Creating a Richer Data Source for 3D Pedestrian Flow Simulations in Public Transport

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ABSTRACT

The distribution of passenger flows in public transport environments can be predicted through simulations of flow characteristics. The flow characteristics are usually based on average values, which do not include behavioural characteristics of people with mobility impairments such as wheelchair users, individuals with prams and small children, elderly people or people with sensory impairments. In the project at hand we gather data on orientation behaviour of these passenger groups through experience and task-related research. In a combination of methods – video and audio recording, user centered scenario and task development, questionnaires, interviews and time-motion-event (TME) recording – qualitative and quantitative data are generated. By linking qualitative information to quantitative measures a multi-dimensional description of the behaviour of individuals and user groups in a transport interchange emerges. It is expected that by comparing and contrasting the resulting behavioural measures to the average values currently used to represent passenger flows, the quality of simulations can be considerably enhanced.

Author Keywords

Usability of environments, behaviour in transport systems, orientation, navigation, wayfinding, pedestrian simulation, environmental design, interaction, decision making, sensory impairment, mobility impairment.

ACM Classification Keywords

G.3 Probability and Statistics: Experimental design. H.1.1 Systems and Information Theory: Value of Information, I.2.0 General: Cognitive simulation

INTRODUCTION

In the planning and adaptation of public transport infrastructures, the distribution of passenger flows can be inferred through flow simulations and, if needed, improved. The flow characteristics are usually based on walking speed, individual space requirement and purpose/intention of travel. However, these average values as incorporated in available simulation tools do not reflect behavioural characteristics of people with mobility impairments. Usually these groups are simply represented by reduced maximum speed and increased space requirement. These simulations also assume that all pedestrians know the infrastructure perfectly and consequently choose the shortest path to reach their goal. There are several phenomena and types of pedestrian behaviour that have a major influence on the overall performance of a transport infrastructure but they cannot be reproduced within the simplifications of traditional flow simulations. Ongoing research is looking to enhance existing simulation models with individual behaviour patterns [2,12,13] and also incorporates persons with reduced mobility [11]. In our approach [3] the cognition of guidance systems is modelled. The main challenge is the realistic adaptation of existing models by adequately representing and measuring group specific behaviour of mobility impaired passenger. We assume distributed attention/cognition as given in any task, when people are not dominated by one single task or focused on tasks involving only local information, but react to their surroundings and to the current context [6].

This extended abstract describes:

- Our general approach to gaining knowledge about behaviour patterns in public transport interchanges,
- The introduction of new combinations of methods for gathering real life user data.

COMBINING METHODS OF MEASUREMENT

The scientific core challenge comprises the evaluation of group specific walking, orientation and navigation behaviour in relation to features in the built environment such as transport-related information, advertising, other wayfinding guidance, architectural features or context-aware information. A variety of empirical methods were combined in order to gain relevant qualitative and quantitative data on passenger behaviour:

- Video recordings at crucial points in the infrastructure (escalators, stairs), data collection through manual annotation.
- Online questionnaire on individual experience of pedestrian journeys between modes of transport.
- Questionnaire-based interviews with respondents on individual behaviour and experiences in public transport.
- Real-world scenario and task development [4].
- Controlled scenario-based experiments in real transport environments with defined tasks to be carried out by the respondents (user and task analysis).
- Documentation of the experiments employing three different techniques: “Thinking Aloud” as used in usability research, “Shadowing” of each respondent with time-motion tracking and observation/annotation of the performed task.
- Time-motion-event (TME) recording of interaction with the environment, based on multi-modal analysis of interaction [9].

SELECTION OF RESPONDENTS

Eight groups of people were identified who may demonstrate mobility patterns clearly distinguished from the general population: 70+ age group [7], people with pram/toddler, visually impaired, blind [5], wheelchair users, mobility impaired, hearing impaired and deaf [8]. All of them were capable of completing the tasks without assistance. Six people from each group were recruited and divided between two different scenarios (see below). The completion of the task took, on average, 20 minutes, depending on the respondent.

Based on extensive experience with a qualitative usability testing technique called “diagnostic testing” we know that it takes just a few respondents to highlight specific issues connected with the use of a product, information or the environment [14]. The resulting indicators provide the basis for research into particular group behaviour on a wider scale.

Expectations

We expect the behaviour differences to relate to walking speed, patterns of gaining information from the environment, orientation and navigation. The relative differences in behaviour patterns within the groups, between the groups and further the given values for the general population provide the required data.

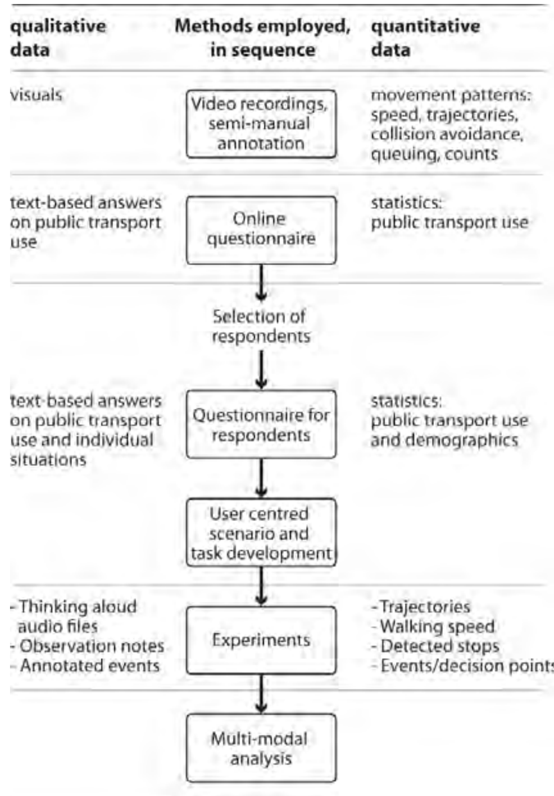


Figure 1. Summary of methods and types of data generated in the process.

DESCRIPTION OF METHODS AND PROCESS

Figure 1 gives an overview of the methods employed, which are briefly described below.

Video Recordings

Video recordings are made at critical points inside the infrastructure in order to quantify effects on pedestrian flow. Each individual person is manually annotated in the crowd, to obtain speeds, trajectories, collision avoidance behaviour, queuing and counts. This data is used to calibrate the operational part of the microscopic simulation model.

Questionnaires

An online questionnaire is set up with open questions on individual experiences as pedestrians in transport interchanges, namely their reactions to obstructions and not hearing/seeing information. Once the respondents have been defined and recruited, they have to answer a set of questions before experiments can commence. Firstly, we need to determine how their disability influences their use of public transport in order to then place them in an appropriate scenario (see below).

Scenarios and Tasks

Two different scenarios with different levels of complexity reflect typical use patterns in the transport interchange selected for this project. The scenarios contain specific user tasks such as buying a drink for the journey, locating timetable information, or using the restrooms in the station.

Experiments

At a pre-defined meeting point the respondent is met by two researchers who "shadow" the respondent: one records the time-motion information using a special application on a tablet PC [1]. The other observer takes qualitative notes throughout the experiment. The respondent is given an audio recording device which requires no operation on the part of the respondent. The researchers follow the respondent without interfering in the process until the task is complete. They only intervene in exceptional circumstances, for instance if someone completely loses their way or forgets what to do next.

As soon as the task is completed, both audio recording and time-motion tracker are stopped. Further observations and comments are recorded in a concluding interview.

TYPES OF DATA GENERATED

In our research we distinguish quantitative and qualitative data. As described above (see also Figure 1), the data is derived from video and audio recordings, notes from observation and interviews, trajectories, speeds, detected stops and events recorded as part of the shadowing as well as transport and demographic statistics from questionnaires.

Categories of Analysis

In preparation for analysis two sets of categories are defined: quantitative and qualitative.

Quantitative categories are objectively measurable data like walking speed, route choice, time of hesitation, decision point (position and context), event relative to position, and preferences (position and context).

Qualitative categories are applied to each objective measure. They are: conscious awareness of guidance information, signage and the built environment; reasons for choices and hesitations; distributed attention in context.

ANALYSIS

The aim is to understand how people move in space and make use of their surroundings. Our analysis is based upon the framework of multimodal analysis of [9,10,15] which state that next to the modes of language (spoken language, written language etc), analyses of complex situations have to include gaze, head and arm movement, body configuration, the interplay of people and spatial environment. We will describe patterns of action and journeys we observed for each category, analyzing selected scenes, with a view to the interplay between the different modes or semiotic resources.

Time-Motion-Event (TME) Analysis

In order to easily compare behaviour during tasks between different respondents and groups of respondents, the scenarios are sliced into "scenes", which can be condensed to one page per scene per respondent (Figure 2). Based on the TME recording, a visual representation is created which

Scenario 1, Scene 1 (U2 -> escalator/stairs/lift)

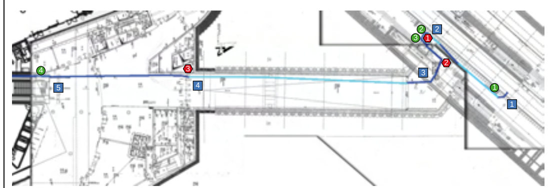
Respondent ID: 11	Date/Time: 07/Apr/2010 12:00 Group: visually impaired female Scenario: (2) U1 to S3 Passerby density: medium Weather: mild/dry Initiation of trajectory: 12:08:19, at 00:02:56 of audio recording Further notes
Duration	Duration for scene: ☐ < 1 min ☐ 1 – 2 min ☒ 2 – 3 min ☐ > 3 min
	 ... Stops automatically detected trough analysis
Decision points, Events	(1) Collision/near collision (2) Waits for elevator (3) In elevator (4) Stands on escalator
Thinking aloud (Translated transcript)	[1] I arrived at Praterstern Station with the U1. Now I'll go to the concourse. [2] Here I found an elevator, which I'll use to get to the next level. [3] I'm looking for the concourse – I'll try to go in the direction of the U2 and use the connecting tunnel. [4] At the glass doors, for me this is somewhat of an obstacle - the ticket cancelling machines, where I always pass very cautiously to not bump into them. So now I'll have to go up, to the concourse and the ticket counter of the commuter trains. [5] Here I use the escalator.
Observer comments	The TP arrives at the U1 platform level. She gets of at the middle of the train and then turns right. Then she nearly collides with another passenger, who walks the opposite way to the stairs; however there is no accident. The TP continues until she reaches the elevator. She has to wait a few moments and then uses the elevator to get to the passageway-level. Getting out of the elevator in the passageway-level, the TP keeps to the right. She passes through the tunnel link, mostly walking near the wall. At the end of the tunnel there are three glass doors, which are always open, followed by a line of ticket cancellation machines and waste bins. It is possible to pass by the cancellation machines without stopping or slowing down. However, the TP slows down significantly. She turns to the wall and continues cautiously, touching the wall with a hand, until she passes the line of ticket cancellation machines. In the debriefing interview the TP refers to difficulties making out the machines and dustbins which are mounted at about 1 to 1,5 meters height. After rather painful collisions she now remembers their location behind the doors and how to evade the obstacles. She continues along the wall until she reaches the tactile paving. She uses the guidance to walk across the open area where passenger flows are redistributed, following the straight line to the next escalators. The TP senses the paving through the soles of her shoes. She did not bring a white cane which she only uses in conditions of reduced visibility (e.g. evening/night). In general the movements of the TP seem cautious. She keeps holding one or both arms slightly in front of the body so she can feel obstacles she couldn't see.

Figure 2. Template for comparative analysis of time-motion event recording showing one person's results within one "scene".

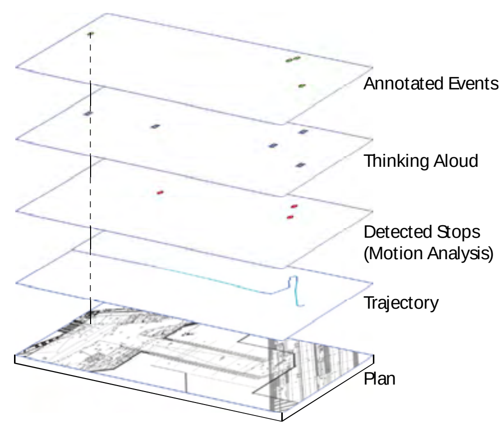


Figure 3. Single result layers of time-motion-event recording.

combines five of six data streams (Figure 3): The floor plan of the environment, the trajectory, detected stops, annotated events and thinking aloud. The TME datasets will be analyzed to extract speed and stop histograms of each trajectory. These histograms will subsequently be used to find clusters of individuals showing the same spatio-temporal behaviour. The spatial analysis of time-motion-event data will reveal the main routes, strong deviations from these routes and clusters where people mainly stop.

Connecting Types of Data

Transcripts of thinking aloud are applied to defined events within the trajectories. Observers' comments are added as a narrative. Demographic and transport statistics are used to define the user groups and bring results into context.

INITIAL OBSERVATIONS FROM EXPERIMENTS

After the first set of experiments we can observe several issues relating to the methodology:

As may be expected, some respondents do not behave naturally in the test situation.

Most respondents do not comment on any awkwardness of being observed and state that after getting involved in the scenario tasks, they had forgotten about the observers.

The "thinking aloud" method may have greater impact: Even though the recording instrument itself is barely noticeable, the fact that people have to talk (and think about what they say) distracts them. In some cases the distraction is such that these cases are of limited use for the calibration of simulation models. Nevertheless, they provide qualitative insight.

Most severe loss of orientation or lack of basic understanding of the scenario tasks occurs with respondents over the age of 70.

One assumption that can be discarded already is that people with sensory impairments would have greater problems carrying out the scenario tasks. Many completed the tasks in very little time or with minimal deviation from the most direct route, sometimes in contrast to test persons without sensory impairments but facing other challenges (parents with prams, elderly).

RESEARCH OUTLOOK

So far the experiments have revealed on the one hand surprising similarities between very different groups of people, on the other hand extreme deviations within a single group, indicating that in some cases determinants other than disability play a more significant role in navigation/ orientation behaviour. First analysis of some field tests suggests that the link between thinking aloud data and time-motion tracking will help to identify elements of the orientation system and the built environment that respondents use to navigate and thus point out typical areas for orientation in the infrastructure. This explorative research will lead to first steps in describing the behavioural patterns and variations within and between the described groups and may point towards further research necessary to enhance the understanding of environmental parameters and their influence on navigation. In addition it may be possible to generate hypotheses on why certain behavioural patterns emerge recurrently in determined areas. The insights gained will provide a basis for simulation model calibration on a tactical level.

REFERENCES

1. Bauer, D., Brändle, N., Seer, S., Ray, M. and Kitazawa, K. Measurement of pedestrian movements – a comparative study on various existing systems. In *Pedestrian behaviour* (2009), 301-320.
2. Braun, A., Musse, S.R., Oliveira, L.P.L.D. and Bodmann, B.E.J. *Modeling individual behaviors in crowd simulation*. In *CASA*, IEEE Computer Society, 2003.
3. Brunnhuber, M., Schrom-Feiertag, H., Hesina, G., Bauer, D. and Purgathofer, W. Simulation and visualization of the behavior of handicapped people in virtually reconstructed public buildings. In REAL CORP, 2010.
4. Carroll, M. Scenario-Based Design: *Envisioning Work and Technology in System Development.* John Wiley & Sons, 1995.
5. Corcoran, C., Douglas, G., McCall, S., McLinden, M. and Pavey, S. Network 1000: surveying the changing needs and lifestyles of 1000 visually impaired people – indicative results from generative interviews. *International Congress Series* (2005), 370-374.
6. Hollan, J., Hutchins E. and Kirsh D. Distributed cognition: toward a new foundation for human-computer interaction research; TOCHI Volume 7, Issue 2, ACM 2000, 174-196.
7. Mollenkopf, H. *Ageing and Outdoor Mobility*. IOS Press, 2004.
8. Neuhold, H. Hörbehinderte und gehörlose Fahrgäste im öffentlichen Verkehr, 2004.
9. Norris, S. *Analyzing Multimodal Interaction – A methodological framework.* Routledge, Taylor & Francis (2000), Chapter 2.
10. O'Halloran, K.L. Systemic functional-multimodal discourse analysis (SF-MDA): constructing ideational meaning using language and visual imagery. Visual Communication *7*, 4 (2008), 443-475.
11. Pearce, L., Powell, P., Duff, R., and Kerr, A. *Passengers with reduced mobility: modelling their behaviour in underground stations.* In European Transport Conference, 2008.
12. Pelechano, N., Allbeck, J.M., and Badler, N.I. *Controlling individual agents in high-density crowd simulation.* In SIGGRAPH/Eurographics, 2007, 99-108.
13. Shao, W. and Terzopoulos, D. *Autonomous pedestrians*. *Graphical Models*, *69*, 5-6 (2007), 246-274.
14. Sless, D., Wiseman, R., Writing About Medicines for People: Usability Guidelines for Consumer Medicine Information, Communication Research Press, 1996
15. Van Leeuwen, T. and Jewitt, C. *Handbook of Visual Analysis*, Sage Publications, 2002.