Specification of Requirements for Visually Impaired Persons in Services in Transportation Electronic Information System

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ABSTRACT

This article highlights the basic concept of the expansion of the current transportation information system in the Czech Republic by employing the Near Field Communication technology for the visually impaired passengers. Nowadays are electronic information systems an integral part of transportation arrangements in every city. They are built with the aim to offer to its constituents various services and to facilitate their orientation in a complex transportation network. These systems, however, do not necessarily take into consideration the needs of the handicapped, for example the visually impaired, although precisely this group needs correct and aptly transmitted information more than any other segment of the population.

Keywords: Visually Impaired Persons, Electronic Information System, Near Field Communication.

1. INTRODUCTION

Today, modern information systems in transportation are widespread and constitute an indispensible support of transportation processes for both the carriers and passengers. However, it is necessary to bear in mind already in the design phase that the transportation system should be designed so as to serve the highest possible number of users, not leaving any group of citizens behind. In case of people with limited movement and orientation capability, this is not an easy task, since each person faces special circumstances and has own special needs. What is suitable for one group may not fit another. When designing transportation information systems, it is therefore necessary to understand the requirements of the different groups and offer complex solutions suitable for all. The process should include continuous consultations with the representatives of the handicapped. When choosing such a consultation partner, it is necessary to exercise prudence, since "Diagnosis is not a qualification." (Viktor Dudr, Czech Blind United).

A whole array of adjustments and expansion of information systems was created for persons with visual impairments to ease their independent movement and reinforce their safety. The available solutions are far from perfect and there is room for improvement. This is the reason why the authors of this paper want to make a contribution in this area.

2. COMPENSATION DEVICE FOR VISUALLY IMPAIRED PERSONS

Compensation device is a tool, apparatus or mechanism specially designed or adjusted so that its use would at least partially compensate the limitations caused by the impairment.

White Cane

The white cane is a vital equipment of the visually impaired, since it enables independent orientation in space. According to their function, they can be categorized as signalization, protective, orientation, or support canes. Most of the white canes can combine up to three of these functions. No universal white cane that would offer all of these functions, however, exists, since some of these functions, such as orientation and support, are mutually exclusive. White canes can also be further divided into folding, non-folding, telescopic, and combinational, according to their construction method. Each has its advantages and disadvantages.

Remote Controller

Acoustic orientation and information mechanism for the visually impaired on the territory of the Czech Republic are controlled by the VPN-type transmitters for the blind. There are six different encoded commands transmitted by the radio signal on the frequency 86.79 MHz (allocated frequency in the Czech Republic). Three types of transmitters with identical functions are available:

- Type VPN 01 – pocket-size box with six buttons. The buttons are arranged in two columns with a tactile mark between button 1 and 2. The numbers of the buttons define the numbers of respective commands.

- Type VPN 02 – it is a modification of VPN 01, the frequency of radio signal can be changed: 86.79 MHz (Czech Republic), 87.1 MHz (Slovakia) and 433.95 MHz (Federal Republic of Germany and other country of European Union)

- Type VPN 03 – white cane component. The transmitter is built into the handle of the white cane (the orientation five-part compact type) with three buttons, which can, however, give six commands, such as the box type.

3. ACOUSTIC SOLUTIONS FOR VISUALLY IMPAIRED PERSONS

Hearing and touch are crucial senses for the visually impaired. Acoustic information can guide the blind and otherwise visually impaired to walk in the right direction or to safely cross the street.

Acoustic Signalization on Pedestrian Crossings

Acoustic signalization on pedestrian crossings indicates whether or not a street can be crossed. The emitted sound has a form of sound beats and their frequency allows to detect the instruction. The sound beat with repeating frequency 1.5 Hz signals "red – stop" and repeating frequency 8 Hz (faster) signals "green – go."

The SZN 01 device, which is so far most widely used in the Czech Republic, makes the characteristic hammer-like sound of an electromagnetic relay. The more modern electronic mechanisms utilize an interrupted sound at the frequency of approximately 400-500 Hz, if it is used at the pedestrian crossing. An analogue device, used where pedestrian crossings and railroads intersect, utilizes an interrupted sound at the frequency of approximately 800-1000 Hz. Thus, the sounds cannot be mixed. None of these devices, however, allows adjusting the volume of the acoustic signal. [2], [3]

Acoustic Orientation Beacons

Acoustic orientation beacon identifies a specific significant orientation point, such as:

- entrance to buildings, typically public buildings, such as administrative offices, shops, banks, post offices, health care centers, or social services providers;
- entrance onto escalators and moving pedestrian belts;
- underpasses, bus and train stations, or hospitals.

Acoustic orientation beacons feature either a choice of a suitable trill, or a combination of the trill with a subsequent voice message and orientation tune. They can sound without an interruption in daily or weekly cycles or after activation by a command transmitter. The Czech Telecommunication Office has allocated for the entire territory of the Czech Republic a unique frequency of 86.79 MHz for the control by radio commands. They are typically placed in the height of 2.2-4 m and their sounds differ according to the purpose of their use.

Expansive underpasses, bus terminals or train stations, hospital complexes etc. can be equipped with a set of remote controlled acoustic beacons so that the blind or visually impaired person can be guided by their sound. Location of these beacons must be carefully chosen and their information message carefully formulated. It is important to take into consideration that beacons located close to one another would be activated by the transmitter simultaneously and thus disorient the user. [2], [3]

Command Systems in Public Transport Vehicles

Clearance and information system of the public transportation vehicles (trams, trolleys, buses) and some trains is typically supplemented by a command system. Once activated by the visually impaired, a voice message containing information about the connection (vehicle number and direction) is sounded. By pushing an additional button, the visually impaired can signal to the driver the intention to board. This device can also announce the current and upcoming stops by activating the respective command. [2], [3]

Electronic Information Systems with Output for the Blind

This category includes for example the so-called "intelligent stops," which reproduce, based on the signal from the transmitter, a voice message containing for example information about arrival of the next vehicle. Another type of such a device are information systems in terminal halls, such as airports, where the system can give information about arrivals and departures. The highest level constitute information electronic stands with voice output, which provide information about timetables, cultural events, accommodation, restaurants etc. [2], [3]

4. REQUIREMENTS ON THE DESIGN OF EXTENSION OF INFORMATION SYSTEM

Key parameters of Transportation Information System

Response Duration: The response duration is the ability of the information system to serve request for navigation to a certain specified maximum duration that can be defined as the probability

$$P((t_{R,i} - T_R) < \varepsilon_{RD}) > \gamma_{RD} \qquad (1)$$

that the difference between the measured duration of i-th response $t_{R,i}$ and the specified maximum duration T_R will not exceed the value ε_{RD} on the probability level γ_{RD}.

A research study conducted by the (now defunct) Institute for Rehabilitation of the Visually Impaired of the Charles University in Prague revealed that three seconds is the maximum response time of the system that the blind person can comfortably accept. A longer response time is less acceptable, because the blind person cannot scan the environment to understand the delay. An acoustic signalization indicating that the system is processing the response would be a fitting solution in such a case.

The total time of response is generally broken down into sub-periods:

- the period of generating the request (p_greq);
- the period of sending the request (p_sreq);
- the period of request processing (p_reqp);
- the period of generating the response (p_gres);
- the period of sending the response (p_sres);
- and the period of response processing (p_resp).

$$response\ duration = p_{greq} + p_{sreq}$$

$$+ p_{reqp} + p_{gres} + p_{sres} + p_{resp} \qquad (2)$$

Intelligibility: Intelligibility is the ability of an information system to provide transportation-related information in a comprehensible form, so that the passenger would not need to repeat his/her request for navigation for the final bus destination or connection. Intelligibility can be defined as probability

$$P\left(\left(\frac{1}{c_{req,i}}\right) \geq \varepsilon_c\right) > \gamma_c \qquad (3)$$

meaning that the converted value of the number of requests for navigation at i-th electronic information stand $c_{req,i}$ will not be lower than the requested value ε_c on the probability level γ_c. Since the electronic information stands are in a majority of cases located in open space, the sound can be drown out by other passengers or passing vehicles. However, NFC technologies allow for a very short distance between the passenger and electronic information stands.

System's parameters of passengers

From the viewpoint of system analysis every passenger can be characterized by the following parameters, which can be interconnected and they limited the passenger in the selection of paths:

- average speed of movement – speed of movement of each person is specific and depends on different variables. Among them are the age of the person, immediate time requirements (for example hurrying to work), health etc. If we consider the average speed to be 5 km/hour, then in case of a person in a hurry the speed would be higher, while in case of a person with a walker, crutches, mechanical wheel chair, blind of a child (with accompaniment) it would be lower. The range of possible speed is therefore large and it is therefore not possible to use only average speed in transportation applications as it would lead to error. In their research the authors gathered the following average speed (in km/h) for different groups of persons:

pensioners	4,51
person on crutches	3,05
schoolchildren	6,68
visually impaired persons	4,12
wheelchair users	4,61

- spatial requirements - ordinary passenger needs about 500-700 millimeters for passage. The table below [4] gives the required width in millimeters for people with various disabilities:

person in a wheelchair	800-1200
person on crutches	900-1200
person with a walking frame	700-900
visually impaired persons	900-1200
person with a stroller	700-900

- movement impairment - this parameter expresses the degree of the locomotor disability and therefore also the higher requirements for barrier-free routes in terms of the locomotor
- visual impairment - this parameter expresses the degree of of visual impairment and therefore also the higher requirements for barrier-free path from the orientation point of view.
- hearing impairment - this parameter indicates the degree of hearing impairment and therefore also the higher requirements for barrier-free path from orientation point of view.

The disability of passenger is expressed by this scale:

1	full disability
2	partial disability
3	without disability

The passenger can thus be characterized by a vector $\mathbf{p}$, whose components are the parameters mentioned.

$$\boldsymbol{p} = (p_1, p_2, p_3, p_4, p_5)$$

System's parameters of path

The path can be expressed as a graph that consists of individual nodes and edges. Each edge is characterized by the following parameters:

- length of the route - the total distance of the route, respectively edge.
- width of the route - if the width of a route is not the same everywhere, gives the value of narrowest part
- capacity of the route - on the route can accumulate passengers who are waiting for a means of transport. The lower capacity routes means less passage the passenger route.
- barrier-free route for people with movement impairment
- barrier-free route for people with visual impairment
- barrier-free route for people with hearing impairment

Barrier-free path is expressed by this scale:

1	accessible route
2	partially accessible route
3	route is inaccessible

The route can thus be characterized by a vector $\mathbf{r}$, whose components are the parameters mentioned.

$$\boldsymbol{r} = (r_1, r_2, r_3, r_4, r_5, r_6)$$

5. EXTENSION OF TRANSPORTATION ELECTRONIC INFORMATION SYSTEM FOR VISUALLY IMPAIRED PERSONS

Acoustic orientation beacons are very useful for the visually impaired. They are activated by a command from the VPN-type transmitter and this command is transmitted by a radio signal – it is all-directional. Their main disadvantage is that the signal is not transmitted to the selected beacon only, but throughout the entire area that the signal covers (tens of meters in the open space), thus activating all the beacons in the area. The information from all the activated beacons can interfere with one another and instead of providing a guidance creates chaos. Visual sense has the ability to filter the unnecessary information, for example by closing the eyes, focusing on the desired information etc., but the sense of hearing does not provide for any such possibility. Another disadvantage of the acoustic orientation beacons is their ability to react only by pre-formulated reaction (trill, trill + voice message). Their reaction is therefore basically static and their adjustment for a new situation cause a delay in providing the right information. Information and communication technology is so advanced today that it is possible to remove these disadvantages. It would be a mistake not to promote the acoustic orientation beacons despite their limitations, since they require only low maintenance (they only require an electronic connection) and can prove to be very effective and practical.

At the Faculty of Transportation Sciences at the Czech Technical University in Prague, we are working on a proposal to expand the information system for bus terminals, which would help the visually impaired in their independent and safe movement in the bus terminal. The information electronic stands with the guidance trill and voice message provide information about arrivals and departures of buses, but they do not provide any guidance on how to reach a particular boarding point. The key feature of the proposed expansion of the information system is a simple electronic information stand, proposed as a thin client, when the main logistics is programmed in the transportation information system of the bus terminal. This information stand has a NFC reader and voice input only. It provides two types of information:

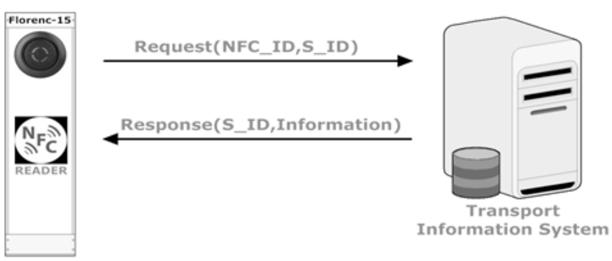
- information about the required connection (arrival time or delay);
- information for independent and safe relocation to the required bus boarding point.

Should the path towards the boarding point be complicated and difficult to remember for the visually impaired person, the electronic stand would provide additional guidance to the next nearest stand in the desired direction. The path between the electronic stands reflects

the need of the visually impaired persons and is dotted with tactile elements detectable with the white cane or distinguished by special surface stepping area. Since the bus terminals tend to vary in size and shape, they would have to be equipped with several electronic information stands, while each stand would need to have its clearly distinguishable identifier (S_ID), which would help to identify the position of the passenger who could thus receive the relevant information for further relocation to the desired bus arrival point.
For easy identification of the required connection, technology NFC is used. For the purposes of the passenger, it is sufficient if it is equipped with the NFC tag. For the information stand to provide the required information, the information system needs to know the connection which the passenger wants to take. This process of data upload into the central database of the transportation information system can be done in two ways at the minimum:

- when purchasing the ticket;
- through a web application.

Using one of these two methods, a unique identification number is read from the NFC tag and deposited by the chip producer, along with the data about the required connection into the database. The passenger is not identified and can own several NFC tags. Given the consent by the transportation providers (and the passengers), the ticket could be uploaded directly onto the NFC tag or a ticket medium equipped with the NFC tag.
The request sent from the electronic information stand contains not only the identification number for the NFC chip of the passenger, but also identification number of the stand in order to determine the position of the passenger in the bus terminal.
Where possible, the connection between the information electronic stand and the transportation information system is carried out through Ethernet, but the method of choice is more typically WiFi due to the existence of the infrastructure and minimalization of costs. The transfer of data is being carried out by the protocol TCP/IP. No sensitive data is being transferred and therefore the communication does not need to be encoded.

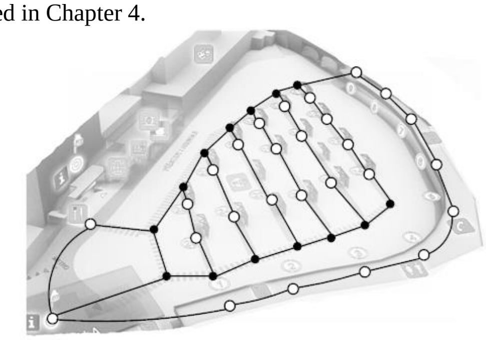


6. ALGORITHMS FOR DETERMINING THE NUMBER AND LOCATION OF ELECTRONIC INFORMATION STANDS

In the previous chapter has been introduced the use of electronic information stand on the example of the bus station. Its use, however, can be successfully used on railway stations or other public transport interchanges.
For the successful use of electronic information stands is important their location. This chapter describes algorithm which is used to determine their location and at the same time it is determined their number needed to cover the terminal, the interchange node. Application of the algorithm will be shown at the bus station Florenc in Prague, Czech Republic.
The algorithm is based on a gradual breadth first search. First, it is necessary to express bus terminal using a graph, where nodes are bus stations and crossing roads (on the example the distinction between empty and full circles) and edges represent the route between them.
The starting node from which the algorithm begins and where it is also located electronic information stand, a stand at the entrance to the terminal. For algorithm it is necessary to define this input parameters:

- maximum distance (maxDistance) of electronic information stand from the farthest station
- maximum complexity (maxComplexity) of routes - the complexity of the route is determined by the amount turn of the last electronic information stand.

The algorithm works with a vector $\mathbf{p}$, that characterizes the passenger, in our case, the blind, and each edge with the vector $\boldsymbol{r}$, that characterizes the route between two nodes. Both vectors were explained in Chapter 4.



```
procedure LocateStand(maxDistanceFromStand; maxComplexity)
numberStands :=1;
FOR every node n∈N
        LOOP
        d[n] := ∞;              -- distance from start node
        pred[n] := NULL;  -- predecessor of node n
        c[n] := ∞;              -- distance from stand
        complex[n] := 0;     -- complexity from stand
END LOOP;

FOR every node n∈N
        LOOP
        IF (r_5  = 1 AND r_2>=1200 THEN
                ENQUEUE(Q, n);
        END IF;
END LOOP;

IF doesn't exist SpanningTree(Q) THEN
        EXIT("It is impossible to find a way to all stations.");
END IF;

WHILE not EMPTY(Q) LOOP
        n := EXTRACT-MIN(Q);
        S := S∪{n};
        FOR every node v∈Successor[u] LOOP
                IF d[v]> d[n]+r_1 THEN
                d[v]:= d[n]+r_1;
                pred[v]:=u;
                c[u] :=c[n]+r_1;
                complex[u] := complex[n]+1
                END IF;
                IF d[n]+r_1>maxDistanceFromStand  THEN
                numberStands := numberStands + 1;
                c[n] :=0;
                complex[n] := 0
                END IF;
        END LOOP;
END LOOP;
```

7. CONCLUSION

The visually impaired persons do not want to live in seclusion from the world, but want to live a full and meaningful life to the extent their disability allows them. At minimum, they want to be self-reliant. When designing an information system (or other applications) it is therefore necessary to respect this and adjust the design to the specific needs and abilities of the visually impaired. The aim of this paper was to introduce a proposal for expansion of transportation information system of a bus terminal, which by utilizing modern information and communication technologies would afford the visually impaired an independent and safe movement. Technical proposal is supplemented by performance indicators, which help to determine if the solution is sufficiently fast and comprehensible for the passengers.

8. ACKNOWLEDGEMENTS

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