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From wayfinding model to future context-based adaptation of HCI in Urban Mobility for pedestrians with active navigation needs

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Abstract: Everyday travel in expanding cities is becoming increasingly complicated. Going to the doctor, to work, to the cinema, or simply discovering the districts of a city requires knowledge of the city and navigation skills. The future challenge is more than just providing correct guidance to make navigation easier; it is more about delivering the relevant information when it is needed and prioritizing the continuous development of the users' navigation skills. This paper aims to present a novel model based on existing literature about the cognitive wayfinding process by proposing a state diagram for interactive system analysis and design. This diagram may help to illustrate different states of the wayfinding task and how navigation aid systems for pedestrians can consider this context awareness to create an adaptive behaviour considering the spatial knowledge of the user. A first study, focusing on one state of the wayfinding process: *Path Following* state, and its results are presented illustrating one example of different studies that can be designed considering our wayfinding model. At the end of this paper, we highlight a set of design guidelines that may lead to the next generation of navigation aid systems based on the wayfinding model.

Keywords: human-computer interaction; information and navigation; wayfinding model; urban mobility; smart glasses; travel experience; pedestrian

1. Introduction

Nowadays, people use more and more often Navigation Aid Systems (NAS) for their mobility. Those systems are based on Global Positioning System (GPS) and best trip algorithms. They may help to provide detailed trip planning instructions (for example mobile applications for route planning). This type of aid might guide people through their environment to reach their destination. Unfortunately, it may lead to decrease the use of their navigation skills due to what we call: Blinded Navigation[1]. For instance, one of these skills is to develop a cognitive map of the surroundings (Gardony et al., 2013). Thus, it causes less spatial awareness, separating them from the real world. The current research aims to introduce the new concept of wayfinding[2] state awareness which may help to design adaptive interaction for mobility assistance. By considering the survey knowledge the users have, the system could provide better active assistance. Moreover, the goal of this work is to help with their navigation skills development and improve the spatial acquisition knowledge about the environment

[1] Blinded Navigation: the way of navigating the environment focusing on the received guidance from different assistance tools and losing the awareness of the surroundings and thus the lack of the ability to remember the path.
[2] Wayfinding consists of a planned trip to a destination that requires the establishment of a route (Montello, 2005).

knowledge. To summarize, the main question being raised is: how could we design an adaptive navigation aid that can consider different states of the wayfinding process?

The next section presents related work about the wayfinding process followed by describing the *old* (current) navigation aid systems (NAS) and highlighting different interaction platforms used by these systems. Section 3 presents our proposed wayfinding model and the way NAS should be improved. Next, a case study is presented through (1) a scenario showing potentialities of the wayfinding model and (2) a preliminary study illustrating an example of numerous studies to be performed. In section 5, we discuss the impact of considering the wayfinding model to design active navigation assistance. We also highlight our recommendations in term of design guidelines. Finally, we round off this article with a conclusion and research perspectives.

2. Related Work

A literature study may help to understand the wayfinding process, which represents the cognitive part of the navigation task. It will also allow comparison of existing navigation aid systems for pedestrians regarding the interaction platform used and the inclusion of different states of the wayfinding process.

2.1. Navigation and Wayfinding Taxonomy

Navigation is the task of people moving through their environment to achieve a destination. It may be understood to include the two components of locomotion and wayfinding (Montello, 2005): (1) **Locomotion** which is the movement of one's body around an environment, coordinated specifically to the local or proximal surrounds - the environment is directly accessible to the sensory and motor systems at a given moment. (2) **Wayfinding** which is the goal-directed and planned movement of one's body around an environment in an efficient way. It requires a place goal, a destination one wants to reach and consists to determine and follow a path or route between an origin and a destination (Golledge, 1999) (cited by (Letalle, 2017)). Frequently, this destination is not in the local surrounds. (Wiener et al., 2009) have elaborated a taxonomy for different wayfinding tasks based on the level of involved spatial knowledge.

Figure 1 provides a representation of this taxonomy. Three levels of spatial knowledge were considered according to (Wiener et al., 2009): “(1) knowledge about a point in space (e.g., a landmark, a destination), (2) knowledge about a sequence of points (i.e., a path to a destination, often referred to as route knowledge), (3) knowledge about an area (i.e., knowledge about the spatial relation of at least two points, often referred to as survey knowledge).” In this taxonomy, an *undirected wayfinding* refers to a state without a specific destination and according to the survey knowledge one can change from a pleasure walk when the environment is familiar and an exploration state when it is not. When the destination is defined, Wiener introduces the directed wayfinding which can be divided, according to the level of spatial knowledge, into: (1) *destination search* while the target location is unknown, it is considered *informed* or *uninformed search* depending on the knowledge about the environment. (2) When the destination location is known, the navigator will proceed to a *path following* task if the path is known or, in the other case, to a *path finding* task. (3) *Path finding* which is also divided into: *path planning* while the environment is known or a *path search* while it is not.

2.2. Navigation aid system (NAS) in Urban Mobility for pedestrians

Of course, smartphones equipped with navigation software already make it partially easier for pedestrians to navigate in the city. However, studies show that this type of passive assistance does not make it possible to memorize journeys and appropriate the environment (Ishikawa et al., 2008; Konishi & Bohbot, 2013; B. Li et al., 2014; Maguire et al., 2000; Ruginski et al., 2019). The current navigation experience, based on GPS, presents one major drawback: Wayfinding using directive instructions leads to decrease navigator skills. Thus, it may reduce the development of cognitive maps causing less spatial awareness (Gardony et al., 2013).

According to (Maguire et al., 2000), the hippocampus[3] and the brain growth positively correlates with the amount of navigation skills' use. The less people use their navigation skills, the less their hippocampus is developed. As a result, it may cause cognitive deficits during normal aging (Konishi & Bohbot, 2013). People tend to keep focusing on instructions change instead of observing their surroundings. Indeed, current NAS may help people with their wayfinding task, for instance: including route planning and following more often using auto-generated instructions. Those instructions drive the navigators through their environment in a blinded navigation. Thus, they influence negatively their spatial knowledge acquisition (Li et al., 2014).

According to (Siegel & White, 1975), using landmarks, which are salient entities in the environment, helps to improve the survey knowledge during the wayfinding task (see also (Khan & Rahman, 2018) for a similar result in urban game environments). These authors suggested a theoretic model explaining the development process of this knowledge acquisition. They found that the representation of this knowledge about a specific area, goes progressively from knowing landmarks then paths to a global survey knowledge. (Montello, 2005) called it: “the dominant framework” considering the big influence of this model on the literature. (Ishikawa & Montello, 2006) describe landmarks recognition as: People tend to recognize a landmark by its importance in the environment in terms of size, shape or colour.

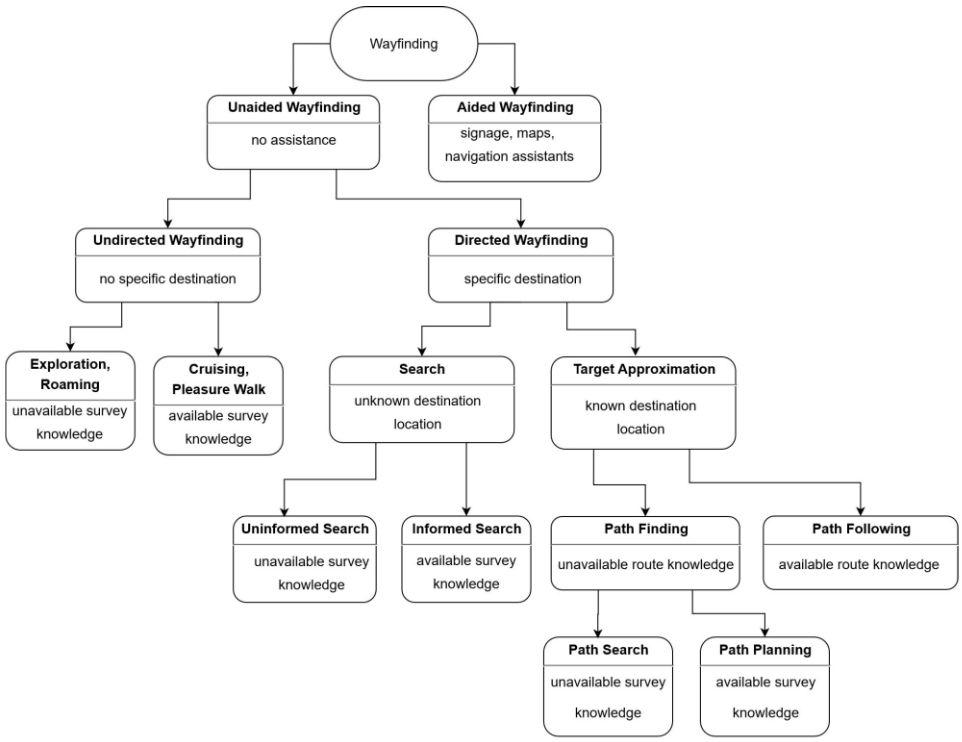

Figure 1: Wayfinding Taxonomy (adapted from Wiener et al. (2009))

3 The hippocampus is a specialized region in the brain to navigate the spatial environment (Maguire et al., 2000).

The Table 1 shows a comparison made between different navigation aid systems from the literature. The attributes below are used:

(1) **Name of the designed system:** to precise if the system has a name.

(2) **Pedestrian Navigation Mode:** if in the current study, the pedestrian mode is considered or not.

(3) **Type of Navigation:** indoor or outdoor.

(4) **Interaction Support:** represents the device used to test the suggested system, for example smartphones, smartwatches, augmented reality glasses, etc.

(5) **Landmarks suggestion:** it is a “Yes” if the guidance given highlights landmarks found in the navigation path.

(6) **Context (Wayfinding task awareness):** The context may be used dynamically to tailor the behaviour of the system or its response to patterns of use (Dey et al., 2001; Dourish, 2004). In our current work, the context of the mobility represents mainly the wayfinding state of the user during the navigation. For example, when the user is in a *path following* state (cf. Figure 1), the context attribute will have the value: *path following* state. This attribute in the comparison table reflects the fact that the system considers or not the different states of the wayfinding cognitive process, explained in the first section. The identification of these states remains a key challenge, as it is the case for all context-aware systems (Dey, 2001; Schmidt et al., 1999); First perspectives, tackling this research question, are mentioned in the discussion section.

(7) **Targeted users:** it describes for whom the system was designed, for people with disabilities as an example.

Table 1: Comparative table of navigation aid systems

Ref. (paper)	Name of the designed system	Pedestrian Navigation Mode	Navigation	Interaction Support	Landmarks Suggestion	Context: Wayfinding task Awareness	Targeted users
(Hile et al., 2009)	NA	Yes	Outdoor	Phone	Yes	No (just path following)	No specific users
(M. Li et al., 2012)	NA	No (Segway)	Outdoor	Smartphone, Augmented Reality (AR)-Vibrotactile	No	No (just path following)	No specific users
(Morrison et al., 2009, 2011)	MapLens	Yes	Outdoor	Phone, Augmented paper map	No	No (just path following)	No specific users
(Frey, 2007)	CabBoots	Yes	Outdoor	Vibrotactile on shoes	No	No (just path following)	No specific users
(Pielot & Boll, 2010)	Tactile Wayfinder	Yes	Outdoor	Vibrotactile	No	No (just path following)	No specific users
(Huang et al., 2012)	NA	Yes	Outdoor	AR-based, Voice-based and Digital Map-based (three applications were installed on a Smartphone)	Yes	No (just path following)	No specific users
(Wither et al., 2013)	NA	Yes	Outdoor	3D panorama view on Smartphone	Yes	No (just path following)	No specific users

(Montuwy et al., 2018, 2019)	NA	Yes	Outdoor	AR glasses vs Spatialized sounds with a bone conduction headset vs Smartwatch	No	No (just path following)	Older pedestrians
(Wenig et al., 2017)	Pharos	Yes	Outdoor	Smartwatch	Yes	No (just path following)	No specific users
(McGookin et al., 2009)	Audio Bubbles	Yes	Outdoor	Audio	Yes	No (just path following)	No specific users
(Coors et al., 2005)	NA	Yes	Outdoor	3D-Maps on Smartphone	Yes	No (just path following)	No specific users
(Walther-Franks & Malaka, 2008)	NA	Yes	Outdoor	AR on Smartphone	No	No (just path following)	No specific users
(Meier et al., 2015)	NA	Yes	Outdoor	Vibrotactile feedback on feet	No	No (just path following)	No specific users
(Velázquez et al., 2018)	NA	Yes	Outdoor	Vibrotactile-foot feedback connected to a smartphone	No	No (just path following)	Blind pedestrians
(Albrecht et al., 2016)	NA	Yes	Outdoor	Music listening with spatial audio for route and beacon guidance using headphones	No	No (just path following) outcomes: beacon guidance[4] is better for familiar surroundings and route guidance for unfamiliar areas	No specific users

[4] Beacon guidance: navigation aid method, different from turn-by-turn instructions, aims to inform the user about the direction of the destination (Albrecht et al., 2016)

(Bertel et al., 2017; Schirmer et al., 2015)	Shoe me the Way	Yes	Outdoor	Vibrotactile feedback on shoes	No	No (just path following)	No specific users
(Chung et al., 2011)	Guiding Light	Yes	Indoor	AR using light projector	No	No (just path following)	No specific users
(Hussain et al., 2014)	NA	Yes	Outdoor	Nonspeech audio (earcons, spearcons and short pulses)	No	No (just path following)	No specific users
(Rehrl et al., 2012, 2014)	NA	Yes	Outdoor	AR vs Voice vs Digital map Using Smartphone	No (highlighting few landmarks on the digital map without using them into guidance instructions)	No (just path following)	No specific users
(Wen et al., 2013)	NA	Yes	Outdoor	AR on Smartphone, Digital map, Compass, Radio	No	No (just path following)	No specific users
(Kamilakis et al., 2016)	NA	Yes (including public transport)	Outdoor	AR vs Digital map on smartphone	No (they were displaying points of interest)	No (just path following)	No specific users
(Kochar, 2017)	NA	Yes	Outdoor	AR vs Digital maps on smartphone	Yes	No (just path following)	Forced migrants (no specific needs)

2.3. Synthesis

According to Table 1, 22 related works were compared. Different systems were designed for outdoor navigation for pedestrians. All of them, except (Kochar, 2017; Velázquez et al., 2018), were targeting users without specific needs. Seven papers (Coors et al., 2005; Hile et al., 2009; Huang et al., 2012; Kochar, 2017; McGookin et al., 2009; Wenig et al., 2017; Wither et al., 2013) considered including landmarks into the guidance information displayed for users. Nine of these studies considered the use of AR basing on the benefit of being able to receive the navigation guidance without altering the users' focus on their environment. To summarize, no work has included the wayfinding process into the design of their navigation aid systems. We argue that the *Path Following* state was the only one targeted without considering different states where the user may feel less supported and less understood. Finally, our current research is motivated to evaluate the use of AR glasses technology as one of the interactions we can use to illustrate the wayfinding states, highlight different landmarks and imagine a better navigation experience.

3. Proposal

In this section, we propose a new representation of the wayfinding model using a UML (Unified Modeling Language) state diagram (cf. Figure 2), with a design point of view. We consider the states of wayfinding task stated in the section before. This model illustrates the link between the navigator state and which component(s) of the wayfinding a person is using. Then, we present how the use of this model can improve and support the design of navigation aid systems.

3.1. Wayfinding Model as design model

The proposed *Wayfinding Model,* illustrated with a state diagram, allows to highlight different states of this cognitive process. This diagram shows how a navigator can change the task of the navigation according to the spatial knowledge s/he has. The main goal of this diagram is to explicit different transitions that a navigator's mind can perform and thus we aim to use this model to create adaptive navigation systems that may assist the user for all the states of the wayfinding. Based on the Wayfinding taxonomy (Wiener et al., 2009), we distinguish three variables representing the user's spatial knowledge, on which the wayfinding state depends. Those variables, notated as a triple, consider the knowledge about: (a) destination location, (b) path towards the destination and (c) the survey. For instance, {?,?,?} (*Undirected* state) means that the system does not know, at a specific moment, if the user knows or not the destination, the path and the environment. {+,-,+} (Path *planning* state) means that the system knows that the user knows the destination and the environment but does not know the path.

We can identify mainly three blocks according to the wayfinding states:

- **Undirected wayfinding:** the navigator does not have a specific destination to reach. According to the third knowledge attribute of the environment, navigator could move from (a) *exploration* to (b) *pleasure walk* and vice versa depending on their knowledge of the environment. Specifically, if the individual does not know the environment in which he or she finds himself or herself, he or she is in a state of exploration. The objective is then to become familiar with the environment by observing the surroundings. For example, if someone goes to a conference in an unfamiliar city, when he/she arrives to the hotel, he/she will walk around to see what is there and learn about the environment (subway station, restaurant, etc.). He/she does not walk with a goal to reach. This knowledge will be useful if he/she decides to go to a specific place (directed wayfinding situation) and make the navigation easier. Conversely, when an individual knows the environment and decides to walk without a specific destination he or she is in a situation of walking for pleasure. The individual gets his/her bearings thanks to the knowledge already acquired.

- **Destination locating:** it is when the navigator decides to reach a specific destination with an unknown location. The goal of this block is to locate this destination using a (c) *uninformed or (d) informed search* depending on the navigator's knowledge of the environment. For example: “we can have a recommendation of a restaurant (specific destination) from a friend. Then, we ask for its location (location search) and he or she clarifies that it is located next to the main post office at the city centre”. The location is well located thanks to the landmark provided.
- **Path Planning & Following:** we assume that the destination is already located. Then, the navigators proceed to build progressively a path. When this second attribute is known, the navigators follow the defined path to approach their destination ((g) *path following*). We continue with the previous example: the landmark provided may trigger, in our minds, a known path if we are familiar with the area ((f) *path planning*) or in the other case, it will invite us to search for a path using a NAS ((e) *path search)*.

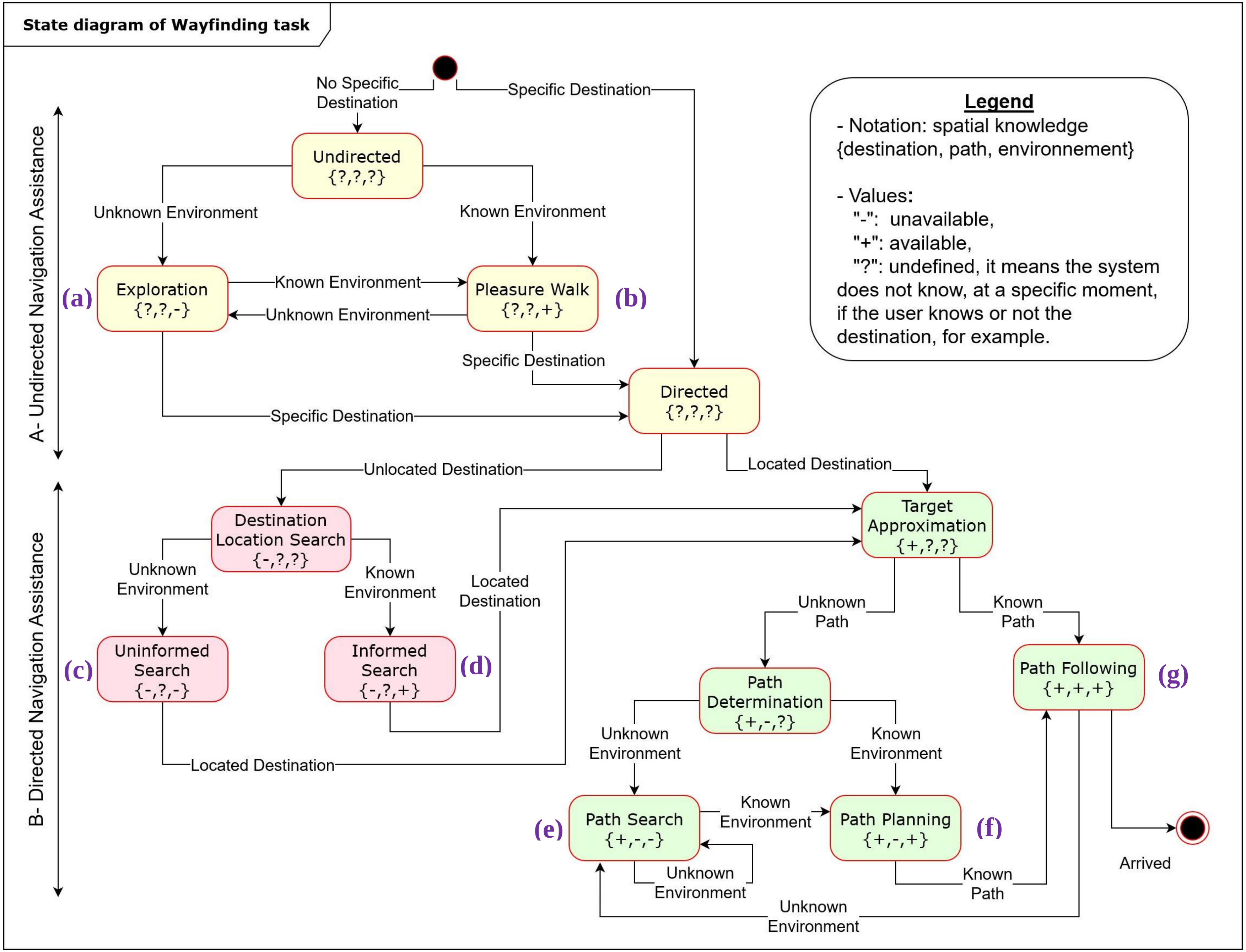

Figure 2: Wayfinding Model illustrated using a state diagram.

3.2. How to improve NAS considering the wayfinding state awareness?

The next UI sketches illustrate how a navigation assistance should be designed considering the wayfinding state awareness. We consider user interfaces using Smartphone for digital maps and AR glasses. Other platforms of interaction (as smartwatches, vibrotactile belts, headphones, etc.) can be adapted regarding the recommendations given for these systems.

A- Undirected wayfinding assistance: The goal of this assistance mainly is to give an augmented informative layer of current environment. This may contribute to enrich the users cognitive map. According to the users' mobility history, we could identify some relevant landmarks which could be recommended. For instance, Figure 3 represents a sketch of augmented reality glasses highlighting a pharmacy as a landmark. This assistance may help with spatial knowledge acquisition and provide more engagement with the surroundings.

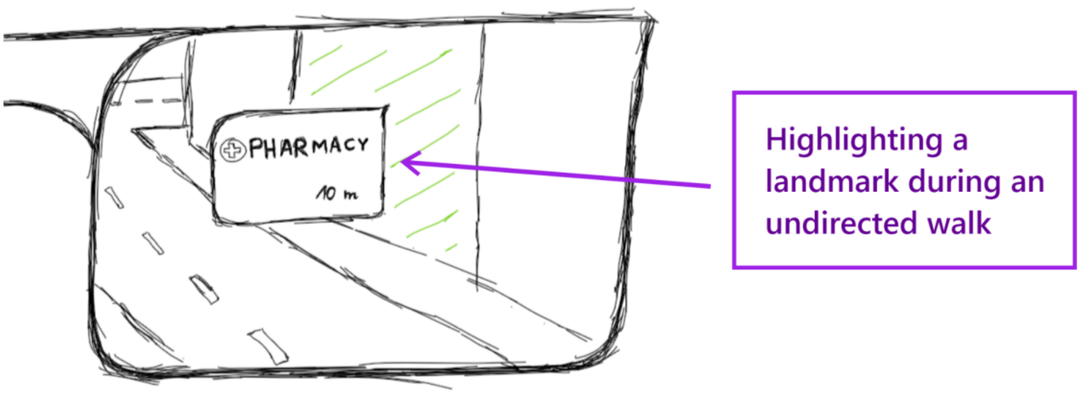

Figure 3: A-Undirected Wayfinding Assistance - AR Glasses

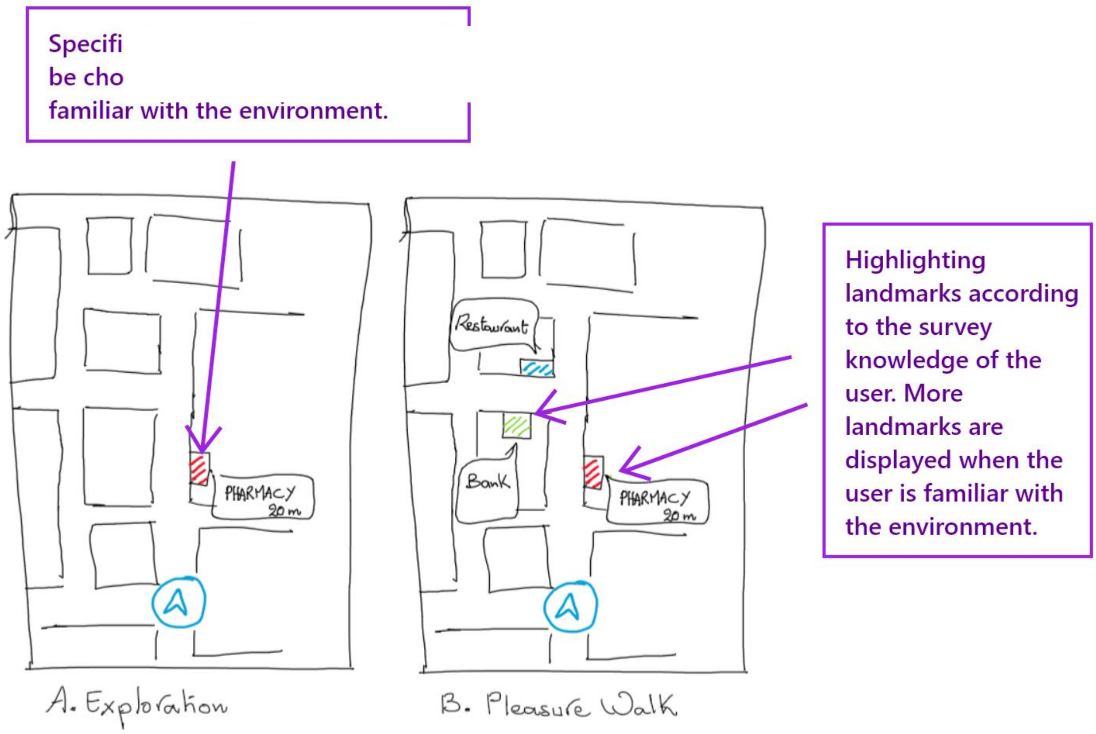

Figure 4: A-Undirected Wayfinding Assistance - Mobile Application

Figure 4 shows an adapted assistance basing on the wayfinding state. When the users are in unknown environment (*Exploration state*), the assistance could provide the users with focused landmark recommendations. Otherwise, when the environment is known (*Pleasure Walk state*), the assistance could suggest some landmarks. In the second case, the aim of the assistance is to refresh the users' memory.

This type of assistance focuses on the first block of the wayfinding model (A- Undirected Navigation Assistance). Thus, it may improve the exploration skills: recognizing and memorizing landmarks.

B- Directed Wayfinding assistance: This assistance aims to help the users to reach their destination. First, it could help with locating the destination. Figure 5 shows how the destination could be identified for the user. When the environment is unknown (*Uninformed Search state*) (Figure 5 – left screen), the direction to the destination is displayed (the yellow flag). This may increase the users' sense of direction. When the users know their environment (*Informed Search state*) (Figure 5 – right screen), the destination could be identified near a recognized landmark for the users. The flag could be also displayed to ensure the development of correct sense of direction.

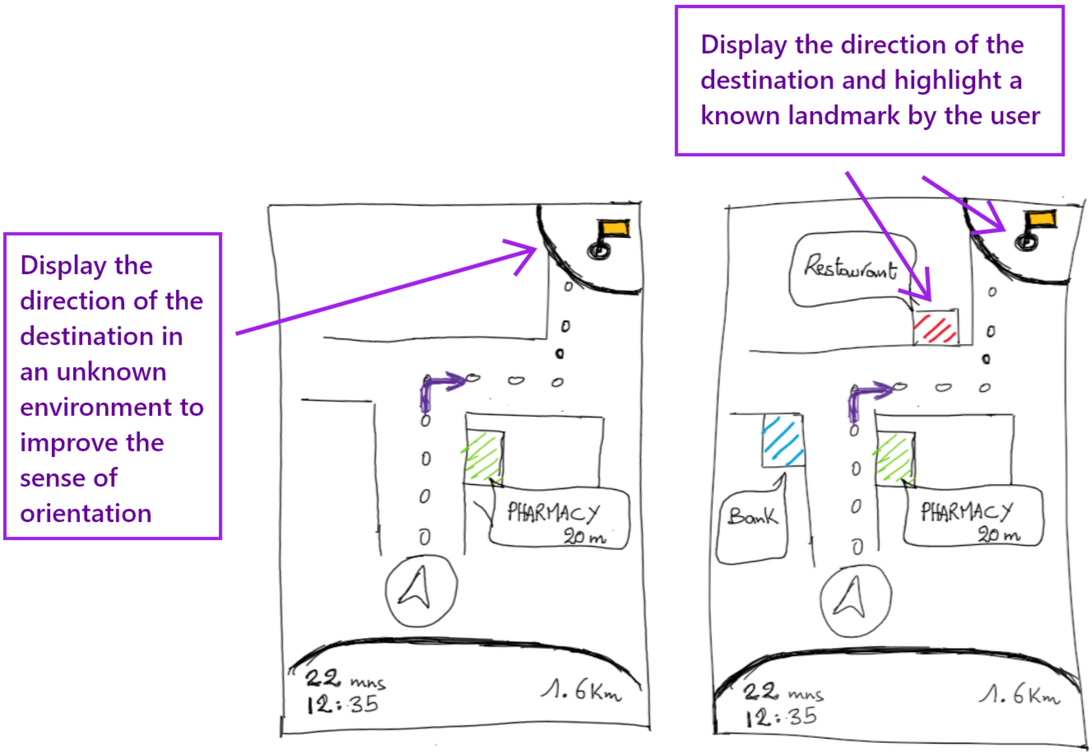

Figure 5: B-Directed Wayfinding Assistance - Mobile Application -

The aid in this stage concerns recommending already memorized landmarks and/or visually accessible ones and also trying to include them during route planning, it means improving the user skills to link between her/his landmarks in an active way.

Second, this assistance may help also with route planning and following. The Figure 6 below illustrates two important recommendations that could be considered as well with the AR glasses and the other platforms of interaction mentioned in the beginning of this section:

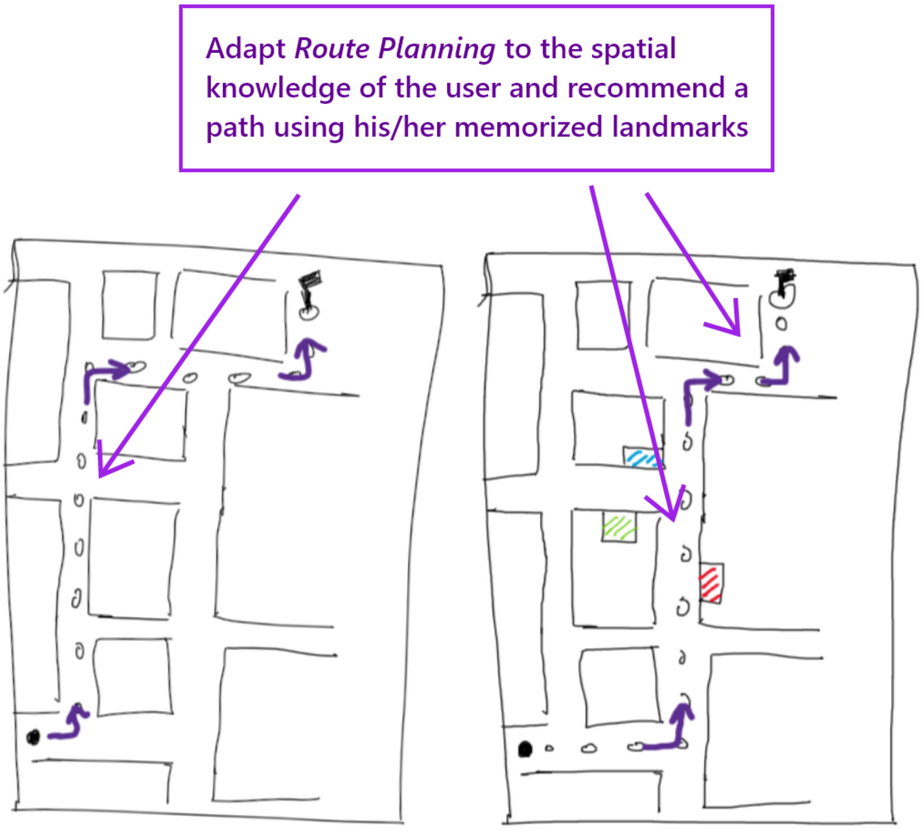

Figure 6: B-Directed Wayfinding Assistance - Mobile Application - Route Planning

1- When the users are in unknown environment (*Path Search state*), the assistance could recommend a better path. This path could include relevant landmarks and easy to recognize ones.

2- When the environment is known (*Path Planning state*), the assistance could privilege a path with memorized landmarks without affecting the user travel cost. This is especially when different paths are possible for the same destination and presenting the same cost (for example: travel time, and/or price).

The skills mainly targeted with this assistance are route planning, retrieving memorized landmarks and building mental route progressively. This second block of the assistance aims to assist the user from having a destination till reaching it.

The previous two subsections are explaining the wayfinding model and how it should be used to improve the current navigation aid systems. The sketches presented illustrate different situations that could be found in real life and their corresponding wayfinding state that may help to understand the need and the expectations of the user. The next subsection will describe the prototype of one of possible systems that can be designed considering different states of the wayfinding.

3.3. A first Illustrative system of future NAS

Figure 7 shows the architecture of an illustrative system of future NAS using the AR glasses. This system considers four main inputs. First, the user profile including his or her preferences that can adapt the recommendation of landmarks and presenting the user abilities for choosing adapted routes. Second, the interaction platform used to display the guidance to the user and for this first prototype, we selected the AR glasses, we can consider the use of other platforms of interaction as the smartphones, smartwatches, haptic feedback belts, headphones, etc. Another possibility is to consider a multimodal interaction with different devices. Third, the characteristics of the external environment (for example: the noise or luminosity level to adapt the user interface and ensure the most profitable experience). Finally, our wayfinding model that may help to identify the assistance the user needs according to his or her current task and also regarding his or her spatial knowledge according to the different levels discussed earlier.

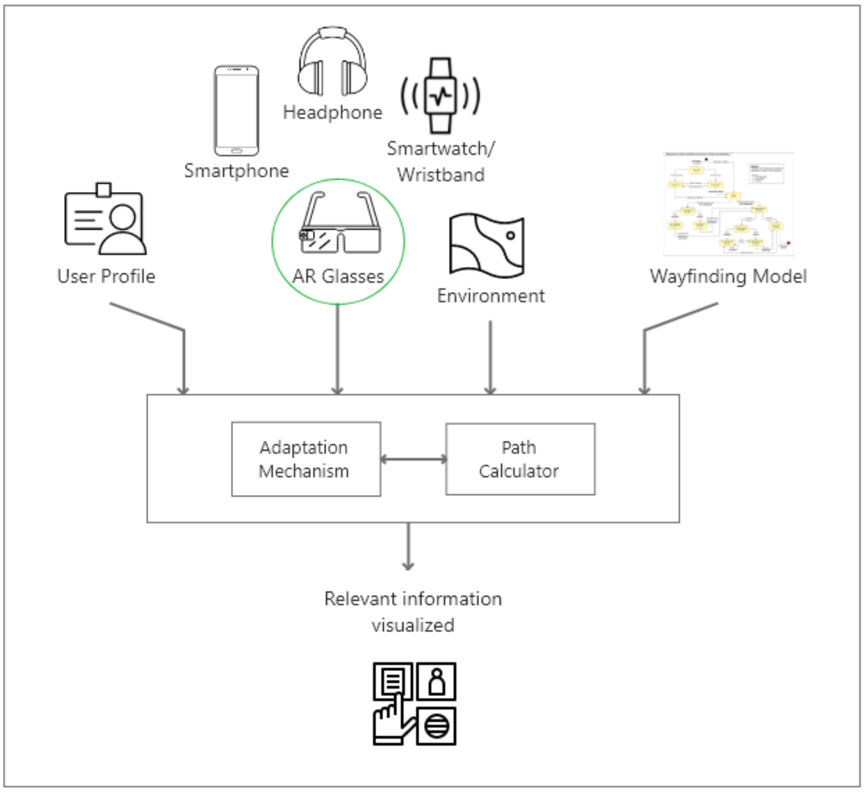

Figure 7: Architecture of the first prototype using AR glasses

Figure 8 illustrates the glasses used to build the proposed prototype. This model is the Vuzix SmartBlade AR glasses, that represents the best compact design found during the year 2019 and which satisfied our expectations to run this preliminary study.

Figure 8: AR glasses used for this study

Figure explains the architecture of the illustrative system of navigation assistance using the glasses. The glasses are connected to a smartphone to use its GPS sensor and to communicate also to an online API that will provide geographic information. This information is integrated into the path calculator module mentioned in Figure 7. Figure is displaying a mockup of the final display to develop using these glasses and shows an example of a landmark highlighted during a real navigation task in the preliminary study leaded. The next section will provide more details about the design and the results of this study.

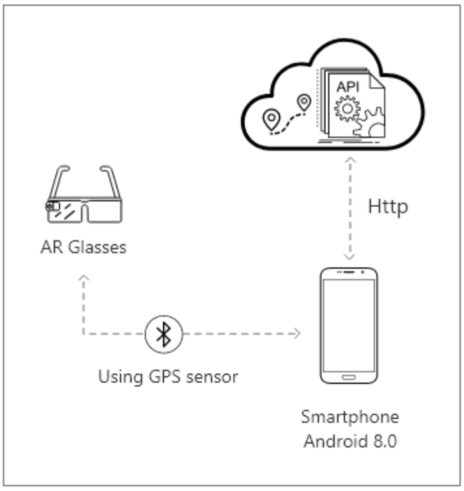

Figure 9: Global architecture of the proposed prototype

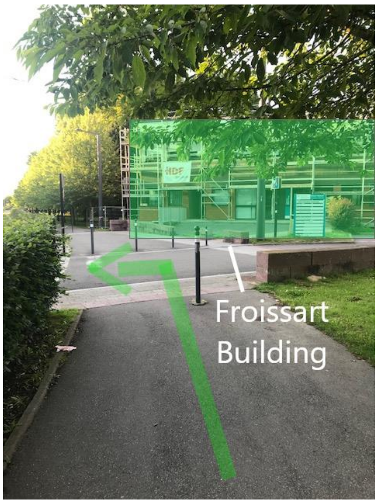

Figure 10: Example of landmark highlighted using the AR glasses

4. Outcomes (Illustrative study)

The results of a preliminary study based on the use of AR glasses and a limited number of parameters will be provided, in order to demonstrate the feasibility of the approach.

4.1. Participants

This study was leaded by 12 participants (7 females and 5 males) with an average of 25 years old. After a sort of questions before running the experiment, we found these characteristics of our population: 9 out of 12 have never used AR glasses but most of them were familiar with the virtual reality; 10 participants use mobile application for pedestrian navigation or while driving; 7 participants have a vision correction (0.25- 6.0).

4.2. Scenario for path following state of wayfinding

To simulate a context of "Path Following in an unknown environment and to reach an unknown destination", the participants were asked to follow the instructions given by the glasses starting from the laboratory to arrive to an unknown destination (the presidential building) (cf. Figure 9). This path was unfamiliar to all the participants. The designed system guides the users by providing instructions that include relevant landmarks at different decision points. For instance: "Turn left in front of Froissart Building" and "Turn left in front of the Gym" (cf. Figure 9 for the complete list of instructions).

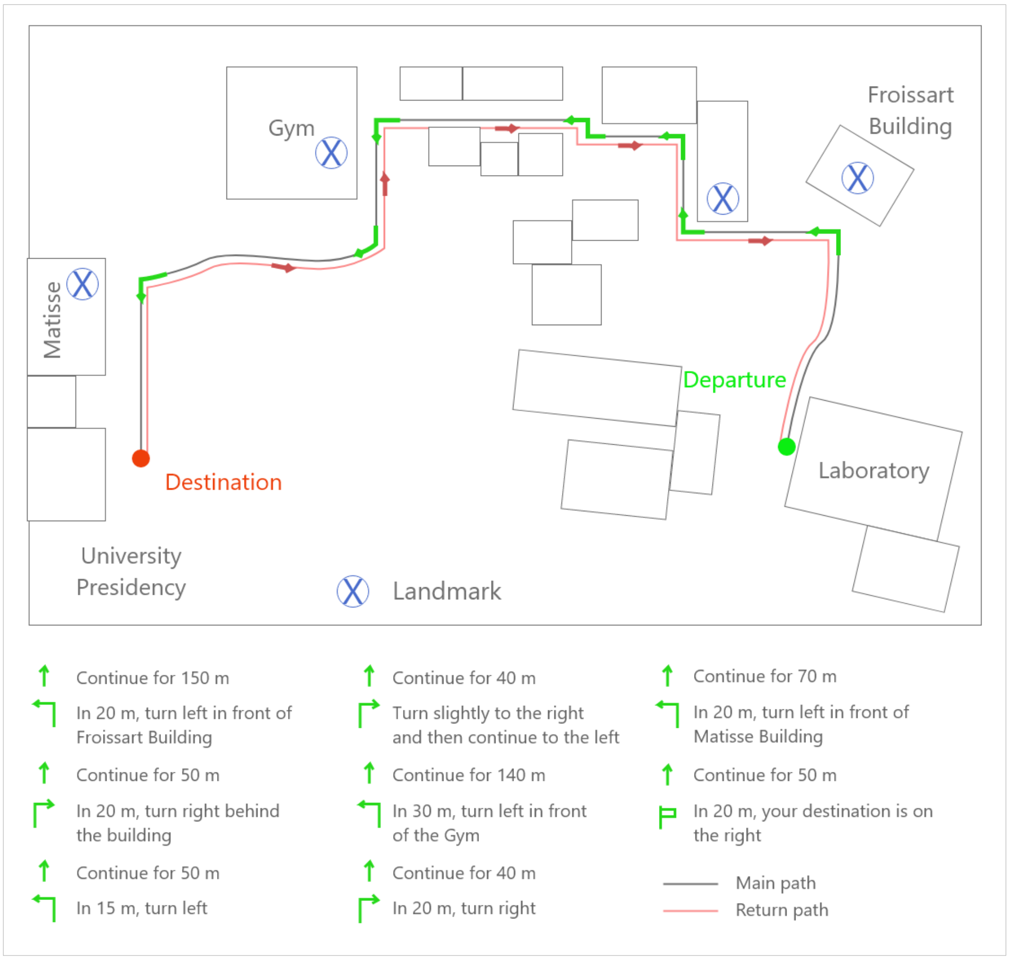

Figure 9: Scenario of the preliminary study (Main and return paths)

4.3. Study design

The study was planned inside the campus of the university and because it was an outdoor activity, the weather state was considered to provide similar conditions for all the participants. The experimenter received each participant providing a quick familiarity session using the AR glasses. This first use could help to verify the good visibility of the display. The assistant placed the participant at the depart position and orienting him or her to the initial direction. When the walk started, the assistant followed the participant from distance behind him or her. After reaching the destination, the participant is asked to follow the same path to return to the departure. The participant is asked to answer a questionnaire with 5 values on a Likert scale about the path followed and the usability of the system in general. Another questionnaire, S.U.S

(System Usability Scale) (Bangor et al., 2009), was provided to the participant at two different times: before and after the walk. The goal of this evaluation is to validate these two hypotheses:

- H1 – the user will succeed to reach the destination following the guidance including relevant landmarks provided by the AR glasses (The path following state assistance is validated).
- H2 – the user finds the glasses easy to use.

4.5. Results & Feasibility approach validation

The obtained results from this study are illustrated by the Figure 10. It shows mainly the difference between the users' expectations before the experimentation and their opinions after the use of the glasses during the walk. We can see that the participants were more convinced of the use of these glasses after using them. Two participants (number 9 & 10) had different results that we can justify with: (a) The first one found that the glasses are a little bit heavier after 10 minutes of use while navigating; it was not as expected at the beginning, comparing to usual prescribed glasses. (b) The second one considered that in specific areas the view as not perfectly clear because of the back light so he or she and other participants were seen using their hands to cover the sun light. We argue that both hypotheses were validated, all the participants succeeded to reach the destination without any mentioned difficulty. We consider that this first study shows the feasibility of the designed system considering the state of wayfinding: *path following*. Moreover, our initial observations show that the participants managed to return to the starting point by remembering the route and taking the opposite route. These promising findings suggest further studies to show that such an approach avoids blind navigation, while improving route learning. Finally, this study will open the way to include more states of wayfinding.

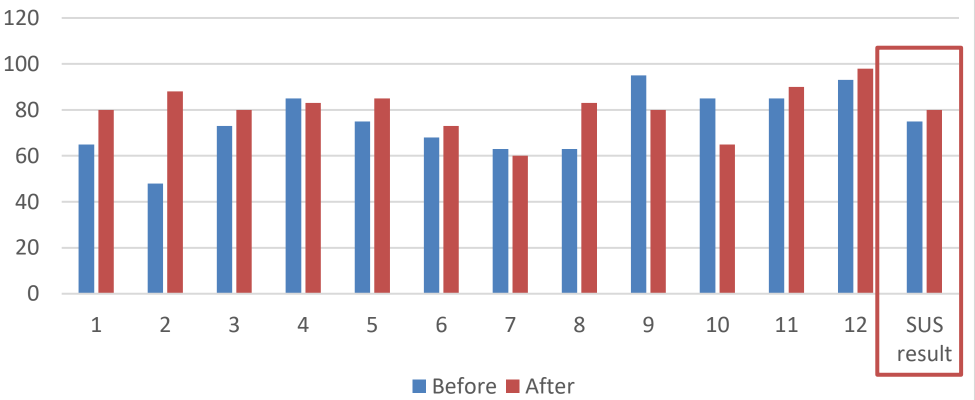

Figure 10: SUS results (Before & After the use of AR glasses in mobility)

5. Discussion & Guidelines

The proposed wayfinding model presents a novel approach to design the future of NAS. It considers the user's knowledge according to three levels of spatial knowledge. This model helps to identify the states of wayfinding task and different possible transitions. Integrating the whole model in NAS design process is the main purpose of our current research work. Before the selected navigation scheme is determined based on the wayfinding state of the user, the identification of wayfinding states may remain on the users' mobility history. These navigation records may help to identify the knowledge level the users have according to the three variables already defined (destination, path and environment) (cf. Figure 2). The preliminary study was designed and leaded in the purpose of validating the feasibility of using AR glasses on one state of the wayfinding process which was the *path following*. The first results of this study allow us to move forward and consider the inclusion of all wayfinding states in order to demonstrate the adaptive selection of navigation assistance depending on different wayfinding states. To reach this goal, further comparative studies should be led, involving several parameters: changes and sequences of states, level of adapted guidance information, number of included landmarks in the guidance messages, guidance devices (for instance: smartphones, smartwatches, AR glasses, etc.; see (Adapa et al., 2018) or (Kortum & Sorber, 2015) for other examples of comparative studies than in Table 1). Many of current systems and user interactions are designed with context aware adaptations. This helps to keep the system adapting to the context changes. We argue that wayfinding state should be included in adaptive NAS design. As a result, NAS could be improved and be more adaptive to different situations of use. For a cold start of the system, it can operate perfectly as the current NAS. Its behaviour should be improved after interacting with the users. We can assume that the user does not have a spatial knowledge at the first use of the assistance. Another possible configuration is that the users may add manually their known delimited areas. This may help to learn the user‘s mobility history and build a knowledge representation.

Finally, we round off with the guidelines below for designing the next generation of navigation aid systems:

- Select relevant landmarks according to the users’ preferences and the history of their daily mobility.
- Highlight landmarks helping the spatial knowledge acquisition: show relevant landmarks at the right moment according to the user wayfinding’s state.
- Highlight landmarks according to the survey knowledge of the user. More landmarks are displayed when the user is familiar with the environment. Whereas, specific focus on few landmarks will be chosen when the user is less familiar with the environment.
- Display the direction of the destination to increase the sense of orientation for the user and help with the mental map construction.
- Select the best path for the user’s navigation considering his or her spatial knowledge about the environment. Prioritize the most known paths for the user.
- Highlight a known landmark near the destination to invite the navigators to use their memory and their navigation skills.

6. Conclusion & Future work

Wayfinding model represents a novel approach to design an adaptive NAS and providing a more engaging experience by considering: the user profile and preferences, the platform of interaction, and the wayfinding states. This wayfinding state awareness may be considered as a new trend for developing better NAS. The current work illustrates a set of guidelines that may ensure better and more informative experience for the navigator. Next challenges are to consider more states of wayfinding, discuss detailed user interface design on different platform of interactions. Finally, many studies could be performed to consider progressively all wayfinding states and transitions present on our model, as in (Lakehal et al., 2020).

Other perspectives could be focused on the human beings and in particular on people with special needs (due to disabilities, age, etc.). Indeed, navigation systems could be enriched with finer models, allowing for more personalized interaction and user-tailored interfaces for instance for people with intellectual disabilities (Aizpurua et al., 2019; Letalle et al., 2020). More generally, this approach may contribute to one of the grand challenges of HCI, particularly *accessibility and universal access* (Stephanidis et al., 2019). Finally, with a transport multi-modality vision, this work could be extended to facilitate the coupling of transport modes to this pedestrian modality.

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