Thinking Inclusively with CAPRIO

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***Abstract*—Accessibility and usability have been key concerns in the design of computer interfaces through which users interact with an application or a system. In developing CAPRIO, our personalized path recommendation system, usability was a design principle for its interface and accessibility was central in its path-finding algorithm, which currently considers user mobility constraints. Motivated by the recent discussions on algorithm biases as well as diversity and inclusion, we have examined the meaning of accessibility under the lens of inclusion and its role in enhancing CAPRIO's development. In this vision paper we discuss how a system like CAPRIO can become fully inclusive that it benefits users from all backgrounds.**

***Index Terms*—accessibility, diversity, inclusion, pedestrian path recommendations, HCI, chatbot, IoT, indoor, outdoor**

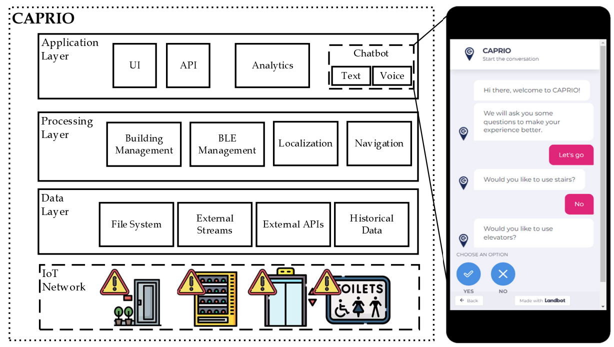

Fig. 1. (left) CAPRIO architecture on top of an IoT network. (right) CAPRIO Chatbot prototype using Landbot.

I. Introduction

In Human-Computer interaction, *accessibility* and *usability* can be defined in terms of the users' ability to effectively interact with an application or a system. Accessibility primarily focuses on supporting users with disabilities, whereas usability focuses on user experience. In general, the focus of accessibility is on visual appearance, interface designs, and assistive technologies' ability to engage with the interface and less on the system's functionality. Here, functionality is defined by the effectiveness of the system's algorithms to offer users the most utility. In developing CAPRIO (Context-Aware Path Recommendation exploiting Indoor and Outdoor information) [1]–[3], our path recommendation system, we employed user preferences to achieve functional usability and accessibility within the University of Pittsburgh and the University of Cyprus campuses.

CAPRIO enables users to personalize their indoor-outdoor paths by means of mobility constraints. These mobility constraints enhanced CAPRIO's usability by collecting information about users' ability to travel through indoor and outdoor spaces when finding the minimum path for a given departure and arrival time between two locations. At the same time, these mobility constraints introduce a degree of accessibility by allowing users to control their outdoor exposure, specify their indoor congestion tolerance, and request space accessibility.

Focusing on usability, some users might prefer to minimize the outdoor exposure of a recommended path during severe weather conditions as a result of individual taste. Others, however, may focus on accessibility, requiring minimum outdoor exposure because they are more susceptible to extreme temperature conditions for medical reasons. Similarly, carriers of heavy boxes might prefer accessible entrances and exits with ramps, avoiding staircases, congested corridors and hallways, all of which users with mobility disability might require. Avoiding congested areas is also important for people that move indoors and simultaneously be safe from crowd diseases, such as flu and coronavirus.

Reflecting on our decision to use *preferences* as a mechanism to support functional accessibility and usability, we argue that preferences can be effective in achieving inclusion that benefits all users regardless of disability to overcome barriers while traveling. As the above examples illustrate barriers could be inherent or transient (i.e., temporary disabilities), depending on the specific user and their circumstances. However, the mobility constraints as currently defined in CAPRIO are not inclusive; they are provincial and rigid by nature as they help in overcoming the barriers faced by a specific group of user. For example, CAPRIO cannot fully support a student with a guide dog, who must always take their guide dog's needs into consideration while traveling. Among these needs is the dog's relieving schedule, where the handler needs to take paths that include open areas of grass and nearby trash receptacles. This scenario cannot be described by CAPRIO's understanding of mobility constraints and necessitates rethinking how we approach solving this problem.

If we want to benefit users from all backgrounds, we need to think holistically how we obtain user preferences in a non-intrusive manner that also does not seek to identify users as having a disability or not.

Our vision is to develop a new generation of context-aware path recommendation systems, which intelligently discover users preferences that can make the path-finding algorithm more effective and inclusive. This means we must revisit the construction of the algorithms that drive the user interface and path recommendations. In the rest of this paper, we present the requirements and challenges of an IoT-enabled *Inclusive-for-all CAPRIO*.

II. Objectives & Challenges

To achieve inclusivity for all requires a solution that would take everyone's needs into consideration. Arriving at such a solution included the following series of steps that have presented their own challenges:

1) Identify subgroups of users.
2) Author sensitive questions to obtain user preferences.
3) Implement a way to represent the data that CAPRIO can understand and use in its path-finding algorithm.

A. Identify Subgroups of Users

Identifying subgroups of users based on disability to thoroughly cover as many scenarios as possible is the first step one can take to implement inclusivity. The reasoning is that if we can find a way to describe users by grouping them based on disability, we may generalize the type of barriers such users may face while traveling and therefore offer the shortest and safest paths. However, this is an extraordinarily challenging task. This approach sets out to leverage overarching disability categories (visual, mobility, or cognitive), but identifying every disability and its proper spectrum is simply not possible given the near infinite number of conditions. Furthermore, individuals may belong to one category but experience variance in the challenges they face. A person who deals with some form of blindness such as Retinoblastoma may be able to read large print but cannot see objects from certain distances. Another person may also be confronted with a form of blindness like Glaucoma that only allows them to determine whether a light is turned on or off. In short, a person's condition is not a reliable way to understand what abilities they do and do not possess. The severity to which the condition impacts the affected sense is also not accurately described by its general name which similarly disregards the afflicted users' ability to overcome different sets of challenges.

An alternative and equitable solution is to approach the issue bottom up rather top down. Instead of focusing on the groups to which individuals belong and we focus more on the fact that they face certain barriers while traveling. For example, instead of highlighting the fact that someone uses a wheelchair as a result of being diagnosed with Cerebral Palsy, we wish to concern ourselves more with the fact they are unable to climb stairs. This also captures temporal impediments and preferences. For example, a mother with a baby in a stroller might require elevators and family restrooms in the path. This way of thinking allowed us to identify users through their abilities rather than the conditions that affect their abilities. Moreover, we do not need to concern ourselves with grouping users based on such criteria and favor a more individualized approach that gathers information about each user to build a more accurate model of the type of paths they wish to take.

B. Author Sensitive Questions to Obtain User Preferences

When the second more individualized approach is adopted, the challenge becomes in determining ways to ask users questions about their abilities in a sensitive and respectful manner. It would be far more beneficial to focus on elements of environments rather than individuals' capacity to engage with them. Such elements include stairs, accessible doors, sensory-overloading areas (e.g., areas with loud noise, flashing lights, and/or strong smells), etc.

Keeping in mind that inclusivity intends to benefit absolutely everyone, we are now more concerned with aspects of environments that are commonly challenging for many people to overcome. For example, a wheelchair user cannot take the stairs and must use the elevator. A janitorial staff member will also opt to use the elevator when moving heavy equipment. A restaurant caterer will also need to use the elevator instead of the stairs when traveling with wheeled carts. In all three of these cases, we are shown that climbing stairs is not the preferred way to navigate to different floors of a building where an elevator is an appropriate alternative irrespective of the circumstances surrounding the reasons for its use.

By framing questions in terms of environmental characteristics, there is no need to ask users about their capabilities and limitations because such information is irrelevant to identifying which factors CAPRIO may use to calculate the shortest and safest paths possible. Obtaining preferences (environmental elements) rather than asking individuals about their abilities (capacity to engage with elements) solves the issue of potentially asking intrusive questions that would discourage the use of CAPRIO. For instance, asking, "do you have difficulty climbing stairs?" is far too invasive and personal. By contrast, asking, "do you prefer to use stairs?" as shown in Figure 1, we are simply interested in whether the user prefers to use stairs or not regardless of their reasons. Perhaps their reasons relate to their ability to overcome these barriers, but these reasons are not necessary for CAPRIO to improve the path-finding algorithm.

Ultimately, this task shaped how we thought about and approached inclusivity. We learned that inclusivity benefits everyone regardless of ability. Questions should therefore be asked based on preference. This makes users feel comfortable answering questions without sacrificing important information CAPRIO requires to build and offer the most efficient paths on an individual basis.

C. Implementation

Establishing in the example above that stairs are a common barrier for users from various backgrounds illustrates a general philosophy that we believe tremendously helps with achieving inclusivity: *it is environments that are disabling; individuals are not disabled*. This approach can be taken with any element of an environment such as noise, light, how users prefer to receive and process information, etc.

This leads to two interrelated questions fundamental to the implementation.

1) How should questions on preferences be phrased and processed?
2) How will information about elements of the environment be obtained and kept up to date?

Aligned with the goal of inclusivity, the answer to the first question could be the use of a *chatbot* (or chatterbot) [4] shown in Figure 1. Chatbots can communicate with and ask the users questions through voice commands or text chats or both. Employing such a solution ensures all users are able to interact with the preference-gathering functionality of our system.

Additionally, user preferences can be expressed in a simple fashion. Questions may take the form, "do you prefer to use X?", where X is a commonly encountered element of an environment. If the user answers *yes*, CAPRIO will include X in its path-finding algorithm. If the user answers *no*, CAPRIO will ignore it and move onto the next question. Here we envision that such a conversion will be structured in the form of questions and answers utilizing decision trees (e.g., Landbot [5]) or leverage AI, active learning techniques with natural language processing (e.g., Amazon Lex [6], Microsoft Bot Framework [7]). It is important to note that elements are treated in isolation, where choosing to use stairs, for example, does not eliminate the use of elevators. The goal here is to include all elements users are comfortable with, which is conducive to our inclusive model.

Currently CAPRIO implements a Building Management system (BMS) that stores the geometry of each floor of all the buildings in a way that can provide the information efficiently to build more accurate models. It is designed and implemented over a NoSQL architecture [8] in order to support all the indoor elements (e.g., doors, corridors, rooms, shelves, etc.) and their characteristics (e.g., exit-only, ramp-accessible, revolving door, family restroom, etc.).

To answer the second question, we envision expanding BMS by transforming it into a general Point-of-Interest (PoI) service that, besides the static characteristics of the elements of the environments (PoIs), provides PoIs' current state, collected by IoT devices. For example, a jammed door, a vending machine out of order, and a restroom or an elevator under maintenance can be reported as currently inaccessible, preventing their consideration when obtaining user preferences and subsequently when finding a path.

Finally, ASTRO [9], CAPRIO's path-finding algorithm needs to be optimized to consider an arbitrary number of preferences in meeting different objectives. Currently, ASTRO considers only three mobility preferences, namely outdoor exposure, congestion, and accessibility and optimizes for the total travel time/distance.

III. Conclusions

The initial design of CAPRIO, our context-aware indoor-outdoor path recommendation system, was motivated by usability and accessibility, in pursuit of offering the best possible user experience for all pedestrian travel. However, the mobility constraints expressed as preferences in CAPRIO are not inclusive and only help in overcoming the barriers faced by a specific group of users. Yet its development led us to the realization that through context-awareness and personalization, we could also achieve broader inclusivity.

Our analysis shaped our view that inclusivity benefits everyone regardless of ability. Our approach is to express inclusivity as preferences in terms of the elements of the environment (or PoIs). Once we have determined how to implement these improvements in preference acquisition, efficient maintenance of PoIs, and optimized processing, we will have successfully implemented a solution to effectively overcome CAPRIO's and similar systems' inclusivity limitations.

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