Certain Uncertainty - A Geospatial Data Physicalization of Water Stress and Population Density

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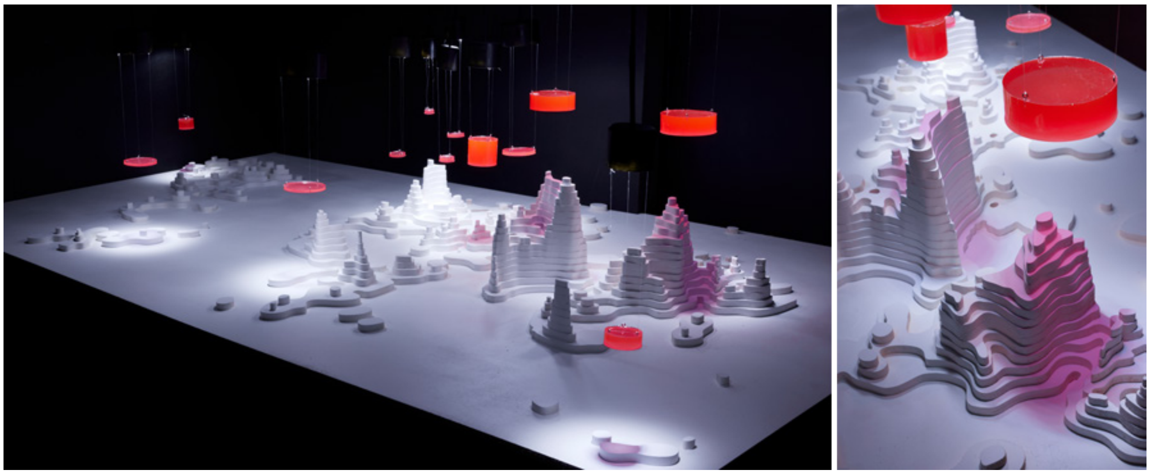

Fig. 1. The images show the data physicalization project Certain Uncertainty from different perspectives.

The paper describes our approach to visualize water stress in a geospatial context in relation to population density. Water stress or scarcity does always need to be reflected in context. While some parts of the world are only sparsely populated, the impact and mitigation of water stress in densely populated areas are potentially critical. While most water stress mappings focus on communicating the water stress within a tempo-spatial context, this project aims to map the water stress of selected capitals within the context of the global population density to enable the viewer to explore the interaction between both dimensions in a meaningful way. By focusing strongly on the data and removing all cartographic borderlines, an abstract space of mountain ranges remains, showing the world as a spatial accumulation of humans confronted with increasingly changing environmental conditions. In this paper, we describe the stepwise development process of the artifact starting data processing and how the individual physical layers were created.

CCS Concepts: • **Human-centered computing → Information visualization**.

Additional Key Words and Phrases: water stress, data visualization, dataphysicalization

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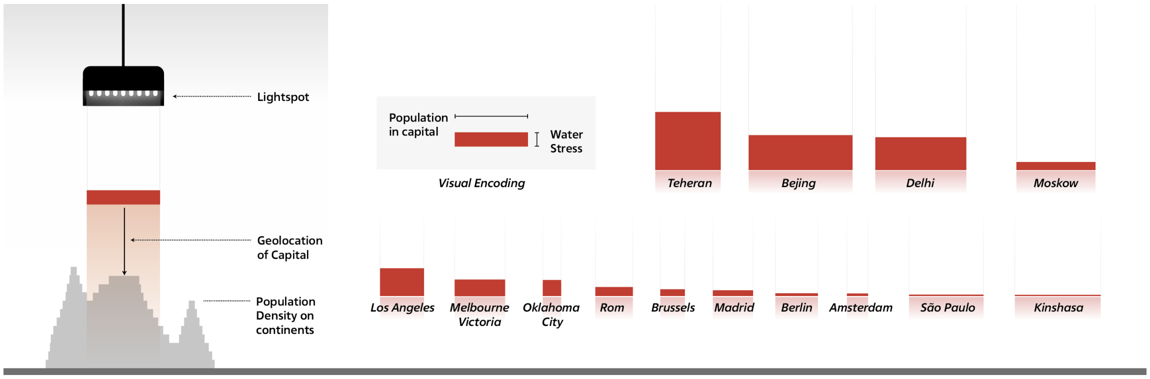

Fig. 2. Schematic view of the visual coding of water stress impact, taking into account the geolocation of selected capitals, the affected population, and the projected water stress.

1 INTRODUCTION

In the decades to come, climate change is getting an more vital role in our daily lives. The IPCC makes it unmistakably clear in its current status report that policymakers and society need to act fast to reduce future risks. Most of the proposed mitigation strategies will influence our society as a whole, and understanding climate in general still poses a significant challenge for citizens [5]. Understanding climate change is vital for the citizens to be engaged and support mitigation measures on climate change [2, 6]. Water stress in particular will have a strong impact on large parts of the world[14, 19, 23, 25].

Visualizing climate change is a challenging task as multiple dimensions need to be considered, and which dimensions are shown heavily frame our perception of the real phenomenon. Looking at the frightening consequences, one tends to focus on where and in which geographical context hazards arise. While traditional two-dimensional maps and visualizations are useful tools for communicating data about water stress, they can offer only a limited view of the problem as the amount of encodable data dimensions is limited.

To overcome this limitation, we propose the use of data-physicalization to add an additional dimension to our understanding of water stress and increase the accessibility as well as creating a more immersive experience for viewers. In this paper, we describe step-wise our approach to visualizing water stress in a geospatial context in relation to population density.

We focus on selected capitals within the context of the global population density to enable the viewer to explore the interaction between both dimensions in a meaningful way. By removing cartographic borderlines and focusing on the data, we create an abstract space of mountain ranges that shows the world as a spatial accumulation of humans confronted with increasingly changing environmental conditions. We also describe the stepwise development process of the artifact, starting from data processing and how the individual physical layers were created. The underlying data, all production files, and impressions from the installation can be accessed on the project website.[1]

2 VISUALIZING CLIMATE AND THREE-DIMENSIONAL DATA

Visualizations of climate change data are often communicated through cartographic or geographic visualizations [10]. Since climate change is a broad term, communication often focuses on a smaller aspect of climate change [7].

[1]https://certainuncertainty.de/project/

Visualisations often address consequences of climate change such as rising sea levels [28], regional temperature increases, and loss of biodiversity [29]. Geospatial visualization of climate data is an active research area. Various techniques have been explored to represent the complex relationships between climate variables and geographic locations, including temperature maps and isopleth maps. However, these approaches may have limitations in accurately representing spatial patterns, the amount of dimensions the can be presented or in interpreting data based on spatial units. Some researchers have attempted to extend the number of perceivable dimensions by utilizing the third dimension, but classical 2D displays still have limitations in accurately representing multiple climate variables simultaneously. Continued research is necessary to develop more intuitive and engaging visualization techniques.

Recent work has explored interactive three-dimensional stereoscopic displays[1, 13, 22, 26, 27, 30] and physical data presentation techniques [8, 9, 17] to represent data in physical forms, such as 3D models or tangible interfaces. These approaches can potentially enhance user engagement and understanding of the data [16, 18] and provide a multimodal and more intuitive representation of the complex relationships between water stress and the geographical context. While the physical representation of quantitative data in a spatial context has a very long tradition [3, 4, 20], a systematic scientific evaluation is a relatively young field.

3 THE DESIGN PROCESS

Water stress or scarcity does always need to be reflected in context. While some parts of the world are only sparsely populated, the impact and mitigation of water stress in densely populated areas are potentially critical. While most water stress mappings focus on communicating the water stress within a tempo-spatial context, this project aims to map the water stress of selected capitals within the context of the global population density to enable the viewer to explore the interaction between both dimensions in a meaningful way. The water stress of each of the selected capitals is encoded in red semitransparent epoxy discs representing four dimensions: the latitude and longitude that puts the disc in the accurate spatial context, a radius reflecting the humans living in the area, and a height representing the projected water stress.

The projection space – an elevation map showing the world's population density – is made of wood and shaped with a CNC cutter based on demographic data. The surface is coated with multi-layer high-pigmented color to allow accurate color reflections of the water-stress epoxy discs. By focusing strongly on the data itself and removing all cartographic borderlines, an abstract space of mountain ranges remains, showing the world as a spatial accumulation of humans confronted with increasingly changing environmental conditions.

3.1 The physical dimension

To create the population-density mountains required for our installation, Nasa population data [11] was utilized as a basis to map the population density. The data was encoded as a heat map [12], showcasing population density across the world. This image was then used as input for generating a 3D model in Houdini. The data was processed through a four-part tree in Houdini to create the mountain landscape. Firstly, the visualization was converted into points with colors represented by vectors. These points were then moved in the normal direction based on the length of the vector, forming the mountain range. Next, the mesh of the range was evenly distributed to ensure a clean result. The mountain range was then sliced to create layers, which were subsequently extruded to their appropriate thickness[21]. This model was then ready for production.

Before the model can be cut out, it has to be reorganized so that the CNC cutter understands how to cut it out. Each layer is cut out of a separate plate, for which the Fusion 360 software was used. This software wrote a gcode

Fig. 3. The four images show the individual stages of the elevation map creation. a) CNC cutting the wood shapes, b) spatial construction of the individual layers c) surface optimization d) surface coating, 2023.

that allowed the cutter to cut out the model. After all the models were cut out, the parts could be assembled into the landscape [24].

We used an overhead projection of the geodata mapping to accurately position the individual layers of the population density map on their respective positions. In the next step, all individual parts were glued together with wood glue.

3.2 Mapping Water Stress

The used water stress data is based on the Aqueduct framework considering 13 water risk indicators combined in a total water risk score[15]. The stress level was encoded into 3d models of cylinders. Whereby the height encodes the stress level, and the radius reflects the affected population (see figure 2). With an iterative, test-based process, several material studies were conducted to figure out which pigment type and epoxy mixing ratio are suitable to project the required color space dependent on the thickness of the discs.

The lenses floating above the mountain landscape have dimensions based on the selected cities' water stress and population data. To produce cylinders with accurate dimensions reflecting the underlying data, we created 3d models. The cylinders are drawn in Autodesk Fusion 360 and then converted with the Prusa slicer to the gcode that the printer

Fig. 4. The design, printing, and assembling process of light spots used for data projections

utilizes to construct the cylinders. Finally, we printed them with PLA and used them to make precise silicone molds of all cylinders. Now we were able to test molds with different casting materials in consistent dimensions. In extensive material studies with different epoxy mixtures and pigment types, we investigated the optical properties necessary to project the stress intensity onto the coated surfaces. The balance between light transmission and color intensity proved to be particularly difficult. In the end, the projection of the data was only possible with a uniform high-power LED array in combination with a precisely adjusted epoxy, pigment and hardener ratio. Then the individual layers were alternately coated with highly pigmented lacquer, sanded, and surface-treated. After a 12-fold coating, the surface properties were suitable for optical data projection.

The lighting system has the same diameter as the cylinders. The lights are designed in Autodesk Fusion 360, consisting of two parts; the body and the holder for the LEDs. The body has a mounting system with a fit for the holder and recesses to support the cylinders. Functions generate the model in the CAD file [**?**]. When the diameter of the cylinder is adjusted, the size of the carrier changes, and the number and location of perforations adjust accordingly. Both parts were 3d printed by generating a gcode with the Prusa slicer in PLA. Power LEDs were soldered to the resistors and attached to mount the lights in the indoor system. This procedure was performed for all cities.

4 RESULTS AND DISCUSSION

The resulting installation provides a novel, physical approach to experiencing water scarcity in a global context with a focus on population density.

A wooden elevation map was utilized to visualize the global population density. The water stress that affects significant parts of the world is illustrated based on the scenario data of 14 representative capitals. The data underlying data is represented by red, semi-transparent disks where the height represents the level of water stress and the radius represents the amount of population affected in the region.

The data discs are suspended under light spots specially tailored to the radius, which project the water stress within the populated areas and thus make it visible. This allows the viewer to explore the data in a broader context.

By focusing strongly on the data itself and removing all cartographic borderlines, an abstract space of mountain ranges remains, showing the world as a spatial accumulation of humans confronted with increasingly changing environmental conditions.

The installation is an ongoing project. Currently, we are working on the interactive components, where we try to expand the multisensory experience through spatial audio cues and interactions with the data so that users can explore multiple projections under different conditions, e.g., different decades, business as usual vs. optimistic or pessimistic

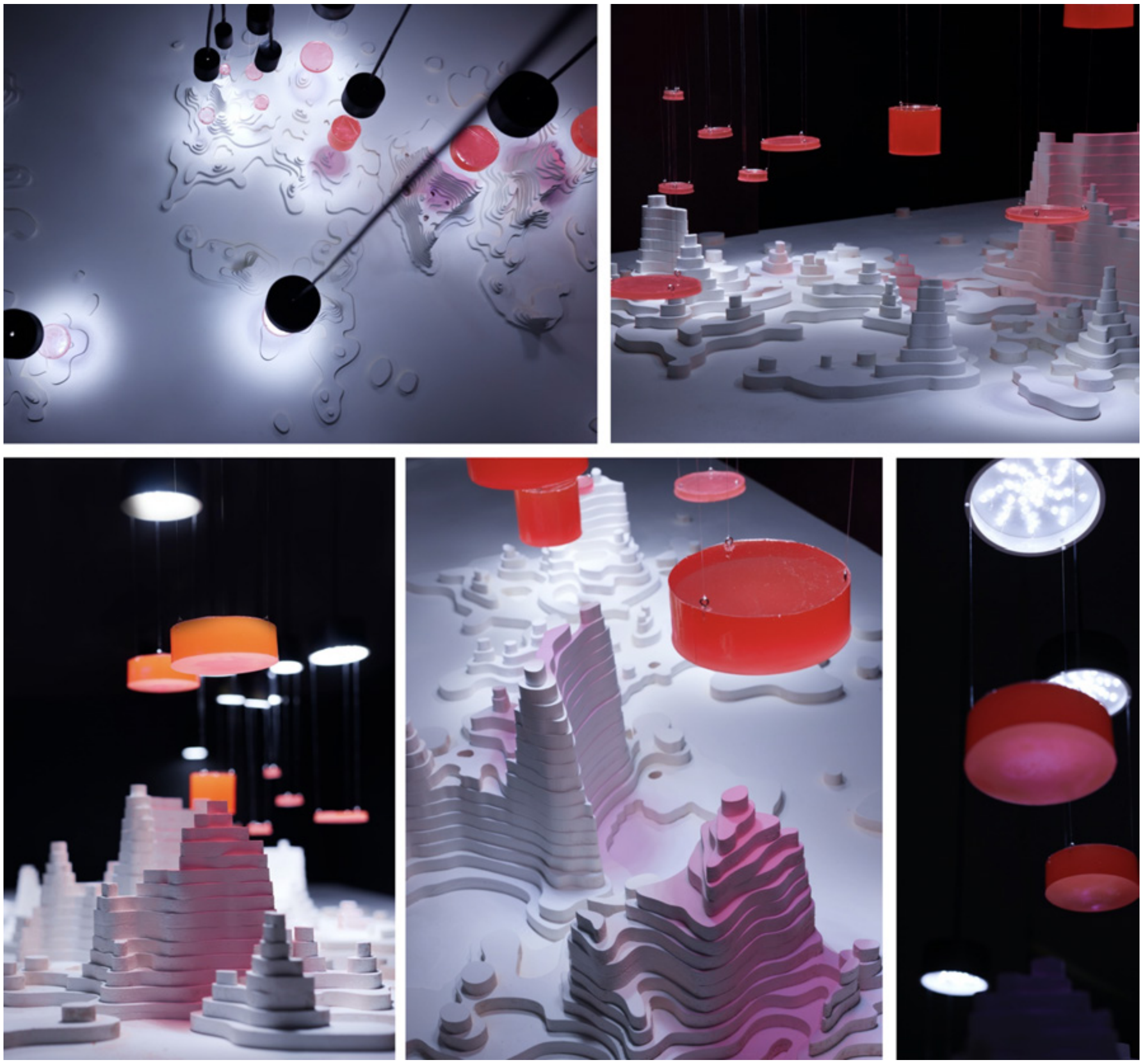

Fig. 5. impressions from the resulting installations

scenario, additional locations and comparison options. As a next step, a formal user study is needed to examine how users understand the underlying data and the effects of the multimodal experience.

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