I. INTRODUCTION

While car navigation systems are already widely commercialized today, in the near future not only motorists will be guided by a navigation assistance system. Recent progress in mobile computing has provided us with the means to realize pedestrian navigation systems. Personal navigation systems will provide location sensitive information, which can be accessed at any place and any time. Since several different means of transportation typically have to be combined in order to reach a destination, it must be ensured that the user interface reacts to the user's alternating situation. Changing the means of transportation implies that a personal ubiquitous navigation service must adapt smoothly to the associated situational context. The necessary change between different positioning technologies such as GPS or GSM/UMTS radio-cell based technologies in an outdoor scenario to the use of infrared and Bluetooth technologies in buildings should remain unnoticed to the user of such a navigation system. Furthermore, the system should adapt the presentation to different output devices and modalities and to the varying accuracy of positional information according to the technical resources available in the current situation. In addition, cognitive limitations of the user put constraints on the system’s presentation and interaction possibilities.

In this article we will discuss the major concepts that help to design and implement navigation systems that are sensitive to technical limitations on one hand and to cognitive constraints of the user on the other hand. We will start by explaining our view on resource-adapted navigation and discussing the various technical and cognitive resources that have to be taken into account. An overview over the relevant literature will provide the basis for the introduction of our navigation system REAL and the adaptation to different limited resources. We will see how REAL adapts graphical way descriptions on three different levels to resource limitations cast by the situational context. The article finishes with an example in which REAL provides the framework for a practical implementation of a fair guide navigation system for CeBIT 2002.
2. RESOURCE-ADAPTIVE NAVIGATION

Personal navigation systems that extend beyond today’s use in cars will play a major role in the future. Especially pedestrians will profit from the ability to get localized information on mobile devices everywhere and at anytime. The generated graphical presentations, ranging from complete route descriptions at a stationary information kiosk to incremental route descriptions given by the mobile devices, are used to communicate content (navigational instructions) between a sender and a receiver (in our case the system and the user). Whenever graphics are presented via a certain medium to a human viewer two different types of resources play an important role: on one hand all the technical resources of the electronic navigational aid and on the other the cognitive resource available to the user.

2.1 Technical Resources

Technical resources cover all types of limitations of the presentation platform. Here, three different subtypes can be identified:

- Quality and precision of the positional information
- Restrictions of the output medium
- Restrictions of the graphics generation process

Since several different means of transportation typically have to be combined in order to reach a destination, it must be ensured that the user interface reacts to the user's changing situation, no matter what kind of transportation is used. When a change of the means of transportation is detected the system has to adapt its interface to the new situational constraints. The essential switch between different positioning technologies, e.g. GPS or GSM/UTMS cells (outdoor) or infrared and Bluetooth (indoor) should ideally remain unnoticed by the user. It is also very important that a mobile pedestrian navigation system takes into account the precision of the location measurements, because sizes of radio cells may vary, GPS-satellites visibility depends on the actual location and the distribution of indoor infrared senders is often not uniform. Our notion of positional information does not only include the absolute or relative location of the user in the actual environment, but also the user's orientation and speed. The knowledge about the quality and precision of positional information can be used to adapt the graphical navigational instructions, as described later in the article. In our case the output medium is the systems’ visual interface. Typical output media are printed paper and computer displays, but also 3D-Display, such as stereo glasses. All the different media are restricted by an outer and an inner scale (Hake, 1982). These terms from cartography describe the maximum size of the graphics displayed, their resolution and thus the amount of detail that will be visible. Both factors influence the graphical presentations. For example it is not possible to reduce the size of a graphic without loosing details, so if the outer scale of the display is limited, it might be better to enlarge some small, but important details, while omitting others which are not so relevant for the navigational task at hand. In our case this implies that we