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Multi-colour 3D printing for supporting tactile perception of geospatial visualizations

Jan Brus [a,*], Radek Barvir [a], Alena Vondrakova [a]

[a] *Palacký University Olomouc, Department of Geoinformatics, jan.brus@upol.cz, radek.barvir@upol.cz, , alena.vondrakova@upol.cz*

* Corresponding author

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Abstract:

While the 3D printing process is a boon for many sectors, it can be limited to those who need to use colours as a source of information. Colour reproduction is the key to the success of many 3D printing endeavours, and one-color objects may be a relevant constraint. Due to this, a full-colour 3D printing is one of the significant trends in the design industry, education and medicine (Chen et al., 2020). It offers many benefits, such as easy colour change, replicability, and rapid prototyping of objects. However, the 3D printing colour process was for a long time limited, mainly through price and several factors like complexity and process requirements. Nowadays, several printer manufacturers offer low-cost solutions to multi-material FDM 3D printing with the possibility of combining five or even more colours. This situation opens completely new possibilities for creating accessible full-colour models also for partially sighted people where combination of colours and 3D model can provide unique synergy. These coloured models are specially designed to allow people with visual impairments to interact with the world around them and colour is used as a bearer of information (Jenny and Kelso, 2007). Although their effectiveness in this regard looks promising, their advantages over one colour tactile equivalents need to be addressed scientifically and tested.

During research at Palacky University Olomouc, we tested several approaches to integrating colours into the models and tactile maps (Barvir et al., 2021). Initially, we started by combining two materials or gradually changing the materials as the model height increased. Using printers such as the Ultimaker 3D or Prusa MK3S, these approaches have helped create haptic maps where individual barriers are differentiated by height (Figure 1).

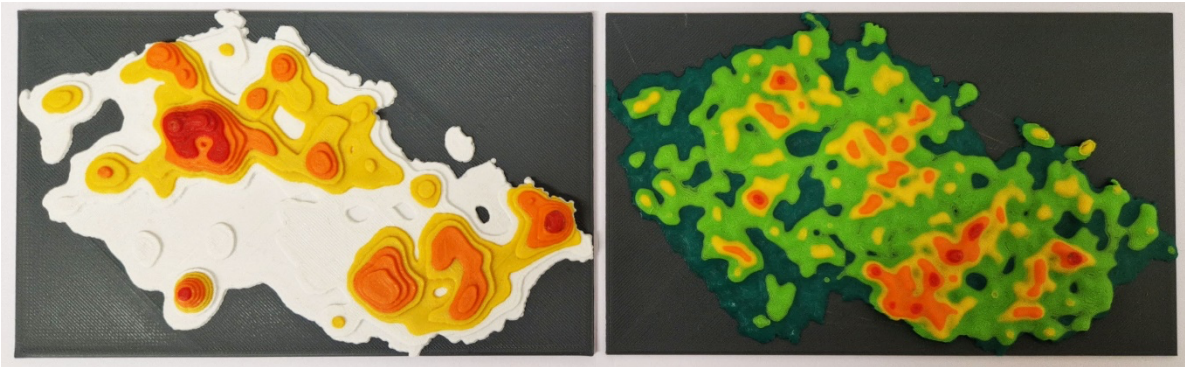

Figure 1. Coloured tactile maps of social surfaces printed with FDM printer by changing colors gradually

However, as we progressed and through testing more complex models, we gained experience that the presence of colour would allow the model to be better explored for many respondents. Therefore, we began looking for a solution that would allow more complex models to be created in colour. In the case of non-interactive models, we used the MCOR IRIS HD paper printer for testing, which uses colour inks and A4 office paper to create the models (Figure 2). The models are faithful, haptically attractive, and relatively cheap to produce. However, the level of detail and the model's final size must be considered. The length of the print run and the post-processing itself, which, due to the need to remove paper manually, almost doubles the length of the models' production. Due to the complexity of production, further experiments were directed toward the implementation of printing using Multi Material Upgrade 2S (MMU2S) for the Prusa MK3S printer. However, this upgrade is quite complex, and the results were not as expected. Therefore, we chose the Palette 3 Pro device for colour combination, installed as an add-on to FDM printer. Palette 3 Pro is a multi-material 3D printing device that simplifies and improves the process of making multiple colour prints. This innovative tool allows users to print in up to eight colours with just one extruder. Printing with up to eight colours allows the model maker considerable creativity,

and the resulting models are attractive even for the visually impaired. The combination of contrasting colours brings possibilities such as displaying maps using e.g., choropleth maps, where the height of a region is also supported by colour. Users are thus given information about the spatial arrangement of a phenomenon, which is very demanding on the imagination when creating a spatial representation using touch alone.

The more advanced and promising path is creating fully coloured models with added interactivity by speech. TouchIt3D technology (Lázna et al., 2022) uses a combination of 3D models connected to the mobile device. It allows users to connect a 3D-printed object with a device and converts pre-defined texts into voice after registering the user touch input. 3D printers with multiple extruders and TouchIt3D technology (Barvir et al., 2019) present a way of producing interactive-coloured models and maps. Since the conductive filament leaves traces when the filaments are mixed, it was necessary to work out how to print in combination with several colours. It was necessary to find a solution allowing one extruder only for the conductive filament while the other extruders would be for the colours. The 3D printer Prusa XL offers this solution. One of the best things about the Prusa XL is its modular bed. The bed allows the user to print with multiple materials, seamlessly integrating each colour into the 3D print. Another feature that this model is known for is its ability to support up to five extruders which mean the combination of four colours and conductive material. When a new tool head is attached, the system automatically calibrates itself. The system is entirely accurate and eliminates the need for calibration prints.

In the following research, we will focus primarily on creating larger models that fully utilize the combination of four colours and added interactivity and their testing. Due to nearly ten years of research with conductive models, many models can be coloured and further tested and built upon existing testing to scientifically demonstrate the importance of colour in 3D models for the visually impaired. When aware of the costs, most of the low-cost FDM printed models have a minimal difference in quality. New generation multiple extrusion FDM printers are a promising avenue for creating 3D printed models for partially sighted people.

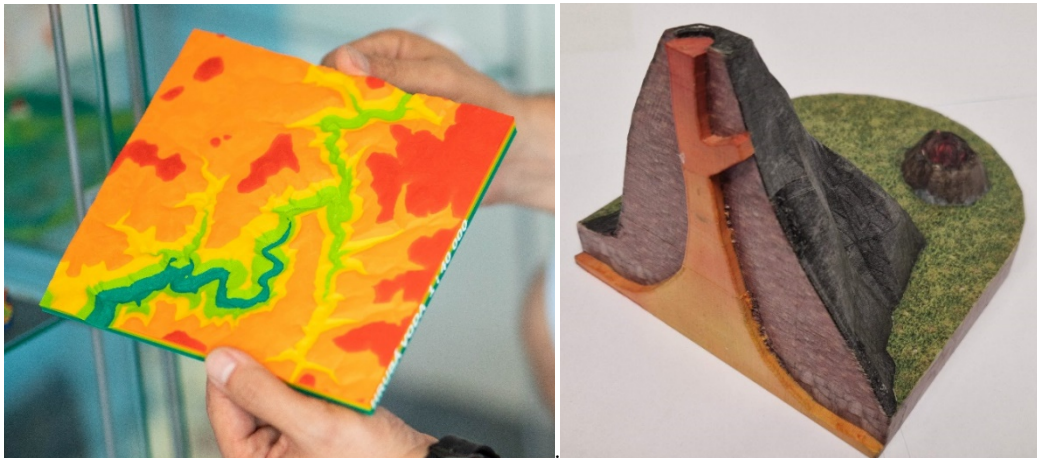

Figure 2. 3D model with hypsometric colours (left) and 3D model of volcano created with paper printer MCOR IRIS HD (right).

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