Towards Understanding Interaction of Visually Impaired Navigators with Surrounding Pedestrians

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***Abstract*— Individuals with visual impairment encounter pedestrians around them during independent navigation on a daily basis. Assistive technologies for such dynamic settings must perceive whether surrounding people will form an obstacle along the path (*e.g.,* due to being unaware of the approaching blind person) or simply walk past the blind person without a physical collision. Nonetheless, there has been little research into analyzing actual behavior of pedestrians surrounding visually impaired navigators. Towards enabling the design of assistive technologies that aid mobility in dynamic environments, we analyze how such interaction events unfold in real-world scenarios, as well as their causes and implications. Specifically, we find that several specific scenarios, both when surround pedestrians are aware and unaware of the approaching navigator, may lead to a potential physical contact event (*i.e.,* with the white cane or the body of the blind individual). By providing practical insights into the design of assistive systems that accommodate pedestrian interaction, this work takes a step towards enhancing personal safety and mobility of individuals with visual impairments.**

I. Introduction

Individuals with visual impairment are often surrounded by pedestrians during daily independent navigation [1]. While static landmarks and obstacles in the environment can be used for non-visual orientation, the presence of dynamic obstacles (*i.e.,* surrounding pedestrian traffic and crowds) provides a potential scenario for collision or social distress [1]–[3]. Therefore, knowledge of surrounding pedestrians, their activity, and potential future movement and behavior can empower a blind person by increasing the feeling of safety and control [1], [4], [5]. While in-depth understanding of pedestrian behavior around blind individuals can inform the development of suitable assistive technologies for coping with navigation in dynamic setting, there has been little research into analyzing and modeling actual interaction events in real-world scenarios. As previous research often emphasizes conveying static scene information [6]–[16], it currently remains unclear how an effective system for aiding a blind person during navigation in areas with dense pedestrian traffic can be developed.

Towards developing assistive system that can accommodate navigation in dynamic environments, we examine how the presence of surrounding pedestrians impacts navigation. Specifically, we analyze real-world interactions to understand how and why contact events, such as bumping or brushing, occur. While our findings do show pedestrian awareness to play a significant factor in such contact events, we also identify several other reasons that could result in such events. Hence, our study complements recent studies in assistive technologies for social interaction [1], [17], [18]. To fill the current research gap regarding close contact events, we conducted a navigation study and data-driven pedestrian-navigator analysis, as detailed next.

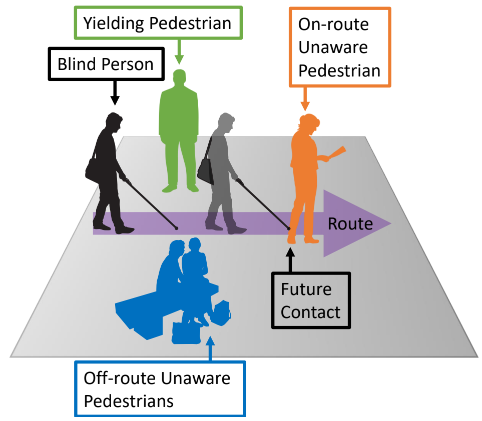

Fig. 1: An assistive navigation system in dynamic environments is required to understand the activity and intent of surrounding pedestrians for providing appropriate feedback to a blind navigator.

II. Apparatus and Procedure

To understand how to develop aids for scenarios involving navigation around pedestrians, we investigate causes for contact events in real-world data. We collected an ego-centered video dataset mounted on blind individuals using a wide view GoPro camera and a chest mount. Following the data collection process, the data was annotated with the time of events and their interaction type for each pedestrian in the scene. Participants followed an indoor smartphone-based navigation aid [9], [19], [20] in order to allow for focusing on the immediate navigation task as they would when walking a familiar route. The system covers a multi-floor indoor area of three connected buildings and multiple floors ($58{,}800m^2$ in total) with nearly $1{,}000$ Bluetooth beacons for the study. While studies often employ supervised experiments with a Wizard-of-Oz procedure, such a procedure would limit our ability to explore many real-world scenarios. Hence, employing a smartphone-based navigation aid provides a way for us to give route instructions over longer routes with minimal supervision and observation, a crucial step in an experiment for analyzing real-world interactions with the environment.

To ensure comfortable navigation, routes were selected to pass through both densely trafficked and less trafficked areas. Routes were chosen to be 200 meters long, each with 12 turns. During the study, each participant walked 6 routes, providing approximately 25 minutes of video data.

While a few of the areas contain many pedestrians in a more complex layout, most of the navigation involves walking through single corridors which may have one or two on-coming pedestrians at a time. We recruited 12 blind participants who employ a white cane as mobility aid. Prior to the study, participants were informed on the scope of the experiment, signed a consent form, and were familiarized with the navigation system and bone conducting headset through a training session. Participants initially experienced the turn-by-turn navigation system on a training route. They were also asked to focus on the instructions to arrive to their destination, while navigating as they would in their everyday life.

Fig. 2: Example contact event during navigation. In this particular case, the pedestrian on the right is talking to the pedestrian in the center, so that the blind navigator is unaware of the pedestrian in the center.

III. Data Annotation and Event Definition

Interaction events were annotated by their context and cause. While there are many interesting types of interactions that could occur, we focus on **pedestrian-navigator contact events**. Within these events, we analyze four types of scenarios potentially useful for informing future system design. The scenarios are defined according to the behavior of the pedestrian, as follows, (1) An **unaware** pedestrian (of the approaching blind person), *i.e.*, due to looking at the screen of a cell-phone or performing a task, (2) An unaware pedestrian that is in **active discussion** with another surrounding pedestrian (the reason for the distinction is that an assistive system can leverage the cue of another nearby person, and the discussion itself may produce audio that could impact the blind walker's path in the study, in contrast to a silent but unaware pedestrian), (3) A pedestrian that is **aware** of the approaching blind person and **attempts** to move to avoid their path, yet spatial environment characteristics (*e.g.,* a wall) restrict them, consequently leading to a contact event, and (4) A pedestrian that is aware of the approaching blind person, yet the blind navigator undergoes a sudden and **unexpected change** in their trajectory, *e.g.,* when notified to turn by the navigation aid, hence not allowing for a proper response by the pedestrian.

There are several important reasons for pursuing such fine-grained event definitions. For instance, while both (3) and (4) involve a level of incorrectly predicting the response to the future behavior of the blind person by a fully aware pedestrian, unexpected scenarios of sudden changes in (4) often lead to a more potentially uncomfortable contact interaction, *e.g.,* possibly tripping a pedestrian. Moreover, context-based assistive technologies can be developed to support safe and comfortable navigation by recognizing and planning for such diverse scenarios.

IV. Analysis and Implications

With the goal of understanding the behavior of pedestrians and its relation to navigation by blind individuals, we analyze the real-world interactions in our experimental environment. While our goal was to maintain comfortable navigation, the occurrence of contact events studied in this work is based on the density and complexity of the navigation environment itself. Overall, we have identified over a thousand interactions in the dataset, *e.g.,* an unaware pedestrian over multiple person is counted as the same interaction and not per frame (at 30 frames per second, the video collected would lead to hundreds of thousands of people instances). As expected, most of the interactions in the data do not lead to contact encounters 98% of the navigation time. Although studying the event distribution is interesting, it is somewhat specific to our environment and route choices. This percentage will vary significantly in environments where the entire route spans a densely crowded area, whereas in our case it only spans a small portion of the route. Out of the total contact events (31), 37% involved an unaware pedestrian, 6% an unaware pedestrian in discussion with another, 30% a failed attempt to avoid the path and 27% an unexpected change in the blind navigator's trajectory.

Despite the relative rarity of the events, we are able to produce some general insights by studying the data. First, we note how a large portion of the events occur due to pedestrian unawareness. Given that most pedestrians pass at close proximity to the blind person without any contact, knowledge of pedestrian awareness can aid an assistive system in providing more useful feedback to a blind person. Another (more surprising) finding is in the overall number of events due to an **incorrect prediction of future behavior** of the blind person, *i.e., unexpected* or *attempt* events. This overall category forms 57% of the events, with pedestrians often at full speed walking. While we expect unaware pedestrians along the path to lead to contact events, this type of interactions is more difficult to address, as pedestrians can be fully aware of the oncoming person. For an assistive system, navigation in such settings could be aided by either (1) providing indication to surrounding pedestrians on the future trajectory of the blind person (which may be effective but socially awkward), or (2) identify a potential contact event and providing feedback to modify the path of the blind walker (*e.g.,* slow down, wait for the surrounding pedestrian to pass, *etc.*). We conclude that such a system must be able to infer a variety of activity modes to determine if the blind person should yield, overtake, or continue on-route, and assist accordingly, beyond simply knowing if a person is facing or approaching the blind person or not. While sighted navigation allows to gauge activity and intent of upcoming pedestrians, we highlight additional dimensions in the complexity of blind navigation around pedestrians.

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