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Defining Traffic Scenarios for the Visually Impaired

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Abstract

For the development of a transfer concept of camera-based object detections from Advanced Driver Assistance Systems to the assistance of the visually impaired, we define relevant traffic scenarios and vision use cases by means of problem-centered interviews with four experts and ten members of the target group. We identify the six traffic scenarios: general orientation, navigating to an address, crossing a road, obstacle avoidance, boarding a bus, and at the train station clustered into the three categories: Orientation, Pedestrian, and Public Transport. Based on the data, we describe each traffic scenario and derive a summarizing table adapted from software engineering resulting in a collection of vision use cases. The ones that are also of interest in Advanced Driver Assistance Systems – Bicycle, Crosswalk, Traffic Sign, Traffic Light (State), Driving Vehicle, Obstacle, and Lane Detection – build the foundation of our future work. Furthermore, we present social insights that we gained from the interviews and discuss the indications we gather by considering the importance of the identified use cases for each interviewed member of the target group.

Keywords

problem-centered interviews, visual impairment, traffic scenarios, vision use cases

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Defining Traffic Scenarios for the Visually Impaired

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For the development of a transfer concept of camera-based object detections from Advanced Driver Assistance Systems to the assistance of the visually impaired, we define relevant traffic scenarios and vision use cases by means of problem-centered interviews with four experts and ten members of the target group. We identify the six traffic scenarios: general orientation, navigating to an address, crossing a road, obstacle avoidance, boarding a bus, and at the train station clustered into the three categories: Orientation, Pedestrian, and Public Transport. Based on the data, we describe each traffic scenario and derive a summarizing table adapted from software engineering resulting in a collection of vision use cases. The ones that are also of interest in Advanced Driver Assistance Systems – Bicycle, Crosswalk, Traffic Sign, Traffic Light (State), Driving Vehicle, Obstacle, and Lane Detection – build the foundation of our future work. Furthermore, we present social insights that we gained from the interviews and discuss the indications we gather by considering the importance of the identified use cases for each interviewed member of the target group.

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Introduction

According to the World Health Organization, 254 million people worldwide are blind or have moderate to severe visual impairments (World Health Organization, 2017). Vision loss leads to a decrease in the autonomous personal mobility (Wahl & Heyl, 2015) leaving visually impaired people in danger of "living in isolation" (Duckett & Pratt, 2001, p. 821). As "transport was felt to be the key to visually impaired people fulfilling their potential and playing an active role in society" (Duckett & Pratt, 2001, p. 821), we research ways of assisting the visually impaired in traffic situations by identifying relevant objects in their immediate surroundings with the help of camera-based object detections.

Research Background and Related Work

We develop a concept for transferring camera-based object detection algorithms in traffic situations from Advanced Driver Assistance Systems (ADAS) to the assistance of visually impaired pedestrians. In Jakob and Tick (2017), we motivate our work, discuss the state of the art in both fields, and present first results.

The next step in the transfer concept development was to gather all relevant traffic situations and especially the vision uses cases for the visually impaired. This was done by the qualitative study we describe in this article consisting of problem-centered interviews with experts and members of the target group. The study was necessary because, to our knowledge, no complete collection of relevant traffic scenarios and possible camera-based object detections exists.

There is, however, some research in the camera-based detection of single objects in traffic situations for the visually impaired such as crosswalks (Murali & Coughlan, 2013), traffic lights (Mascetti et al., 2016), or general obstacle detection (Tapu et al., 2013). These papers give explanations on why and how the specific detection is of interest for the visually impaired but focus on the algorithmic implementation.

The project "CrossingGuard" (Guy & Truong, 2012) examines information requirements of the visually impaired but is limited to crossings and does not take the use of camera information into account. From the results of a formative study with four visually impaired individuals and two specialists for orientation and mobility, they developed the system "CrossingGuard" that delivers "sidewalk to sidewalk" (Guy & Truong, 2012) directions at crossings. Afterwards, they tested their system by means of a user test with ten visually impaired participants.

Quiñones, Greene, Yang, and Newman (2011) present a study concerning the needs in navigation of visually impaired people, focusing on localization via GPS. In 20 semi-structured interviews with participants from the U.S. and South Korea, they discuss routine, infrequent, and unfamiliar routes. They go deeper into wayfinding techniques and the differences between known and unknown routes than our study, but they do not discuss which camera-based object detections could provide support during navigation. As in contrast to us, Quiñones et al. (2011) do not intend to use a camera in their GPS system, both studies, theirs, and ours, are tailored to the specific problem the research groups address and therefore complement each other.

The goals of our study were to create an overview of relevant traffic scenarios for the visually impaired and to collect the corresponding vision use cases that represent specific camera-based object detections. Furthermore, we needed to state which of the identified use cases are also of relevance in ADAS. The overlap from both fields will be examined in our future work to develop and formulate the before mentioned transfer concept.

Before interviewing members of the target group, we conducted expert interviews (Meuser & Nagel, 2009), whose results we present in Jakob, Kugele, and Tick (2017). As these results needed to be extended by the new findings from the interviews with target group members, we present a common evaluation of both interview types in this article.

Methodological Background

Creswell and Creswell (2018) define four different worldviews (Postpositivism, Constructivism, Transformative, Pragmatism), each as a "general philosophical orientation about the world and the nature of research that a researcher brings to a study" (Creswell & Creswell, 2018, p. 5). We see ourselves as representatives of the pragmatic worldview. Pragmatism includes that "researchers are free to choose the methods, techniques, and procedures of research that best meet their needs and purposes" (Creswell & Creswell, 2018, p. 10). For this study, we chose to conduct qualitative interviews because their narrative nature allows us insights into the daily life of the interviewees themselves and, in the case of experts, the people they are in contact with, while simultaneously leading us to the collection of traffic scenarios and vision use cases we need for our future work. Additionally, we decided to summarize the results by means of software engineering to make them easily accessible for developers from the field of computer science.

Creswell and Creswell (2018) state further pragmatists, and in a similar way mixed method researchers, "look to many approaches for collecting and analyzing data rather than subscribing to only one way." (Creswell & Creswell, 2018, p. 10). Although we used exclusively qualitative methods in our study, we approached the problem from different perspectives by interviewing experts as well as members of the target group. At the same time, our study can be seen as the first phase of an "exploratory sequential" (Creswell & Creswell, 2018, p. 218) mixed method design. Although we will not pursue this soon because it is not needed for the success of our current research project, the results of this study can be used as the foundation for quantitative studies. Based on the traffic scenarios and vision use cases we collected and described, it is e.g., possible to create a quantitative study that explores the correlation between the nature and degree of a visual impairment and needed vision use cases in traffic scenarios.

The word "problem-centered" (Creswell & Creswell, 2018, p. 6) is used as one of four dimensions to outline the pragmatic worldview. As researchers with strong connections to applied computer science, our research usually evolves around specific problems, in this case around the question of how a camera-based assistive system could support visually impaired people in traffic situations. This is in accordance with Patton (1990) who states that looking for solutions to problems is central to the pragmatic approach. Not only the research question itself is problem-centered; we also used a problem-centered method (Witzel, 2000) to design the interviews we conducted.

Methods

Problem-Centered Interviews

Witzel's problem-centered method (Witzel, 2000) is a semi-structured interview form in which the guideline is handled flexibly so that the interview can turn into a conversation between interviewer and interviewee. In addition to the guideline as a structuring framework for the interview, Witzel names three more required instruments: A short questionnaire to gather basic information about the interviewee, a recording for later transcription, and a postscript to write down nonverbal aspects of the conversation and spontaneous ideas for the evaluation.

We apply this method to two different sets of interviews: The expert interviews concentrate on accessing the "contextual knowledge" (Meuser & Nagel, 2009) the interviewees have gained concerning the visually impaired whereas the interviews with members of the target group focus on the interviewee's personal experiences. We define experts as people who are regularly, through voluntary or professional work, in contact with a diverse group of visually impaired people concerning age, gender, and impairment. An own visual impairment is possible but not a requirement. A person is considered a member of the target group if they have a visual impairment and are frequent road users.

Interview Guidelines

Both interview types essentially followed the same guideline. After going through the informed consent procedures, we gathered basic information about the interviewee in the short questionnaire. We then discussed traffic situations and after finishing the interview, we wrote a postscript.

While explaining the informed consent procedures, the interviewees agreed to recording and transcription of the interview and were ensured that their identity will not be revealed throughout the research. Furthermore, they were informed about the possibility to end the interview at any time and withdraw their consent to recording and transcription.

The short questionnaire as well as the discussion of traffic scenarios differed for the two interviews. In the short questionnaire we asked the expert interviewees about their age, gender, own impairment, profession and if their expert work with visually impaired people is voluntary or professional. In addition, we asked about age and gender distribution, kinds of visual impairments, and affinity to technology of the visually impaired persons the experts have regular contact with. For the interviews with members of the target group, we concentrated on personal characteristics: age, gender, kind of impairment as well as use of smartphones and computers.

To discuss traffic scenarios, we asked the experts about the three biggest challenges visually impaired pedestrians face and if there are differences in the problems for people of different ages, gender, and degree of impairment. Starting to talk about the three biggest challenges usually resulted in the discussion of further problems. If during the interview no new topic came up, a prepared list with traffic situations helped to give impulses to the interviewee. Towards the end of the interview, we asked about the differences between the visually impaired and the sighted when it comes to the preparation for a trip to an unknown address.

For the interviews with members of the target group, we chose a different approach: We gave the interviewees a concrete situation involving traffic challenges and let them talk us through the process of solving this situation, while keeping in mind to mention when and how a camera-based assistive system could provide support. We told them to imagine a system that has no limitations in the identification and communication of objects captured by the camera. The four discussed situations were:

a) *Familiar route, familiar surroundings:* You want to go to a concert that takes place in your home city/village. You know the concert hall and have already been to concerts there.

b) *Unfamiliar route, familiar surroundings:* You have a doctor’s appointment in your home city/village. You do not know the doctor and have never been to their office.

c) *Familiar route, unfamiliar surroundings:* You want to visit a friend who lives in another city/village. You have known the friend for a long time and have visited them frequently.

d) *Unfamiliar route, unfamiliar surroundings:* You want to travel to a city in which you have not yet been, because there is an event that interests you.

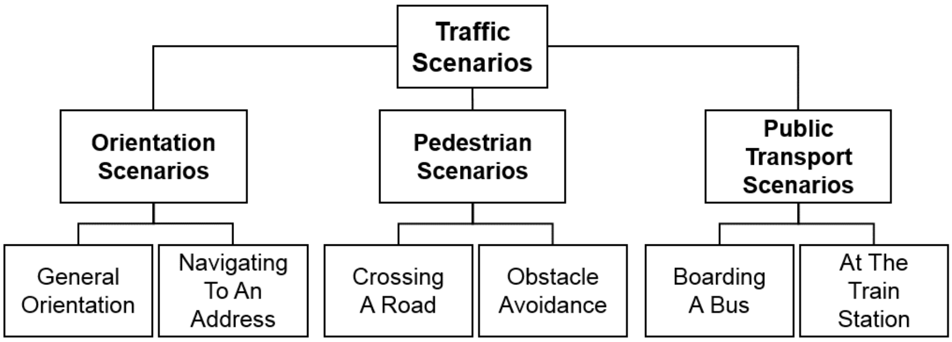
After the first interviews, we observed that the discussion of four problems produced a lot of repetitions in terms of traffic scenarios and vision use cases. As a result, the interviews took longer than expected and the motivation of the interviewees seemed to decline. We therefore reduced the interview to the discussion of two topics, one in familiar and one in unfamiliar surroundings. It depended on what we had learned to this point about the interviewee which ones in particular we chose. For example, if the person already told us that they do not travel unfamiliar routes, we discussed the familiar ones.

Data Collection and Analysis

The interviews were conducted in German language via phone. We translated the quotes presented in this article from German to English. Originally, we wanted to conduct the interviews in person, but when we planned the interview dates and locations with the interviewees, we realized that travelling to a meeting location, even close to their home, meant a great effort for some interviewees. We scheduled two interviews via phone to see if the course of the interviews met our expectations without meeting in person. As this was the case, we decided to conduct all interviews via phone and thus reduced the effort for both, interviewer, and interviewee. All interviewees live in Germany meaning that their statements refer to German traffic situations and not all results may be transferable to other countries. The experts come from different parts of the country, whereas the members of the target group all live in the southwest in rural and urban areas.

For transcription as well as data analysis and evaluation, we used the software MAXQDA Version 12 (2017). We defined codes to categorize the answers of the interviewees according to the six identified scenarios that we present in Figure 1. The codes were not predefined but developed inductively as proposed for example, by Mayring (2000). Every time an interviewee talked about a new situation; we added another code. We then merged some of the codes, for example, crosswalk, traffic light and others to crossing a road, to have a manageable number of codes. The three categories: Orientation, Pedestrian, and Public Transport were added at the very end after reviewing the coding to provide a better overview. As the subjects addressed in the interviews are social situations that can be clearly separated, we decided to have the coding done by one single person.

Figure 1
Hierarchy of the Identified Traffic Scenarios (Jakob, Kugele, & Tick, 2017)



During the expert interviews, we reached data saturation after three interviews: in the course of the interviews with members of the target group after six. To ensure data saturation, we conducted one more expert and four more interviews with members of the target group. Data saturation, in our case, is understood as the moment where further interviews did not lead to new insights concerning traffic scenarios and according to vision use cases.

Participants

Table 1 presents information about the interviewees of both interview types. We interviewed four experts, all being male and covering an age range from over 40 to over 70. As pointed out in Jakob, Kugele, and Tick (2017), three of them are blind, whereas the fourth person has no visual impairment. Two are active members of interest groups who work as volunteers and the others are employees of educational institutes. The visually impaired people the experts work with cover a wide range of age, gender, and degree of impairment. Concerning age, the students of one of the educational institutes are generally not older than 19, but the interest groups consist mostly of older members, due to demographic reasons and the fact that visual impairments are often age-related. We furthermore interviewed ten members of the target group, three female and seven males, covering an age range from 43 to 76. Three are blind, whereas the others have residual vision. Two of the interviewees are gainfully employed, the others are in retirement. They all use at least smartphone or computer but mostly both. The predominant used operating systems (OS) are Apple's iOS for smartphones and Windows for computers.

Table 1
Characteristics of the Interviewees (EI: Expert Interviewee, MTG: Member of the Target Group)

ID	**Age**	**Gender**	**Impairment**
EI1	40-50	Male	Blind
EI2	40-50	Male	Sighted
EI3	70-80	Male	Blind
EI4	50-60	Male	Blind
MTG1	50-60	Female	Residual vision
MTG2	60-70	Female	Blind
MTG3	50-60	Female	Blind
MTG4	70-80	Male	Residual vision
MTG5	50-60	Male	Residual vision
MTG6	60-70	Male	Residual vision
MTG7	50-60	Male	Residual vision
MTG8	40-50	Male	Residual vision
MTG9	70-80	Male	Blind
MTG10	40-50	Male	Residual vision

The study was not guided by an ethical review board. At the time of the study, the ethics committee of Hochschule Furtwangen University was not yet fully established and an according board does not exist at Óbuda University. As stated in the interview guidelines, informed consent procedures were thoroughly discussed with the participants. The participants could end the interview at any time and withdraw consent to recording and transcription of the interview.

Results

After discussing social insights, we gained from both interview types, we present details about the traffic scenarios we extracted from the interview data and analyze them concerning use cases that can be solved by computer vision and would facilitate the according traffic scenario. Each scenario is then summarized in the form of scenario tables inspired by Software Engineering (Sommerville, 2011). We present a first version of the six tables, one for each scenario, in Jakob, Kugele, and Tick (2017). In this article, we show the final tables updated with the data from the interviews with members of the target group (see Table 2 to Table 7). They brought new insights to the tables about General orientation, Crossing a road, and Obstacle avoidance (Table 2, 4, and 5). The others remain unchanged in comparison with the ones presented in Jakob, Kugele, and Tick (2017).

Afterwards, we mention non-traffic scenarios that came up during the interviews and present insights on the importance of the use cases for the members of the target group.

Social Insights

In Jakob, Kugele, and Tick (2017), we describe the social insights gained from the expert interviews. We summarize the findings in this article and complete them with the data from the target group interviews.

We asked the expert interviewees about differences in gender and age when it comes to dealing with traffic situations. Only one expert interviewee, EI1, named a particularity concerning gender. In his experience, girls and young women are more likely to attend voluntary mobility workshops than boys and young men. The workshops' purpose is to provide additional advice and to pass on further knowledge beyond the mandatory mobility training. According to the expert interviewees, age is less important to solve problems in traffic situations than life experience with visual impairment, but it must be noted that an increased age often causes further limitations, for example in hearing and motor skills. The data from the target group interviews is insufficient to make a statement about differences in gender and age.

The experts attest to the community of the visually impaired a certain openness regarding the handling of technology, "When you have a limitation, you depend on technology and of course you use it" (EI4). This is underlined by the fact that all interviewed members of the target group use at least PC or smartphone.

When visually impaired people prepare for a trip to an unknown address, they essentially cover the same topics as the sighted, but the amounts of needed information differ. One of the blind expert interviewees summarized it in the sentence "I just simply need more precise information" (EI4), but "if one does so [collect detailed information bevor going on a trip], surely also depends on the personality" (EI1), no matter if a person is sighted or visually impaired. According to the impressions of the expert interviewees, a minority of the visually impaired attempt to travel to an unknown address on their own: "The greater number of those affected behave in such a way (…) that they prefer of course to travel with a companion in an unknown environment," (EI3). The results from the interviews with members of the target group confirm this. Many interviewees state that they do not travel alone before knowing a route. Mostly, it is difficult for these interviewees to imagine how and if an assistive system could change that. From our research, we cannot make a statement about if the use of an assistive system would encourage more visually impaired people to travel unknown routes on their own.

A topic often discussed during the target group interviews is that visually impaired people frequently have to ask for support, for example ask the bus driver about bus number and direction. Whereas some interviewees say that they do not mind asking and like to be in contact with people: "Even if I know the way, I always let myself be helped. You then start a conversation and communicate with the people, and I find that very important" (MTG2), others report bad experiences such as unfriendly and false answers: "[…] because it has happened that I asked passers-by and they told me the wrong [bus] line." (MTG6). For the latter group of people, an assistive system offering support and reducing the dependency on asking, would significantly improve their daily life.

One expert interviewee pointed out that when discussing differences between the visually impaired and sighted, we must keep in mind that "the blind and visually impaired are as different individuals as you and your colleagues," (EI4). Duckett and Pratt (2001) underline the importance of the acknowledgement of diversity when doing research for visually impaired people: "Participants were opposed to being clumped together in large groups of visually impaired people with whom all they shared was owning the same diagnostic label" (p. 827).

Traffic Scenarios

As shown in Jakob, Kugele, and Tick (2017), and Figure 1, we extracted a total of six traffic scenarios from the expert interviews that can be clustered into the three categories: *Orientation*, Pedestrian and Public Transport scenarios. Each category contains two scenarios: General orientation and Navigating to an address are Orientation scenarios, whereas crossing a road and Obstacle avoidance form the Pedestrian scenarios. The Public Transport scenarios consist of Boarding a bus and at the train station. We did not define scenarios for subways and trams, because in terms of scenario description and according use cases they can be seen as a mixture of Boarding a bus and at the train station. The interviews with members of the target group confirmed this hierarchy of traffic scenarios.

General Orientation

It can be difficult for a visually impaired person to know their exact location and to be aware of their direction and surroundings. The two expert interviewees EI1 and EI3 explained this as follows:

> The main problem for a blind person is to have an inner idea of an unfamiliar way, (…), the psychologists call it a mental map. (…) That is of course relatively difficult for a blind person and maybe one can program some sort of exploration mode where the camera says “Ok, I’ll just try to detect objects and describe the ones close to you.” (EI1)
>
> (…) the orientation, when I’m in an unknown environment, I first have to know, have to ask the question, where am I? How can I cope there? (…) [It is] problematic in general to ‘keep an eye’ on your destination. (...) You can simply get lost easily. (...) And this is a really burdening point for us. (EI3)

Special navigational apps, such as Blindsquare, can help to keep track of direction and also surroundings, as it announces points of interest such as shops and restaurants, but the app can only announce places in the database; if the data is not maintained or if the person is in a remote area, there might not be much information: “Blindsquare announces for example partially which shops there are but not every shop. There, I would wish (…) that the camera identified the names [of the shops],” (MTG3). Furthermore, not every important detail is announced by the app, for example position of the curb: “The curb is very important. If you don’t have that you can’t orient yourself while walking down the street. The curbside is very important” (MTG2). Signposts: “I could make my way from (…) to (…), I’d know the way, but I’d not be able to decipher signposts” (MTG7). Street name plates (“What I often don’t recognize is the street name itself,” (MTG5). Or traffic signs: “Or are there traffic signs that I need to be made aware of?” (MTG9). The inaccuracy of GPS is another problem and will be discussed in the next section.

On a smaller scale, Tactile Ground Guidance Systems (TGGS) help with orientation, but in an unknown area, a visually impaired person might not know if and where to find them. Furthermore, it is possible to walk a TGGS in the wrong direction because they are not directed. Interviewee EI1 states:

> What can generally be a problem with TGGS is (…) that you know that there is something, but you need to find the guidance system first. In a sense, you would need a guidance system to the guidance system. (…) Let’s say I as a blind hit the TGGS with the cane and know it guides me somewhere, but I don’t exactly know where. (…) They are not oriented. They lead from A to B and from B to A. (…) There [at a station] is a hustle and you drift away from the TGGS, you get back there, and now the question is: Did I stupidly turn 180 degrees while I sidestepped other people and am walking back now? That actually happened. (EI1)

If a person gets lost, they can ask passers-by or use the app BeMyEyes, which connects them via video chat to a seeing person who is willing to help. As stated in the section about social insights, asking passers-by can be unpleasant for some people. We give more details about BeMyEyes in the next section.

Based on this information, the following camera-based detections would be helpful in this scenario: Describing the surroundings and lane detection (to identify the course of the road) to help form a "mental map" (EI1), analogous and digital displays to detect and read different signs (shop signs, signposts, street plates), curb(-sides), traffic signs with importance to pedestrians, and TGGS.

Table 2
General Orientation

Quote	"[It is] problematic in general to 'keep an eye on' your destination. (...) You can simply get lost easily. (...) And this is a really burdening point for us,“ (EI3).
Initial assumption	A visually impaired person wants to know where they are and be aware of their direction and surroundings in order not to get lost.
Normal	Navigational smartphone apps, for example Blindsquare, help the person to keep track of their direction and also their surroundings as the app can announce crossings, shops, restaurants and such. On a smaller scale, Tactile Ground Guidance Systems (TGGS) help the person to find their way. If they get lost anyway, they can ask a passer-by or use the app BeMyEyes, which connects them via video chat to a seeing person who is willing to help.
What can go wrong?	The navigational app can only announce places in the database. If the data is not maintained or if the person is in a remote area, there might not be enough information for the person to create a "mental map" (EI1) of their surroundings. Not every important detail of the surroundings can be announced by the app (e.g., size and height of the curb, course of the road, street names). Depending on the location of the person, GPS can be inaccurate. As TGGS are not directed, it is possible that they do not know, if they are walking it in the right direction. The person cannot find the TGGS even though it is there.
Vision Use Cases	TGGS Detection, Description of the surroundings, Traffic Sign Detection (e.g., to find pedestrian zones), Curb Information, Display Detection (to find shop signs or street name plates), OCR (Optical Character Recognition; to read text on displays), Lane Detection

Navigating to an Address

If a visually impaired person wants to walk to a certain address that is not part of their routine ways, they use a GPS based app in addition to aids used anyway such as cane or guide dog. However, due to accuracy, the GPS app can generally not lead them to the exact place of the entrance door. To find the right door and possibly the doorbell sign, they must ask people who pass by or call someone:

> The blind-specific [apps]. (…) There is a well-known one called Blindsquare and it always warns you when the accuracy falls under a certain critical value. (…) And then this has relatively little use for you, I'd say. Ok, you know, you are close, but without experimenting or asking someone, you really wouldn't find the door. (…) Doorbell signs are a typical camera task. There is already the app BeMyEyes, you might have heard of it before. It is a social network. I call some nice people and they get my camera picture and say „Yes, it's the third [doorbell] from the top." (EI1)

> We have a certain amount of uncertainty, but you get roughly informed that you are in the vicinity of this property and that's already half the rent. And then, of course, you move on with the white cane and (…) you have to make sure to (…) find an entrance somewhere. Then, you have to ask [someone], is this the right place or not? (EI3)

From this, we extract that it would be useful to detect house numbers, doors, and text on doorbell signs. With the help of this information, it would be possible to compensate the inaccuracy of GPS based systems and help navigate the user to the right door(-bell) without them having to ask for direction.

Table 3
Navigating to an Address

Quote	"[One] has to make sure to (...) find an entrance somewhere. Then, one has to ask someone, is this the right place or not?" (EI3).
Initial assumption	A visually impaired person wants to walk to a certain address.
Normal	The person enters the address into a GPS based navigational smartphone app. The app leads them to the specified address.
What can go wrong?	Due to GPS accuracy, the navigational app cannot lead the person directly to the entrance of the building. If the building is unknown to them, they have to ask in order to get to the entrance and possibly find the right door bell.
Vision Use Cases	House Number Detection, Door Detection, OCR (Optical Character Recognition; for doorbell signs)

Crossing a Road

When a visually impaired person wants to cross a road, they first must find a crosswalk or traffic light, which can be hard in unfamiliar areas. Then, they must make sure that it is safe to cross the road. Intermediate platforms can make them unsure how to proceed:

> Well, then I would say, it's exactly these three problems. Finding possibilities to cross the road, meaning finding traffic lights and crosswalks. The second would be to safely cross the street (…), which starts with knowing when the light is green and in which direction I have to go exactly and there's the question: If there is a traffic island, do I have to stop there or can I cross over? Is it still green on the other side? (EI1)

TGGS and acoustic signals offer support for finding crosswalks resp. traffic lights but are not always available. Even when available, it can be hard to find the TGGS (as discussed before) or the traffic light and its pole to activate the acoustic signal: “There, I often look for the traffic light to cross the street. I often don’t find it. Then, people tell me “There it is.” And I always have to ask where “there” is,” (MTG2); “Then, it would be important that it [the camera] finds me traffic light poles. As a blind person (…), I always must search a bit until I find the pole and can press the traffic light,” (MTG3).

If there is no support in the form of crosswalks or traffic lights, crossing a road involves risks: “Crossing a road with high traffic frequency without any safeguarding is always a very big danger for a blind person,” (EI3). The visually impaired person must rely on their hearing to identify a safe moment to cross the road, which can be difficult, for example because “Electric cars are a problem. (…) On the other side, it’s nice for the sighted, when the traffic flows quieter. For the sighted, this is quite good, but for us blind people, it’s really a problem,” (MTG3).

No matter If there Is a traffic light, a crosswalk or neither, curbs can be a problem for a visually impaired person who is crossing a road: “One time, I did not have my white cane with me and the tram (…) had its exit on a higher curb. And I crossed the road and stumbled on the curb,” (MTG7).

To help find a crosswalk, a camera could detect the TGGS leading there, the crosswalk itself and/or the according traffic sign. For traffic lights, it is important to detect the traffic light itself, its pole, and the state (red, green). Other relevant vision use cases are the detection of driving vehicles to know when it is safe to cross the road, lane detection to extract details about the road’s size and course, and curb detection to obtain information about its position and height.

Table 4
Crossing a Road

Quote	“Crossing a road with high traffic frequency without any safeguarding is always a very big danger for a blind person,” (EI3).
Initial assumption	A visually impaired person needs to cross a road.
Normal	With the help of TGGS or acoustic signals, the person finds a crosswalk or traffic light and safely crosses the road.
What can go wrong?	There is no TGGS in front of the crosswalk or the traffic light does not offer acoustic signals. The person cannot find the TGGS even though it is there. The person does not find the traffic light pole in order to activate the acoustic signal. An intermediate platform may make them unsure on how to proceed. Not knowing the height of the curb, can cause stumbling and falling. It can make them unsure, if they do not know the size of the road.
Vision Use Cases	Crosswalk Detection, Traffic Sign Detection (to detect the crosswalk sign), Traffic Light Detection, Traffic Light State Detection (red, green), Traffic Light Pole Detection, TGGS Detection, Lane Detection (to extract information about the road’s size and course), Driving Vehicle Detection (to know if the road can be crossed), Curb Information

Obstacle Avoidance

When moving in traffic situations, a visually impaired person must check constantly for obstacles in order not to collide with someone or something and thereby they must be careful not to lose direction and orientation: "They [obstacles] impede the walking flow, they interrupt you, you lose direction," (EI4).

Guide dog and white cane are the usual aids in this situation. Two different kinds of obstacles, namely grounded and elevated obstacles, must be considered. Whereas guide dogs are usually trained to detect both types, it is not possible to detect elevated obstacles with the white cane:

> Concerning the obstacles, a trash can or garbage bin or whatever someone has put there (…), these are the so-called grounded obstacles. You'll catch them with the cane in any case and also a guide dog would go around it. In obstacles, the so-called elevated obstacles are problematic. Drooping branches or cargo areas of trucks, perhaps very low hanging signs or anything that can hang into the sidewalk from above. A good guide dog is trained on them, but with the cane you will under-swing them. (EI1)

Other obstacles that must be considered specifically are construction sites: "The biggest problems in traffic are actually construction sites and of course unknown situations. (…) Construction sites can be very confusing" (EI2). Stairs: "When steps are ahead, for example. (…) You have to be pretty careful. I can feel it with the cane, but (…) I must slow down," (MTG3). And bike-riders: "It's hard to recognize them [bike-riders]. Especially if they drive very undisciplined. (…) And this undisciplined behavior of bike-riders is extremely fatal for the visually impaired. They drive everywhere, they drive on the sidewalk and everything" (MTG4).

Therefore, besides a general obstacle detection, the following vision use cases are of importance: The detection of construction sites and the according traffic sign, TGGS detection in case one loses it while moving around obstacles (as pointed out in General orientation), stairs, and bicycle detection.

Table 5
Obstacle Avoidance

Quote Initial assumption	"They [obstacles] impede the walking flow, they interrupt you, you lose direction," (EI4). A visually impaired person is on the move as a pedestrian in traffic situations and has to take care not to collide with obstacles.
Normal	With the help of the white cane or a guide dog, obstacles are detected and avoided.
What can go wrong?	Whereas guide dogs are usually trained to detect ground as well as elevated obstacles, it is not possible to detect elevated obstacles with the white cane. The detection and avoidance of a construction site can be difficult. While moving around an obstacle, the person can lose orientation and/or drift away from the TGGS. Although stairs are detected by white cane and guide dog, the person might still be unsecure. Bike-riders can be difficult to perceive because of their speed in combination with their often unpredictable behavior.
Vision Use Cases	Obstacle Detection, Construction Site Detection, Traffic Sign Detection (to detect the construction site sign), TGGS Detection, Stairs Detection, Bicycle Detection

Boarding a Bus

Taking the bus can be challenging for the visually impaired: "The bus is also the most difficult means of transport, because it is so flexible" (EI3). After having found the right bus stop, a visually impaired person usually waits on the entry field marked with TGGS to enter the bus that stops directly in front of the entry field. Problems occur at larger stops where several buses can hold at once. In this case, it is hard to find the right bus and its door.

> You have a so-called entry field at the beginning of the bus stop. You stand there and when the bus arrives, it stops exactly with the door at the entry field. You enter and that's it. But if you have two or three buses behind each other, you don't get it. (...) You have a lot of difficulties finding the entrance door. (…) You then have to feel along the vehicle to find the doors. (EI3)

Another limitation at bus stops is information that is presented in written form such as displays: "At bus stops, there are displays announcing the next bus or tram. I can't read that" (MTG4). Timetables: "The system could help me read the timetable at the bus stop" (MTG7). Or number and direction of the bus: "At bus stops where only one bus departs, it's no problem at all, but if there are several buses (…), I have to try to see the bus number so that I don't get on the wrong bus" (MTG4).

The vision uses cases that could support the visually Impaired In this traffic scenario are traffic sign detection to find the bus stop, TGGS detection to find the entry field, display and text detection to find and read information, and door detection to find the entrance to the bus.

Table 6
Boarding a Bus

Quote	"The bus is also the most difficult means of transport, because it is so flexible," (EI3).
Initial assumption	A visually impaired person wants to board a bus.
Normal	The person waits at the bus stop on the entry field (marked with TGGS). When the bus arrives, they enter.
What can go wrong?	The person cannot find the bus stop. They cannot find the entry field even though it is there. There is no entry field, and the person has to rely on hearing to find the door. They do not know, if the arriving bus has the right number and direction and they might not want to ask every time. At a larger stop, where several buses stop at once, it is difficult to find the right bus.
Vision Use Cases	Traffic Sign Detection (to detect bus stop signs), TGGS Detection, Display Detection (to detect displays with important information), OCR (to read the text on the detected displays), Door Detection

At the Train Station

Although train stations are "easier to overlook and (…) at least at most train stations, there is some logic that you can understand" (EI1), there are some problems that can occur.

The bigger train stations in Germany offer some guidance for the visually impaired such as TGGS leading from the entrance hall to the information counter and platforms, oral announcements, and Braille indicators under the handrails. Additionally, the German railway company offers a mobility service meaning that employees guide visually impaired travelers at the train station. Problems occur for example at smaller stations with less infrastructure and when someone cannot find the supporting infrastructure or does not know that it exists. The following quotes from interviewees underline this problematic:

> There is a guidance system with which I can reach the information [counter]. From there, I use the mobility service. It's often difficult when the platform where the train departs changes. The people from the [mobility] service know that faster. Until I figure it out, the train is already gone. (MTG2)

> At new or newly renovated stations, you usually have TGGS that lead from the hall to the platform. (…) It's more of a problem at smaller stations where you have little to no announcements. (EI2)

> If the station is unknown to you, you usually have to ask, because not every handrail has Braille indicators or (…) it may exist, but you have to know that in the first place and you have to get there. (EI1)

Again, all kinds of signs such as departure boards: "(…) the departure of some trains can change. It would be quite good if the system could read that" (MTG3), coach numbers: "There is a certain problem that the coach number on the ICE [Inter City Express] is hard to recognize" (MTG4). Seat numbers: "Even if I have reserved a seat: How do I find it?" (MTG3), or platform sections: "Imagine the platform, 400 meters long, and you are looking for section C where your coach with the number 12 stops" (EI1) are hard to impossible to receive for the visually impaired.

At train stations, the following vision use cases could support visually impaired travelers: TGGS detection to find the guidance system leading to points of interest, traffic sign detection to detect different signs such as platform or section indicators, display and text detection to find and read important information, and door detection to find the door of the right coach.

Table 7
At the Train Station

Quote	"It [the train station] is easier to overlook and (...) at least at most train stations, there is some logic that you can understand," (EI1).
Initial assumption	A visually impaired person wants to travel by train.
Normal	A TGGS leads the person to the platforms. They find the right platform with the help of Braille indications under the handrails or they know the design of the station. Additionally, they can use the mobility service of the German railway company.
What can go wrong?	There is no TGGS leading to the platforms, or the person cannot find the TGGS even though it is there. There are no Braille indications, or they do not find the handrails. The mobility service is not available. Small train stops do not always offer announcements.

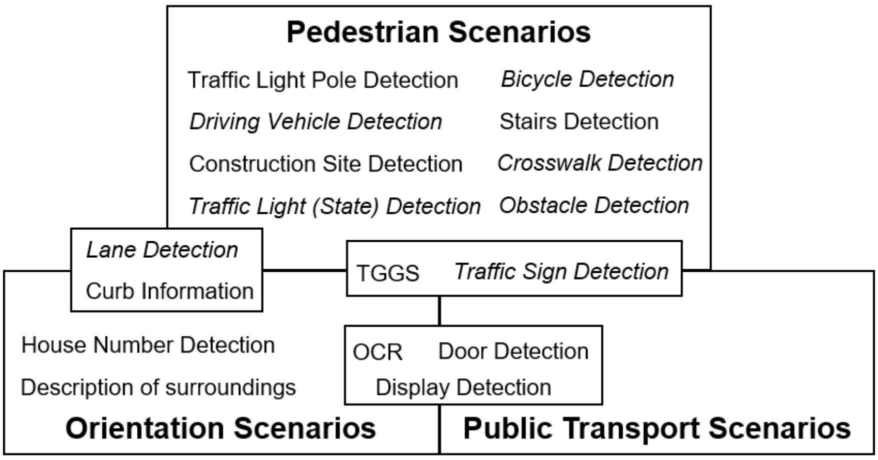
Quote	"It [the train station] is easier to overlook and (...) at least at most train stations, there is some logic that you can understand," (EI1).
	They do not find the right track section, which matches their seat reservation or other signs/displays such as coach and seat numbers.
Vision Use Cases	TGGS Detection, Traffic Sign Detection (to detect platform numbers and platform section signs), Display Detection (to detect displays with important information), OCR (to read the text on the detected displays), Door Detection

Vision Use Case Summary

In our future research, we focus on the derived use cases, especially the ones that are also of relevance in the field of ADAS. Therefore, Figure 2 gives an overview of the extracted use cases sorted by the hierarchy categories presented in Figure 1, and Figure 3 lists the overlapping use cases from both fields, ADAS and assistance of the visually impaired.

Figure 2

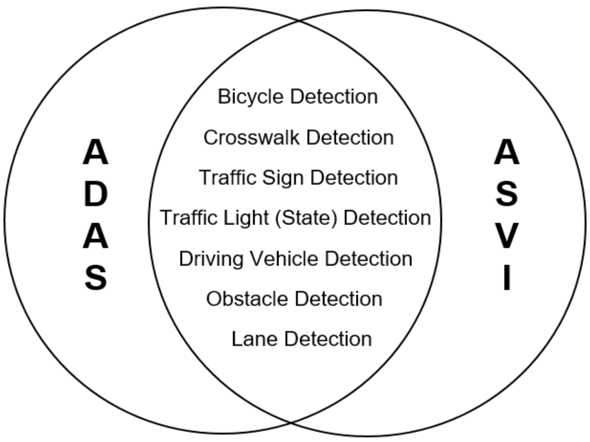
Italic Use Cases are of Relevance in ADAS.



Note. Traffic scenarios and their overlapping Use Cases

Overlapping vision Use Cases for Advanced Driver Assistance Systems (ADAS) and Assistive Systems for the Visually Impaired (ASVI):

Figure 3



In Jakob, Kugele, and Tick (2017), we present a literature review for algorithmic solutions from ADAS for the identified overlapping use cases except the newly added bicycle detection. For this use case, we refer to Lin and Young (2017) who present a side-view detection for bicycles based on the mutual arrangement of two circles and one triangle. They furthermore give an extensive overview of related work in the field of image processing-based bicycle detection. The literature review about the overlapping use cases cited here and in Jakob, Kugele, and Tick (2017) is the starting point for the next step in the transfer concept development. We examine the ADAS algorithms concerning problems that occur when using them unmodified for visually impaired pedestrians. Afterwards, we develop adaptation methods to overcome these problems.

Non-Traffic Scenarios

When asked whether a camera-based assistive system could offer support for the handling of the problems we described, the members of the target group often mentioned not only traffic situations but also indoor scenes. Because of the problems we confronted them with, they named navigational help inside of buildings in general and different use cases inside the doctor's office as well as the concert hall where camera-based detection could support them. Although we did not present a scenario containing a supermarket, two interviewees pointed out that navigational support in supermarkets, for example finding a certain product category, would improve their daily life. We will not pursue those scenarios any further, because we focus on traffic situations, but it is important to point out that detecting or recognizing any kinds of signs or displays and reading the text, if there is any, are very important use cases in almost every situation of daily life, indoor and outdoor.

Use Case Importance

Table 8 gives an overview on the importance of the discussed use cases sorted by the members of the target group we interviewed. As the interview's focus was to gather as many use cases as possible, not every use case was discussed with every interviewee. Therefore, in some cases; we cannot know from the answers of the interviewees if a certain use case is needed or not. Furthermore, we must consider the following effect: MTG1 does not use public transport on her own and therefore states that she does not need the according use cases, but it was not discussed during the interview if she would consider travelling by public transport on her own, if she had the support of an assistive system.

Table 8
Use Case Importance (✓✓: Needed, ✓: Useful addition, -: Not discussed, ×: Not needed.)

Use Case/ID	MTG1	MTG2	MTG3	MTG4	MTG5	MTG6	MTG7	MTG8	TG9	MTG10
Traffic Light Pole Detection	-	✓✓	✓✓	✓✓	-	✓✓	×	-	-	-
Bicycle Detection	✓	✓✓	✓✓	✓✓	×	✓✓	-	×	✓✓	✓✓
Stairs Detection	✓✓	-	✓✓	-	-	✓	×	-	-	-
Construction Site Detection	-	✓✓	-	×	-	✓	×	-	-	✓✓

Use Case/ID	MTG1	MTG2	MTG3	MTG4	MTG5	MTG6	MTG7	MTG8	TG9	MTG10
Driving Vehicle Detection	-	×	✓✓	✓✓	×	✓✓	×	-	-	✓✓
Crosswalk Detection	✓	✓✓	-	×	-	✓✓	×	-	-	✓✓
Traffic Light (State) Detection	✓	✓✓	-	✓✓	-	✓✓	×	✓✓	-	✓✓
Obstacle Detection	✓✓	✓✓	✓✓	✓	×	✓✓	×	✓✓	✓✓	✓✓
Lane Detection	✓✓	-	✓	-	-	✓✓	-	-	✓✓	-
Curb Information	✓✓	✓✓	✓✓	-	×	✓	✓	✓✓	✓✓	-
TGGS Detection	-	-	-	-	-	-	-	-	-	-
Traffic Sign Detection	-	✓✓	✓✓	-	✓✓	✓✓	-	×	✓✓	✓✓
House Number Detection	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓
Description Of Surroundings	-	-	✓✓	-	-	-	-	-	-	-
OCR	✓✓	✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓
Door Detection	×	✓	✓✓	×	-	-	×	-	-	✓✓
Display Detection	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓

The use case overview in Table 8 confirms what we stated in the section about social insights: visually impaired road users are a very distinctive group with different needs. While for the blind interviewees (MTG2, MTG3, and MTG9) almost all discussed use cases are marked as needed, the interviewees with residual vision give very differing answers. This has in general two reasons: First, it depends on the concrete impairment and second, the person's personality and autonomy in road traffic plays an important role on how much support is required by an assistive system. For the conceptual design of such a system, it is therefore important to take possibilities of personalization into account.

Considering the lines about Traffic Sign Detection, OCR, Display Detection, and House Number Detection, we see that the ability to perceive different kinds of displays and signs, indoor as well as outdoor, is essential for many visually impaired persons. Additionally, Obstacle Detection in general and Bicycle Detection as well as Traffic Light (State) Detection are often needed use cases.

Conclusion

In this study, we collected the problems visually impaired pedestrians face in traffic situations by conducting four expert interviews and ten interviews with members of the target group using Witzel's (2000) problem-centered method in both cases. From the data, we extracted a set of six different scenarios (General orientation, navigating to an address, crossing a road, Obstacle avoidance, boarding a bus, At the train station) clustered into the three categories: Orientation, Pedestrian, and Public Transport scenarios. For each of the six scenarios, we created a descriptive table that summarizes the usual procedure of the respective scenario, the problems that can occur and which vision-based use cases could help to overcome these problems. As it is our objective to formulate a transfer concept for vision-based use cases and according to algorithms from ADAS to the assistance of visually impaired people, we base our future research on the overlapping use cases we pointed out in Figure 3.

With the data from the interviews, we were able to formulate some further findings that go beyond the collection of traffic scenarios and are of importance for researchers who want to build a camera-based assistive system. Although there are some use cases that seem to be of general importance (see Table 8), the diversity of visually impaired people concerning kind and degree of impairment(s) as well as personality leads to very differing needs. Therefore, it is necessary to consider possibilities of profiling and personalization when building an assistive system, for example by using an Ambient Assisted Living Platform as presented by Kuijs, Rosencrantz, and Reich (2015). Among the generally important use cases, the perception of any kind of signs and displays must be emphasized because of its importance in numerous situations in daily life. Shen and Coughlan (2012) for example address this problem algorithmically.

That the idea of a camera-based assistive system in traffic situations is met with approval is underlined by the following two interviewee quotes:

> One would be much more independent. It could help in all areas of life. (MTG1)
> We currently have the rapid development of smartphones, and with that we are also experiencing more and more comfort. And in this context, such a development and research as yours is of utmost importance, so that one can achieve more safety in road traffic. (EI3)

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