TangibleChannel: Data Physicalization for Teaching Visual Marks and Channels

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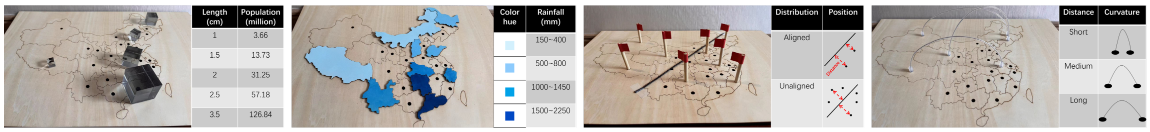

Fig. 1. *TangibleChannel*: the data physicalization used for teaching the effective use of visual marks and channels.

This report reviews our early steps in teaching visual marks and channels using data physicalization. We discuss our design considerations and the first phase of the prototype. Furthermore, we reveal our next research plans. We believe our research will inspire more visualization educators and researchers to explore the use of data physicalization in teaching practices.

CCS Concepts: • **Human-centered computing → Visualization application domains**.

Additional Key Words and Phrases: Information visualization, data physicalization, visualization education

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1 INTRODUCTION

Data physicalization is the process of converting digital data into a physical form that can be perceived by users through human senses such as touch and hearing. It is designed through tangible representations like physical objects and materials [3]. While data physicalization has been used for centuries to represent data, the term 'data physicalization' only appeared recently in academic literature in the past decade. It is designed to provide assistance in exploring, interpreting, and communicating data [4]. In education contexts, data physicalization has been used to help students gain a better understanding of data structures and algorithms, communicate results more accurately [8], and make easy-to-understand visualizations [9]. Additionally, it can potentially engage students in meaningful learning experiences that encourage critical thinking. It has been widely used in geography education [1, 11], urban education [7], modeling building [5] and STEM learning [2]. However, there is limited work using data physicalization to aid teaching visualization, which led to the development of a new research agenda to enhance the teaching of visual channels in visualization through data physicalization tools. The proposed system, *TangibleChannel*, aims to provide a more intuitive and interactive learning experience than traditional teaching methods, by taking into account five critical design factors (teaching objectives, audience, data accuracy, interactivity, and aesthetics) and three design goals.

2 DESIGN

Our education system is designed as a physical visualization tool that helps students gain a more intuitive understanding of d visual coding channels. While traditional methods of teaching visualization often rely on printed or digital pictures, physical visualization tools offer great potential to better support this sector of education. Through the education system's design process, we aim to obtain a comprehensive understanding of creating physical representations, such as selecting appropriate materials for visual marks, identifying their strengths and limitations, and making alternative choices in various scenarios (**DG1**). Furthermore, we seek to explore the potential advantages of using physical

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visualization in education (**DG2**) and investigate whether the value of data physicalization comes from its physical form or the user's direct interaction with it (**DG3**).

To design and develop our data physicalization prototype, we consider the following five design factors: **(1) Teaching objectives**: we summarize and refine the teaching objectives by consulting with teaching staff or collecting relevant online teaching manuals and slides; **(2) Audience**: we design the physicalization with audience in mind, taking into account their level of expertise, age, and cultural background, to meet their needs and interests; **(3) Data**: we ensure that the data used in the physicalization is accurate and reliable; also, it is important to select data that accurately represents the effectiveness and efficiency of the different coding channels, especially when these quantities are significantly different or differ by relatively low magnitudes; **(4) Interactivity**: we make the physicalization interactive, allowing for exploration and experimentation on these physical channel to promote student engagement and encourage deeper learning; **(5) Aesthetics**: we design the physicalization to be visually appealing and well-designed, using colors, shapes, and textures to enhance the learning experience.

Fig.1 presents our initial prototype of the *TangibleChannel* system. The prototype was created by laser engraving the rough outline of Chinese provinces onto a wooden board and using Epoxy Resin blocks, color shades of each province, wooden sticks, and plastic tubes to materialize the coded channels. The visual channels of volume, luminance, position, and curvature were employed to represent various data attributes of the Chinese provinces. The visual channel of **volume** was employed to represent the population of a particular province [6] using cubes with varying side lengths. The material used for the blocks was epoxy resin due to its light transmission properties, which can ensure that the content on the board was not obstructed. A light gray color was chosen to ensure that the edges of the cubes can be easily distinguished. The visual channel of **luminance** was employed to represent the annual rainfall data for 34 provinces in China [12]. The visual channel of **position** was represented by the distance between the stick and the Heihe-Tengchong line [10]. The positions of the sticks are divided into two categories: same-side and opposite-side; helping the user to gain a sense of the accuracy of position perception in the aligned (where the points compared are all on the same side) and unaligned cases (where the points compared are on different sides). The visual channel of **Curvature** was employed to represent the distance between different cities by using pipes inserted into holes at both ends, with the greater distance resulting in the greater curvature of the pipe. The TangibleChannel prototype provides students and teachers an opportunity to explore and learn from physical channels. Moreover, there are plans to design and create more physical channels for educational purposes.

3 DISCUSSION AND CONCLUSION

In this paper, we present our initial physicalization prototype of an education system designed to teach visual marks and channels using tangible materials. Our study utilizes a mixed-methods approach, including both quantitative and qualitative data collection methods. We assess the impact of data physicalization on student engagement, comprehension, and retention of visual coding concepts. In addition, we gather feedback from both students and instructors to understand their perceptions and experiences with the use of data physicalization.

Through our discussion of three design goals and five design considerations, we aim to make a meaningful contribution to the broader field of data physicalization. Specifically, we provide evidence supporting the effectiveness and value of physical visualization as a tool for teaching visual coding. The integration of data physicalization into teaching visual channels has the potential to facilitate a more engaging and interactive learning experience. Students can manipulate physical objects and link them into a visual channel, providing a more tangible and immersive understanding of the concepts they are learning. We believe that our study will inspire other educators and visualization scholars to explore the use of data physicalization in their teaching practices.

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