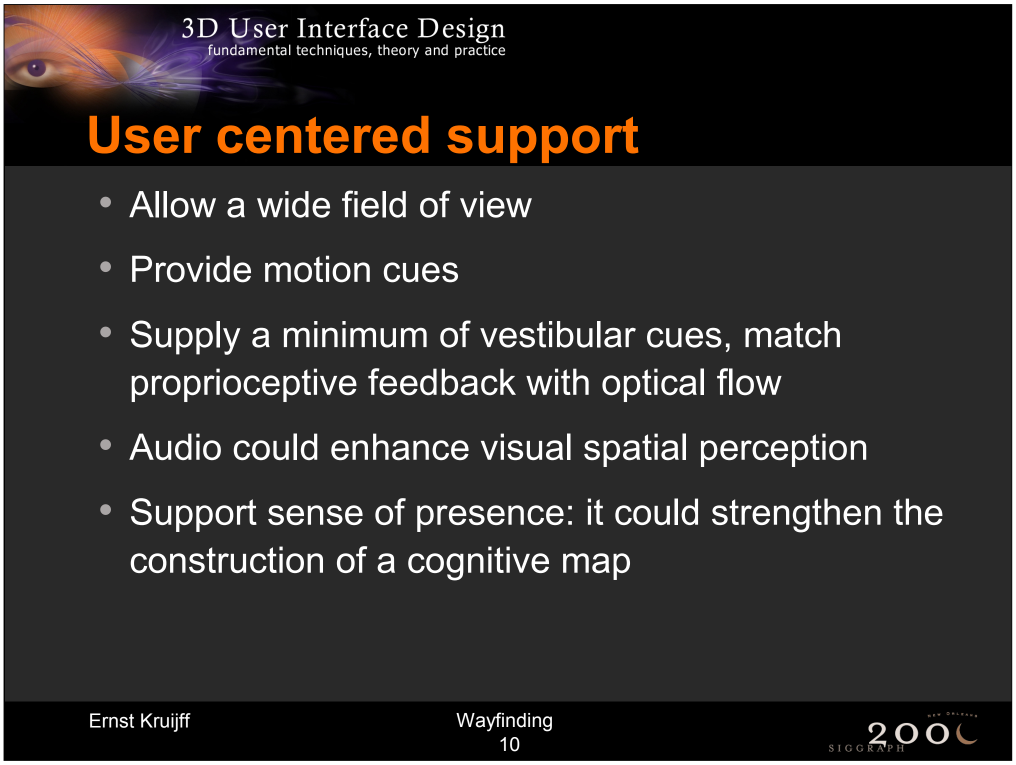
For a detailed description of egocentric and exocentric reference frames, please refer to (Howard 1991).

Reference: (Howard 1991)

Reference frames (II)

- **Exocentric reference frame:**

  - position, orientation and movement are defined in coordinates external to body, namely object shape, object orientation and object motion

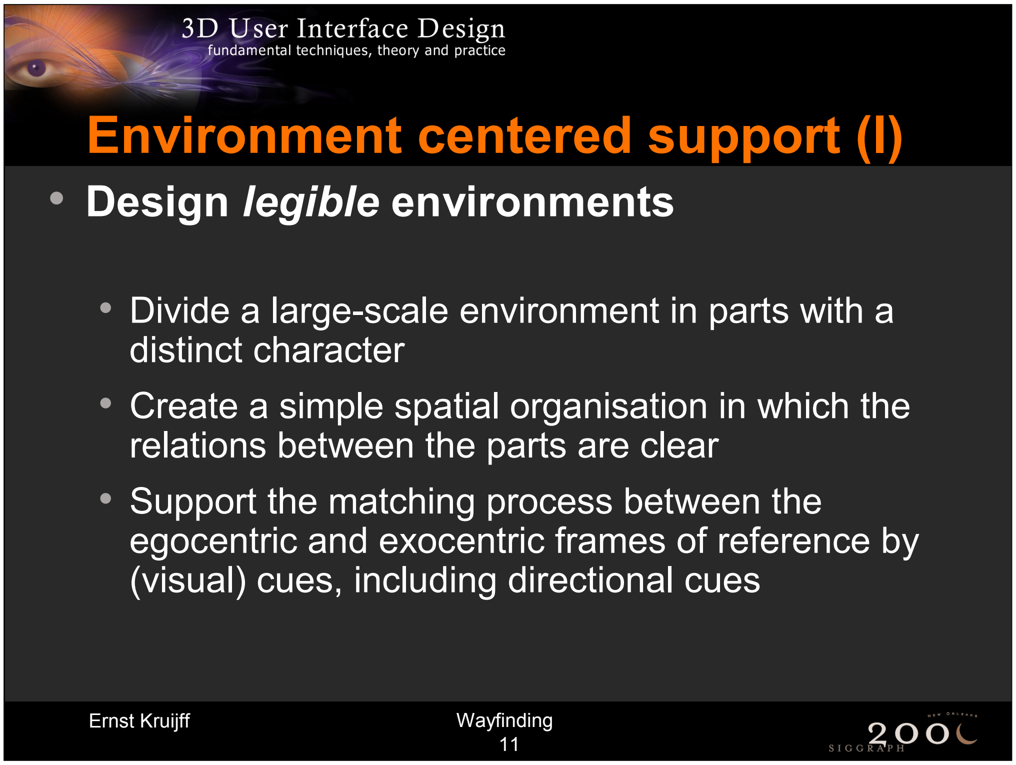


Field of view (FOV) is important for spatial knowledge acquisition. Enabling a large FOV reduces the amount of head motion to get a view on the environment. It enables the user to interpret data at once and extract relationships more easily than when multiple head movements are required. Also, a larger FOV supplies the user with more peripheral vision, important for optic flow field. Peripheral vision offers strong motion cues, which deliver information about the user's direction, velocity and orientation while moving. It may cause simulator sickness, however.

Supplying motion cues enables the user to judge both depth and direction of movement and supplies indications necessary for dead reckoning - motion parallax is found to be much more important than stereoscopic cues for spatial judgments (although stereopsis is also desirable). Also, it is very important to supply the user with additional vestibular cues (real motion cues). A lack of vestibular cues causes an intersensory conflict between visual and physical motion. This can be both the reason for motion sickness and can disturb judgments of egomotion, which are important to build up the cognitive map (i.e. support for proprioceptive cues is lacking).

The sense of presence (the feeling of "being there"), which is also described as the adoption of an egocentric reference frame, is a much explored but still not well understood phenomena - it is at least believed that it has a large impact on spatial knowledge too. The sense of presence consists of a large body of affecting factors (which we will not discuss here), including visual sensory data, proprioception and the user's internal model. With respect to these three factors, it also believed that the usage of a virtual body (VB) can aid in the building of context awareness, which in turn has a positive effect on spatial knowledge acquisition and usage. Furthermore, the addition of audio seems to aid to the sense of presence and supports auditory spatial localisation. But, as stated, presence is a complex issue which we will not discuss here in detail. Please refer to work by Slater and Regenbrecht for more details and further references.

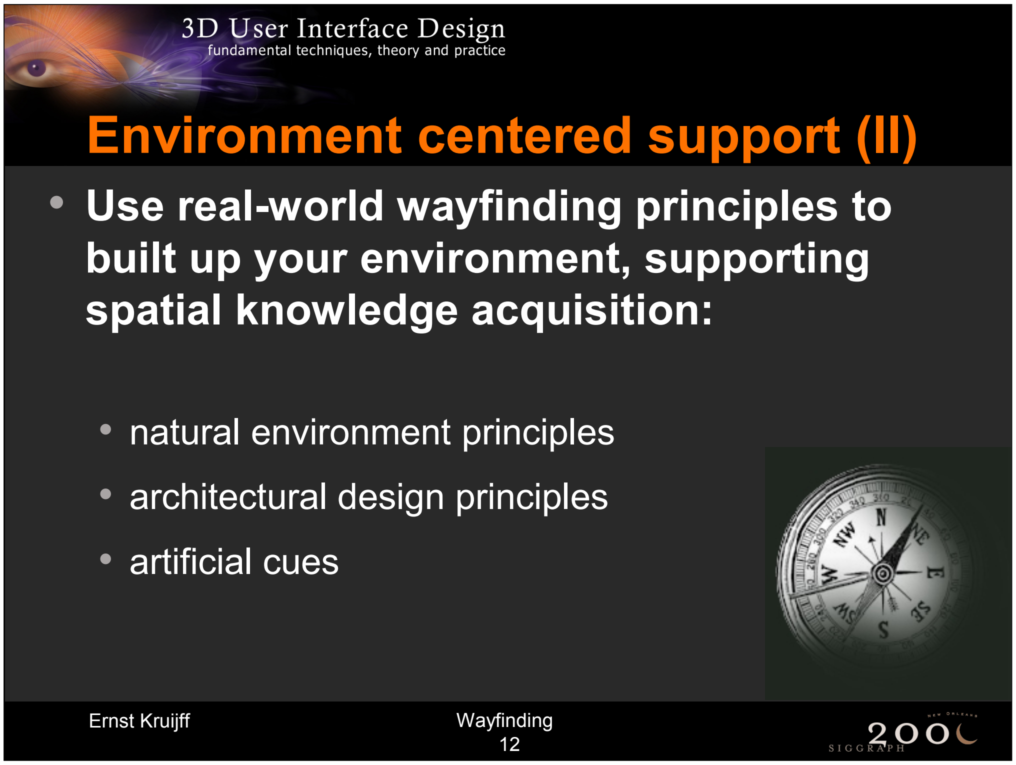
References: (Davis et al 1999), (Draper 1995), (Harris *et al* 1999), (Regenbrecht *et al* 1997), (Slater et al 1995)



Most of the environment-centered support presented here is related to environments related to the real-world. Little is known about wayfinding in environments which are highly dynamic and not directly related to the real-world. Basically the effects of general issues like color and form are known from the field of visualization to have an effect on structuring information.

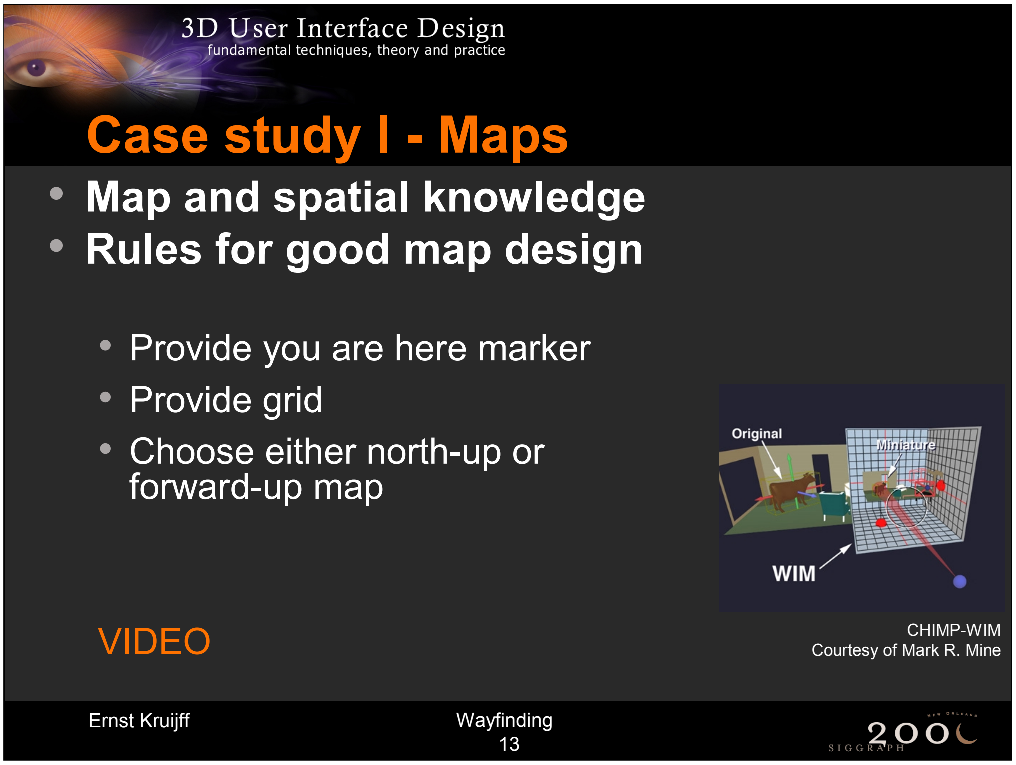
The structuring of an environment has a large impact on the acquisition of spatial knowledge, on all levels - the better the environment is structured, the easier qualitatively high (survey) knowledge can be acquired. This is also what the term legibility refers to: allow the user to see easily the spatial organisation of an environment, enabling the establishment of a cognitive map. The theories based on Lynch's *Image of the city* form a major influence on the design of legible environments. Lynch built environments from paths, edges, districts, nodes and landmarks to make them more legible. The book forms a wealth of information on structuring of environments. Another good reference is www.spacesyntax.com .

References: (Ingram *et al* 1996), (Darken *et al* 1996), (Lynch 1960)



Using real-world wayfinding principles can be important for supporting the wayfinding process in virtual environments Below, one can find a list of (possible) cues, which aid in all fields of the wayfinding process.

- Natural environment
  - horizon
  - atmospheric perspective / fog
- Architectural design principles
  - lighting
  - texture and texture gradients
  - colour
  - open versus closed
  - detail versus ambiguity
- Artificial cues
  - signs
  - text
  - maps embedded and non-embedded
  - grid (over map or world)
  - compass



Since it is known that users can obtain spatial knowledge from a map (due to its exocentric character, it can aid survey knowledge acquisition), the map has been a popular artificial cue to support wayfinding. During map usage, we often make use of two views on a data set, namely both an egocentric and an exocentric view. To be fully useful, the matching process between these views has to be optimal. Several guidelines can help to make a map a useful attribute in a virtual environment:

•Provide a “you-are-here” marker and viewing angle to allow correct matching of exocentric viewpoint (top view on map) with the egocentric view of the user. The user needs to know *where* he is and what (the direction of) his *field of view* is

•A forward-up map is preferable in egocentric search tasks (when egocentric wayfinding is suitable), whereas in exocentric search tasks a north-up map seems to perform better (Darken *et al* 1999)

•Make the map legible: show the organisational structure, for instance by a grid

•Make the organisational elements clear

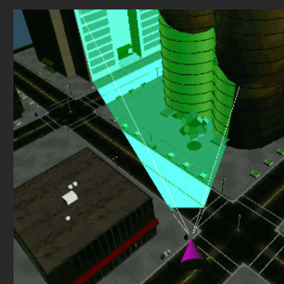
One of the most famous uses of a map is the World-in-Miniature (WIM). Although the WIM was actually intended for manipulation and selection tasks, it also performs well as a navigational aid. Besides the overview and the user’s position provided by the *scene-in-hand* technique, the WIM provides the user with an easy way to perform route planning. Furthermore, the WIM enables different viewpoints on the complete environment (“WIM fly-by’s”, by moving the use’s representation within the WIM), without actually moving the (egocentric) viewpoint in the larger environment, and allows different levels of scaling. The WIM also has negative sides. First of all, it can occlude a large part of the viewed environment, thereby making certain interaction tasks harder or even impossible within the egocentric viewpoint. Furthermore, the WIM can rapidly lower frame rates. Finally, and most likely the most important point is, that a WIM is less useful for large environments, although especially for these kind of environments a map would be most appropriate.

References: (Darken and Cevik 1999)(Elvins 1997)(Stoakely *et al* 1995)

3D User Interface Design
fundamental techniques, theory and practice

Case study II - Landmarks

- **Landmarks and support of spatial knowledge**
- **Guidelines for landmark design**
  - distinguish landmark by color and form
  - distinguish landmark by place
  - Example: Worldlets



Frustum Worldlet
Courtesy of T. Todd Elvins

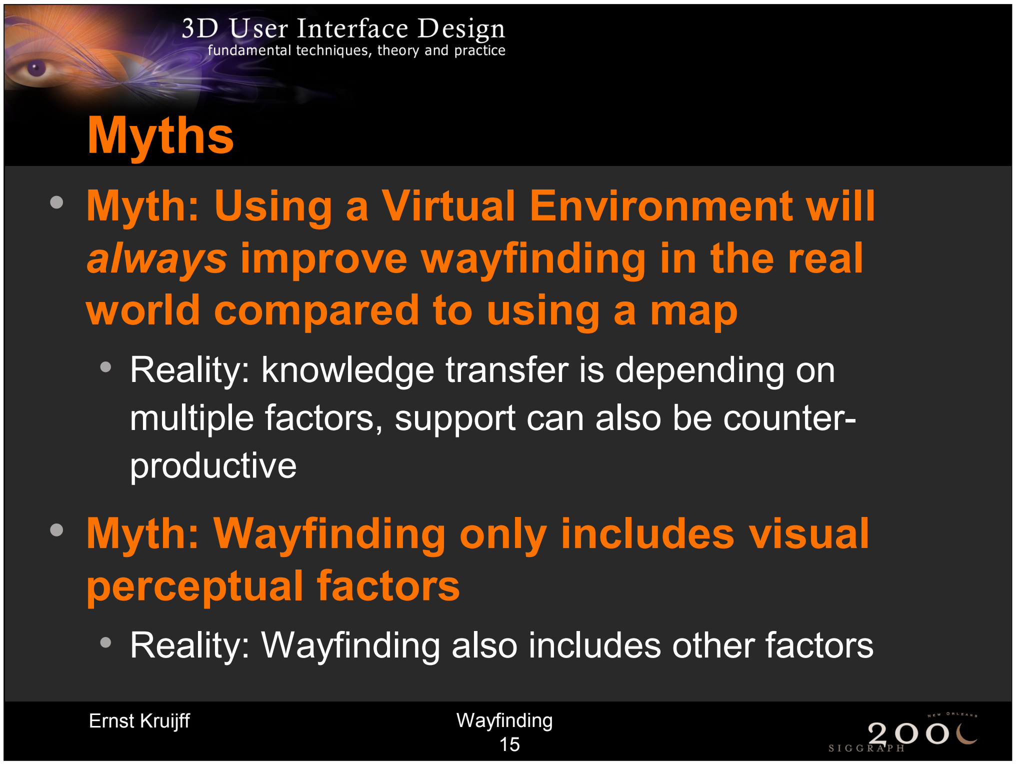
Ernst Kruijff — Wayfinding — 14 — SIGGRAPH 2000

The design of landmarks to be used within a virtual environment includes a large amount of factors, which still need to be researched in further detail. At least, a landmark should be quickly spotted, easily visible and distinguishable from other landmarks and its surrounding environment. To achieve this we can provide several *possible* guidelines. First of all, use visual characteristics (like form, color and texture) which are clearly distinguishable from the environment in which the landmark is placed. Secondly, give the landmark a prominent place: when placing the landmark, we can use the requirement of legibility to station it at a place where it can easily be spotted, like a corner in a city structure, instead of placing it within a city block. Use the structure of your environment to support the identifiability of your landmark.

A good example of the usage of landmarks are *Worldlets.* A Worldlet reduces the mismatch between the mental representation of the landmark by the user and the landmark presentation itself in menus or guidebooks, due to the different viewpoints on the landmark. This mismatch normally results in disorientation. We can identify two kinds of worldlets, namely frustum worldlets and spherical worldlets. Worldlets are, in contrast to the WIM, browsed outside the actual environment, avoiding occlusion and frame rate decrease.

References: (Baker *et al* 1992), (Elvins *et al* 1997)

Pictures obtained from T. Todd Elvins, San Diego Supercomputer Center as supported by the National Science Foundation

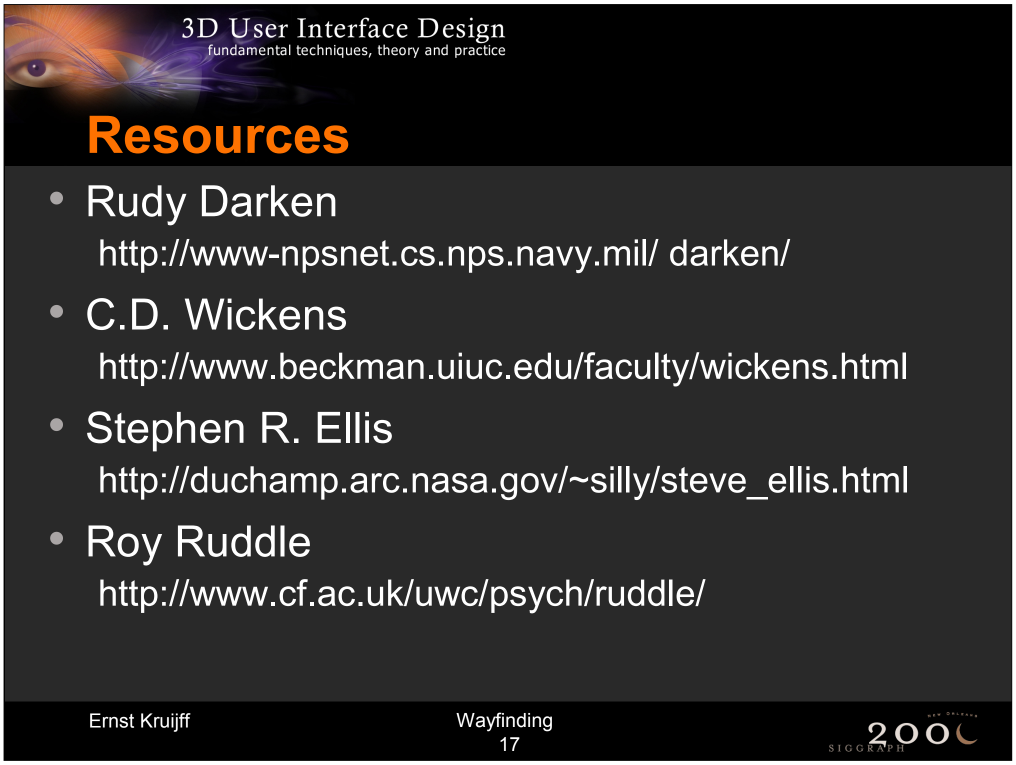


Porting spatial knowledge from a virtual environment to a real environment can be counter-productive. Wayfinding is dependent on exposure time, previous experience with searching tasks, search behavior, and many more factors. However, one can support wayfinding - Virtual Environments need to be thoroughly designed according to human and design principles. Please refer to the resources and the 3DUI BIB for more references.

It is also a common misunderstanding that wayfinding is only influenced by visual-perceptual factors. Research provides us with many clues to support the thought that for instance auditory spatial perception also has an impact on wayfinding.

Conclusion

- Supporting wayfinding is important in order to allow effective navigation
- Virtual Environments can be used for training purposes, details about knowledge transfer still need to be further researched in detail
- Wayfinding support at this moment is basically focused on realistic worlds, less on worlds which have no real-world metaphor



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For most references, refer to the "20th century 3DUI Bib". Below are those references that are not in the main bibliography.

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