Development of 3D Tactile Models for the Partially Sighted to Facilitate Spatial Orientation

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Lacking or poor provision of comprehensive information about the spatial environment for the purposes of effective orientation is a problem that primarily affects the blind and partially sighted, but it can also cause difficulties for older people with increasing visual impairment. This research project in progress aims to obtain new scientific findings with regard to the basic suitability and required composition of tactile models to facilitate spatial orientation for the blind and partially sighted. Tactile scale models serve as an orientation aid. Their intention is to make it easier for visually impaired people to "experience" selected structural characteristics of the real space, even if in scaled-down form. This experience allows them to experiment with space and to better recognize spatial elements and their interrelationships. It also helps them to better recognize subspaces, possible spatial sequences, as well as decision-making situations in these spaces. These tactile processes are supported by the highly sensitive tactile faculties of people with visual impairment, which are far more finely differentiated than those of sighted people who experience objects without this disability. The amount of available digital model data is constantly growing and would allow for the creation of tactile models.

***Keywords**: rapid prototyping; 3D printing (3DP); visual impairment; scale modeling; haptical interface*

Project aim and scope

A tactile model serves as an orientation aid for the blind and partially sighted in the (built) environment (urban space, architectural objects): by producing physical scale models with appropriate haptic qualities, the aim is to convey "tangible" information about a spatial context. This applies to both outdoor and indoor spatial situations. In addition, a model of this kind can give a clear idea of a spatial expanse as well as of the relationships between individual parts of a building through "spatialization" of ground plans and cross-sections.

The project comprises the following components: Based on a series of validated psychological perception tests with prototype tactile models, procedures for the development of models as an orientation aid for the blind and partially sighted are to be validated and conceptually expanded. Three-dimensional model prints, mainly generated using rapid prototyping techniques, will be tested in layered combinations to produce tactile models capable of reproducing spatial relationships. Special attention is to be given to different levels of detail (LOD), scales and the haptic qualities of the models.

The amount of digital data is constantly growing. These data stocks can serve as the starting point for appropriate computer-based further processing. This will create increasingly favourable preconditions for the cost-effective production of tactile models in different forms and scales.

Information content and orientation

First of all, it appears important to make the distinction between blindness and partial sightedness. Blind people are unable to use any "residual vision" for practical orientation purposes. "Partially sighted", on the other hand, refers to people whose vision is limited, but who cannot be described as blind. People who are blind from birth have no visual relationship at all with the spatial environment they live in. People who become blind later in life, on the other hand, do have a mental picture of visual spatial relationships, which often allows quicker familiarization with a new spatial situation. There are thus significant differences among blind and partially sighted people in terms of both spatial perception and the orientation process. Lacking or poor provision of comprehensive information aiming at orientation can also cause difficulties for older people with increasing visual impairment. This frequently applies to public transport installations which were designed for the efficient movement of large numbers of people. Pedestrian underpasses and subterranean stations have frequently been the target of criticism because of the orientation problems they pose. Moreover, it is not only blind and partially sighted people who are affected by this difficulty.

Orientation in the architectural and urban space is based on the positioning of built objects in relation to one another. For blind people, being able to follow the sequence of objects is usually of decisive importance, because they are unable to acquire a visual overview of the spatial relationships and thus recognise any inconsistencies. Blind people first have to acquire a "picture" of these relationships by repeatedly walking through the space taking several different approaches. With the aid of the memory, the information content required for orientation can then be (re-)constructed in many cases.

Is the orientation system used by blind people fundamentally different to that of sighted people? One certain difference is that the blind person, if the space is unfamiliar to him/her, has to be able to recognise a sequence of orientation cues with as few gaps as possible in order to get to his/her desired destination. The sighted person, on the other hand, can skip cues in this sequence, because he/she can simultaneously perceive more distant objects and thus fill in the gaps in perception to produce an overall picture. Misinterpretations often occur if the situation is unclear: the reference cues are then ambiguous or cannot be clearly perceived. Such situations often result in false conclusions, meaning that the impressions gained suggest something that is not really there. Information gaps occur when exclusively visual orientation systems are used, however sophisticated these may be.

With the aid of tactile models, complex structures could also be made tangible to people who have been blind from birth. Furthermore, orientation in complex spatial situations could be significantly facilitated by placing orientation models in the vicinity of staircases. The desirable dimensions of such models are to be determined on the basis of comparative studies with different sizes. Prototypes can then be developed and used to evolve an expanded approach to the use of models as an orientation aid. We thus have model orientation on the one hand, and tactile orientation on the other; however, the two paths could also be pursued in parallel. From one case to the next it should be borne in mind that sighted people can also benefit from a set of tools developed as an aid for the blind; efficient orientation in university buildings, for instance, is not only of interest to blind people.

Creation and use of tactile models

Computer-aided model making has gained in importance over the last few years (Streich, 1999; Breen and Stellingwerff, 2005) and today is no longer a novelty per se. A large number of educational institutions have been gathering experience in the field for a long time now (Kenzari 2005), though the number of conference papers on the subject is limited. However, the fact that the publication channel is less often used by no means implies that there is no exchange of experience and findings, but rather that the relevant empirical parameters tend to be generated through undocumented direct contacts. A wide range of appropriate tools is now on offer in the market, which has resulted in the establishment of a commensurately large group of people who are versed in their practical application. The personnel resources required to operate the equipment are easy to keep track of, though it would be premature to talk of "plug-and-play" use at this stage. In parallel to this, attention focuses on the subject of *digital fabrication*. Generally speaking, however, *construction* of models in the traditional sense might well regain importance as it would appear that a good many undergraduates are becoming increasingly addicted to the downright "unbuildable". Minimum wall strengths, for example, are to be taken into consideration during model production. Furthermore, the production volume is subject to certain dimensional limits. From a certain size upwards it thus becomes necessary to divide up the 3D model accordingly and reassemble the component parts after printing. For this reason, sound data preparation is absolutely vital. The conversion of the data into so-called STL format also requires special attention, particularly since not every package delivers truly "clean" STL data, even though an interface is installed.

The software that is often delivered along with the equipment (e.g. Zprint) is a great help, as it allows the positioning of the model and the production volume to be simulated in advance, even without a direct connection to the device. In this way, errors can be located, the consumption of materials determined and costs estimated (in the context of university use the personnel costs for operation, etc. will possibly not be charged for at all). At this point it seems justified to compare computer-aided model building with various plot services, which are made available to students in a similar way and where the charges are primarily geared towards covering real costs and the cost of maintenance (and/or provision for the acquisition of a replacement device when the present one wears out) and not towards generating commercial profits.

The project team was able to gather important experience with computer-aided model making in the course of its work on the virtual reconstruction of Viennese synagogues (Martens and Stellingwerff, 2005). The main façade and the Holy Ark of the no longer existent synagogue in Schopenhauerstraíe were the first "tangible" results to be produced from the CAD model (Oberhofer, 2005). In addition, it should be pointed out that computer-aided model making very much supports the development of projects for new buildings and could indeed be described as the Renaissance of the architectural model. Although in many cases only a single model is produced, the latter is not a *one-off* in the classical sense because further *model prints* could be produced at any time at the touch of a button using the available data. In this context, the costs in terms of materials and equipment are fully calculable.

The experience already gathered thus represents an essential working basis for the production of tactile models. The necessity of touching is to some extent contradictory and stands in stark contrast to the brusque "Please don't touch!" often heard in relation to conventional physical models. The danger of mechanical damage is ever present, though the model can be prepared accordingly for mechanical handling (impregnation and/or other appropriate surface treatment).

Tactile scale models aim to make it easier for visually impaired people to *experience* selected structural characteristics of the real space, albeit in scaled-down form, enabling them to experiment with space and to better recognize spatial elements and their interrelationships, subspaces and possible spatial sequences, as well as decision-making situations (e.g. crossings of ways) in the space.

These tactile processes are supported by the highly sensitive tactile faculties of people with visual impairment, which are far more finely differentiated than those of sighted people who experience objects without this disability.

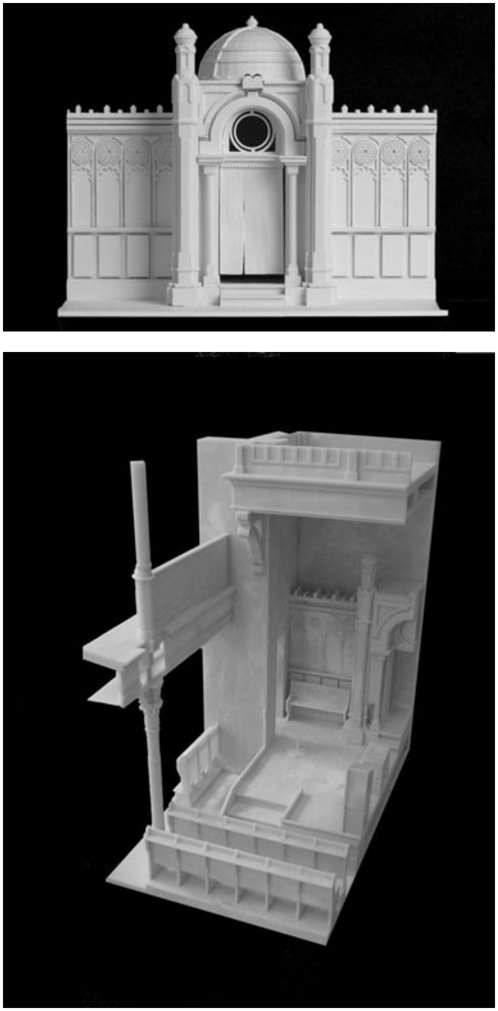

Figure 1a-b
Examples of 3D Model prints (Synagogue Schopenhauerstraíe).

Outlook

The entire spectrum of scale offers itself as a field of discovery, from architectonic objects (interior and exterior space) through to urban space with different layers of spatial detail. The range of potential uses extends, for example, from the everyday orientation needs of residents in their living environment and orientation in public buildings through to conveying spatial information in and about artistically, culturally and historically important buildings and/or tourist sites (including the reconstruction of entities which are no longer existent) and orientation in spatial situations that have not yet been visited for real.

Tactile models can both convey a spatial impres-

Figure 2
First tests with a tactile model.

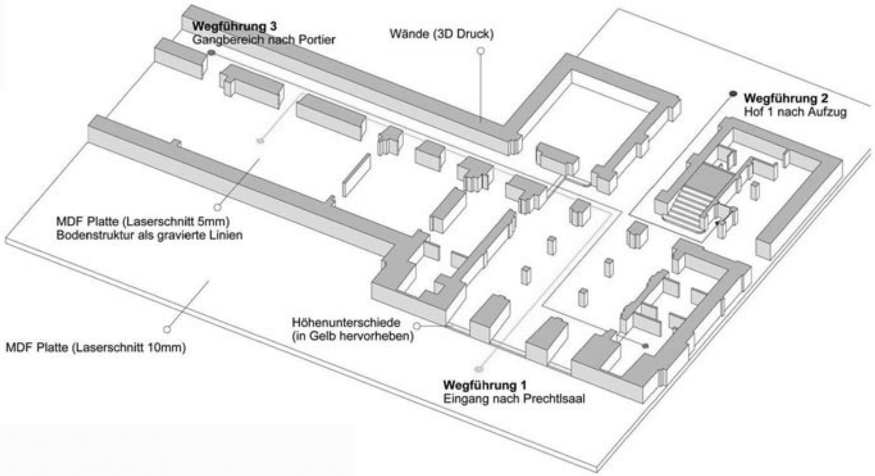

Figure 3
Layout for a tactile model of the main building at Vienna University of Technology .

sion prior to a real visit and serve as training for real orientation processes as well as acting as an aid to orientation on the spot and/or as a means of adding detail to the "mental map" afterwards. There is a definite need for tactile models as an orientation aid for blind and partially sighted people, and this need is likely to increase in view of the growing proportion of older people in the population who suffer from visual impairment.

Further work steps will involve a series of in-depth tests with blind, partially sighted and elderly test subjects to validate the findings regarding the possible purposes of the models (fields of application and spectrum of use) and their required characteristics (e.g. scale, level of detail, meta-information). These tests will include a questionnaire directed at the test subjects as well as evaluations of the visual documentation of the tactile processes.

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