Adaptive Navigation Support with Public Displays

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ABSTRACT

In this paper, we describe a public navigation system which uses adaptive displays as directional signs. The displays are mounted to walls where they provide passersbys with directional information. Each sign is an autonomous, wirelessly networked digital displays connected to a central server. The signs are position-aware and able to adapt their display content in accordance with their current position. Advantages of such a navigation system include improved flexibility, dynamic adaptation and ease of setup and maintenance.

Categories and Subject Descriptors: H.5.2 [User Interfaces]: User-Centered Design

General Terms: Management, Human Factors.

Keywords: public displays, pervasive navigation.

1. INTRODUCTION

Effective support for wayfinding is an important design aspect of large building complexes such as airports, hospitals, and office buildings. People who find themselves in unfamiliar environments often face the challenge of having to find their way to a particular destination. This implies the need to know where they actually are in the complex, the layout of the complex, and the location of their destination in order to formulate their action plans. Most building complexes posses more or less sophisticated wayfinding systems in the form of building names, room numbers, directional signs and other elements. However, wayfinding is also influenced by architecture, lighting, landscape and landmarks. Good wayfinding aids help users experience an environment in a positive way and facilitate getting from point A to B.

Oftentimes wayfinding needs are related to events or people rather than locations. At a typical university campus, for example, visitors, staff and students regularly need to find their way to another person's office, a lecture or a conference being hosted in a particular building. The destination is often dynamic as an event may have to be relocated or various sessions relating to the same event might be taking place in different buildings. Similarly, alternative wayfinding information may be required in case a particular path is blocked due to building or refurbishing works or when the navigating person has special requirements such as wheelchair accessibility.

Existing wayfinding systems are not able to adequately address these changing needs. Handheld maps as well as stationary signs such as posted maps and directional signs have the problem that they are static and difficult to update. Recent mobile computing solutions (PDA + GPS + mapping software) are easier to update, but have a number of shortcomings: limited availability of navigation information (especially for semi-public buildings such as airports or hospitals), varying accuracy and availability of navigation information indoors due to shielding of GPS signals, and usability problems (e.g. resulting from small screen size). Using mobile devices for navigation also requires the user to concentrate on the device itself, which may cause interruptions of the navigation task and may even provoke dangerous situations. Using clues from the environment can be a more natural and safe way to navigate through a space.

2. THE GAUDI DISPLAY SYSTEM

To address the problems outlined above we have developed GAUDI, a prototype of a pervasive wayfinding system which is dynamic, adaptive and embedded in the built environment. The GAUDI system (Grid of Autonomous Displays) consists of a set of autonomous wireless displays and a navigation server. The displays, shown in Fig. 1 (right side), function as adaptive wayfinding signage and are intended to be deployed at strategic public locations across the Lancaster University campus. Their purpose is to assist visitors (and also staff and students) in navigating their way around campus. Each GAUDI display presents the following information: the name of the event or *destination,* the *direction* in which to go to reach the destination, and the approximate *distance* from the display to the destination.

The first release of GAUDI, described in this paper, is designed to support *temporary signage for event-based navigation.* A large number of events are held at a university throughout the year, which attract considerable numbers of outside visitors. These include concerts, performances, public lecturers, and award ceremonies. Quite a few of these events are not held at obvious and clearly identifiable locations, but in small venues, which are difficult to find. Traditional wayfinding systems are especially poor in their support for temporary events. Hence, a pervasive wayfinding system for temporary events must meet the following

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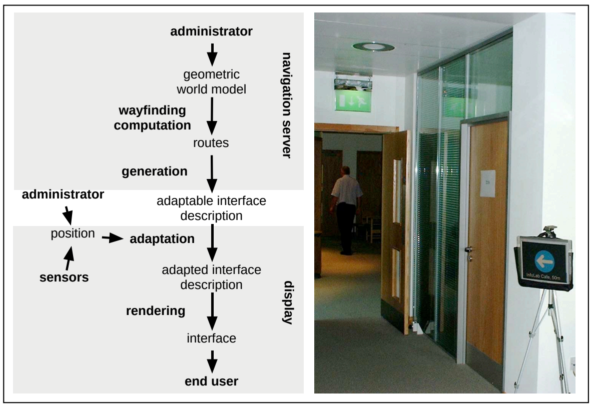

Figure 1: Adaptation process and a GAUDI unit

requirements: *easy deployment and maintenance* of the displays, *automatic adaptation* of the displayed presentation when the display is moved to a new location, and *simple modification and authoring* of wayfinding information.

Adding and removing a display is done simply by turning a GAUDI display unit on and off as it will automatically connect to and disconnect from the navigation server. To support temporary signage and event-based navigation GAUDI display units can be re-located easily since it only consists of a screen with limited computing power and a wireless network connection. It can either detect its new location via an attached sensor (e. g. ultrasound transducers) or an administrator can set the location manually using the GUI provided by the display. Once the display detects that is has been relocated, it automatically adapts its interface to accommodate for its new location and orientation (i.e. by displaying an appropriate arrow in the new direction as well as the new distance information).

3. POSITION-AWARE ADAPTATION OF WAYFINDING INFORMATION

The unique feature of GAUDI displays is their ability to automatically adapt their presentation to their position. In the following we will outline the overall system architecture and the adaptation process. A complete GAUDI system consists of two main components: a navigation server and an arbitrary number of autonomous display units. The navigation server supports those administrative operations that apply to all display units, such as the definition of the global route network, calculation of the routes, and the description and generation of the display interfaces. The display units currently consist of self-contained wireless computers running the GAUDI software. (In the future, more cost-efficient display units could be built based on electronic paper and an embedded computing system.) The displays determine their positions or allow the administrator to set it (through a GUI). They adapt their presentations according to the interface descriptions they have received by the server.

3.1 Spatial Model and Route Calculation

The server runs an interactive application which allows administrators of the wayfinding system to define destinations in a two-dimensional campus model. The model indicates buildings and passage ways, and the current location and orientation of all displays. The spatial model used in the adaptation process is encoded as an annotated graph (similar to the one used in [6]. It consists of nodes and edges connecting nodes, which are annotated with information such as coordinates, names, or whether or not they are part of the route. The calculation of routes operates on this graph, and is based on an A* algorithm. Clicking on a location followed by the 'broadcast' button will update all connected displays to indicate the direction and distance to the new destination. Similarly, the interface can be used to modify the existing spatial model or to author a new one.

3.2 Process of route adaptation

The adaptation of navigation information to a certain destination is shown in Fig. 1 (left side). An administrator specifies a destination in the geometric world model, which in turn triggers the wayfinding computation. The resulting routes inform the generation process that produces an adaptable interface description. This description is then passed from the navigation server to the displays. On each individual display, the adaptable interface description is first stored locally, and then adapted according to the location of the display. Its location is either set by an administrator (who physically sets the display up) or by sensors that automatically determine the position of the display. The outcome of the adaptation process is the adapted interface description (encoded in plain SMIL [7]), which is then rendered to produce the actual interface an end user will see.

3.3 Adaptable interface description

The adaptable interface description consists of an annotated graph – which models the route network as well as geometric properties of the area covered by the navigation application – and an abstract representation of the interface. This representation is encoded in a standard format (SMIL), that we extended to incorporate adaptation rules. These adaptation rules are embedded in the SMIL code and are evaluated by the display units using the annotated graph as well as information about their current location. The evaluation results again in a standard SMIL document, which is then displayed by the unit. We encode the rules using a small set of geometrical and logical primitives such as $< AngularDeviation > e_1, e_2 < /AngularDeviation >$ (computes the angular deviation between two edges e_1 and e_2 in the annotated graph) or $< Select > key, item1...itemN < /Select >$ (evaluates the key expression and selects the corresponding item from a list of given alternatives).

3.4 Position-aware interface adaptation

Whenever a display unit receives a new adaptable interface description, it first caches all related files (graph, interface representation, images) locally before evaluating the rules embedded in the interface representation. It then extracts all adaptation rules from the interface representation and evaluates them using a lazy evaluation scheme: whenever it encounters a function within an adaptation rule, it uses the annotated graph (e. g. by searching for the nearest edge to its own location) to replace the function with its corresponding result. Once the rule has been fully evaluated, the display unit replaces the code representing the rule with its evaluation. After evaluating all rules, it stores the resulting SMIL file locally and displays it.

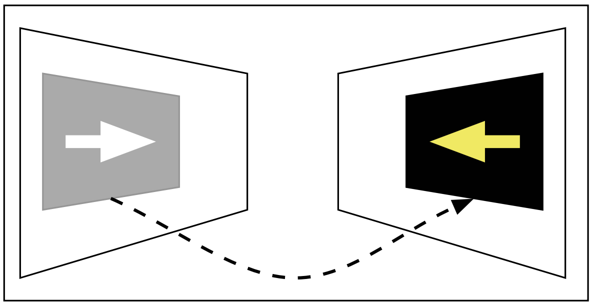

Figure 2: Moving a display to another location triggers the automatic adaptation process

Figure 2 illustrates the basic idea: Let us assume that the current destination is located somewhere beyond the end of the corridor depicted in the figure. Therefore, people will have to walk straight ahead in order to reach the destination. When the GAUDI unit hanging on the left wall of the corridor is re-located to the right wall, it automatically adjusts the arrow it displays to point in the right direction.

3.5 Display management

Since the original adaptable interface description is kept as well, the unit is able to re-adapt its interface without further interaction with the navigation server. For example, if the display unit is re-located, it re-evaluates the adaptable interface description using its new location in order to generate the proper interface. Hence, the server only needs to contact the units when a new target location is set, i. e. a new adaptable interface description has been generated. Adding a new display unit to the network corresponds to starting the GAUDI application (respectively to turning the device on if the unit application is started during the bootup procedure). In order to remove a sign from the network, it is sufficient to shut down the display (or the GAUDI application).

Both the server and the display application are written in Java and communicate using standard TCP/IP sockets. The interface is encoded using the SMIL 2 standard [7], and it is rendered using the XSmiles XML rendering engine [8]. The display unit provides a simple control GUI to define the display location in the absence of automatic sensing of its current position.

4. RELATED WORK

Interactive display systems have been one of the most prolific research areas in computer science and human-computer interaction. In recent years, a lot of work has centred on situated displays and on the use of large displays as public artefacts [3, 5, 4]. While most public display systems make use of single large-scale interactive surfaces, a few projects have explored the coordinated use of multiple, distributed displays. Examples include RoomWizard [4], Hermes [1] and the Plasma Poster Network [2], both systems comprised of collections of small displays attached next to office doors, and the Plasma Display Network [2] which uses poster-sized display. The Plasma Display Network is a content storage and distribution infrastructure that allows for the posting of content to all registered Plasma Posters. RoomWizard and Hermes demonstrate the potential of combining clusters of networked displays with context-awareness. Each of these systems is comprised of collections of small interactive display units placed outside people's offices or meeting rooms. However, compared to GAUDI these systems do not exploit their spatial relationship to each other to support event-based navigation.

5. CONCLUSION AND OUTLOOK

In this paper, we presented GAUDI, an initial version of a pervasive navigation system. It enables untrained users to easily set up a set of dynamic signs that will automatically adapt to their current location. The whole network of displays can be controlled from a single server, where clicking on a target location is sufficient to trigger the automatic adaptation of all connected displays.

The work presented in this paper is a first step towards a transparent pervasive navigation system. In the future, we will extend the system to support multiple concurrent targets as well as individual routes. Furthermore, we will provide access to the route planning mechanism on the displays in order to enable users of the public screens to specify their destination locally. Finally, as more displays are deployed throughout the campus, we intend to perform empirical studies on the acceptance and effectiveness of our approach.

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