The Grain No. 12/11 W4 102 1 From the City: Integrating a 3D Model with Audio Data as an Experimental Creative Method

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Figure 1: Object No. 12/11 W4 102 1 in exhibition view.

ABSTRACT

The research project "A Grain Of" presents an experimental, creative method for manipulating hybrid datasets collected by the authors during fieldwork, transforming them into tangible, hybrid interfaces for experiencing and knowing the city. This process is based on integrating a 3D model with audio data. It converts and materializes data points into physical artifacts that can be interacted with through sight, sound, and touch, thereby offering a multisensory experience. This paper details the procedure by examining one of the collected materials — a piece of concrete foam — for the creation of a multi-sensory artifact showcased at the Shenzhen Design Week. The authors describe a methodological approach that oscillates between the tangible and the intangible, culminating in the production of a 3D-printed artifact extended with small electronics. This artifact not only embodies the data visually but also incorporates a built-in loudspeaker driver, allowing it to emit sound and produce vibrational haptics on its surface. This work contributes to the discourse on interdisciplinary practices in art

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and design, proposing a novel method for making data perceptible and engaging in a museum context.

CCS CONCEPTS

• **Social and professional topics** → *Geographic characteristics*; • **Applied computing** → **Media arts**; **Fine arts**; **Sound and music computing**.

KEYWORDS

Speculative Design, Material Sampling, Additive Manufacturing, Auditory-Haptic Interface, Data Materialization

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1 INTRODUCTION

Creatives now have an unprecedented range of media to explore, which allows them to discuss complex issues in original and engaging ways. "A Grain Of" is a research project – based on data from the city of Shenzhen and its hybrid materiality [2, 3] – that uses creative technologies in an interdisciplinary framework to materialize heterogeneous data and make it perceptible to museum visitors in a physical form that includes visual, auditory, and haptic modalities to produce a multi-sensory experience.

This paper closely traces and analyzes the process of moving from one exemplary data point from our database – a piece of foam found on the street – to producing through interdisciplinary and speculative methods a manufactured artifact for the Shenzhen Design Week. In this paper, we propose a method that integrates a 3D scan derived from a found sample with audio data from the found location, thereby materializing abstract, non-spatial, heterogeneous data into a tangible artifact that integrates the collected data with the physicality of an artificial surface topology on an extended 3D print – "extended" because it is equipped with a built-in loudspeaker driver that emits sound from within the artifact and creates vibrational haptics on its surface. The following sections will first discuss the theoretical underpinnings of our method before describing in chronological order the process of creating the data materialization artifact and its presentation and reception at the Shenzhen Design Week, so as to understand the connection between the original data and that which the audience then experiences.

2 DATA MATERIALIZATION AS A METHOD

Technological tools and open-source scientific knowledge are arising interest in science-driven, techno-driven, speculative, and lab-looking contemporary art and design creations based on emerging technologies, and suggest a "potential for new forms of artistic expression and public engagement" [11] – including those relating to new forms of data visualization [12, 13, 20]. Recently, more and more creative projects are based on generated or real-world datasets that allow to produce novel knowledge (see for example [24]). Méndez et. al. conclude that "exploring modeling techniques to generate a wide range of artifacts", including "artistic styles", is one of the five key areas of the VINCI community [15].

The creative research project "A Grain Of" – which had been presented earlier in a preceding, different-looking version, see [14] – following the above interests of new technologies and public engagement, integrates methods from different disciplines to create an artistic way of data representation. It adopts an approach of data materialization that speaks to multiple senses: visual, haptic, and auditory, combined in a series of manufactured artifacts produced for, and exhibited at, the Shenzhen Design Week, Nanshan Museum, from April 27, 2024, to May 19, 2024. What renders the method developed for "A Grain Of" experimental is the way the multiple modalities are integrated and combined within single poetic artifacts that the exhibition audience then engages with.

"A Grain Of" is based on a data set representing the hybridity of the city of Shenzhen [2, 3], and in order to render this dataset perceptible for the audience, it produces a series of artifacts that hold an ambiguous position between artwork and data materialization – an artifact displayed in an exhibition that visitors can understand as a scientific interface for viewing the city's data, while they also experience it as a poetic object that generates – when exhibited as a larger series as shown in figures 11 and 12 – an immersive multi-sensory space. The problem of representing a heterogeneous or spatial dataset with multiple dimensions has been addressed, for example when representing "regional weather patterns" [6], or when integrating multiple databases with one another [26]. Digital manufacturing has made it possible to transfer this process to artistic domains, by enabling the manipulation of data in the three-dimensional space.

In creative fields, data materialization has been used in hybrid and different ways, such as using datasets for generative design or rendering data more accessible, compelling, and engaging. For example, Starret et al. [2018] use data materialization to prioritize design as opposed to data visualization which prioritizes the clear and accurate communication of data. What they emphasize is that, for some disciplines, like design and art, "the object's looks are more important than the direct communication of the data" [22]. In their newer work, Starrett and Reiser suggest this method for data that is "abstract" and without a "spatial layout", so as to translate it "into a meaningful and tangible form" that can "communicate information about a relevant issue of our time" [21].

Yet for "A Grain Of", we suggest a novel form of data representation in a physical space that includes visualization, sonification, and haptic interaction integrated into a single extended artifact manufactured through 3D printing. This method compares to "data physicalization" as formulated by Jansen et al. [2015]. They emphasize the enormous and multi-dimensional potential offered by digital technologies in computer science combined with advanced manufacturing which allows artists and designers to literally "craft [] data sculptures". They choose the word "physicalization" to be consistent with the neologisms such as sonification and haptification [8, 17] without favoring one specific sense. Their main contribution is to define "data physicalization" as a systematic research approach with its agenda and challenges "such as how to encode data physically, how to support interaction, what enabling technologies are needed, and how to evaluate physicalizations" [8].

In this research, we suggest a method similar to Jansen et al.'s [2015] "physicalization". While we do not want to corroborate Starrett et al.'s [2018, 2024] statement about the "priority" of the look on the information, we embrace their design-oriented approach which negotiates data statistics with symbolic, metaphorical, historical and emotional values. We argue that this aspect cannot be data-driven but creativity-pulled and requires the artist and designer's sensitivity to craft fascination and intrigue.

Therefore, as exemplified with "A Grain Of", we present data materialization as a specific way to combine seeing, hearing, and touching through a physical interface in space. The project shows the integration of physical matter with sound and haptic feedback (vibration) that emphasizes the material quality of the presented data, while keeping with an aesthetic agenda that includes poetic-emotional expression. Ultimately, "A Grain Of" creates an interdisciplinary, complex artifact speaking to multiple senses; an artifact that enables visitors of the Shenzhen Design Week to perceive the complexity of the city's materials.

3 REINTERPRETING THE MATERIAL SAMPLE

3.1 Shenzhen

The City of Shenzhen has been planned and developed to become a major hub in South China, and one of the new centers of China's Greater Bay Area. Shenzhen holds an important position as a model city for the imagination of what future novel cities might look like [23]. With its specific geographical features [25] as a subtropical monsoon city on the shore [10], it is intertwined with its natural surroundings in complex ways [7]. The metropolitan area of Shenzhen constitutes the basis for the research project "A Grain Of", which entails rendering perceptible the hybrid material ecology [2, 3] that we speculate to be particular in a city as recently developed as Shenzhen. "A Grain Of" renders perceptible to the visitors of the Shenzhen Design Week the fact that each piece of material in this city contains traces of natural as well as industrial-technological processes, and that each piece of material can tell us metaphorically the story of how it has been shaped over long time spans by different forms of human activity – similar to the grain of sand at the beach of a Caribbean island that can tell us about the oppressed and enslaved who had once stood on it [1].

We first conducted desk research on geographical, economic, and social dynamics of Shenzhen, so as to then select three characteristic sampling locations that signify dense wholesale, recreational, and high-tech areas: Dongmen is a vibrant commercial area in the older part of the city; Wutong Mountain is one of the city's urban forests; and Qianhai is one of the newest and largest construction areas on reclaimed land. At each of these locations, four smaller sites, on which nature, humans, and technology intersect in visible ways, were selected. Data sampling consisted of solid and liquid materials, as well as environmental qualities that include temperature and weather, and on-site media recordings that include audio, video, and photo.

3.2 Sample No. 12/11 W4 102 1

The material sample No. 12/11 W4 102 1, a piece of inorganic foam (concrete foam), was found on the pathway on Wutong Mountain on one of the days during the 8-week sampling period (see figure 2). The weather at the moment of sampling was partly cloudy at 27 degrees Celsius. It was collected by hand and archived and brought to the lab in a plastic envelope. Audio data has been recorded and photographs have been taken of the sampling locations, and a video recording of 10 minutes duration shows the environmental context in which this sample was found. Once transferred to the lab, the sample was 3D-scanned, photographed, and its data was cataloged and included in the systematic field collection database.

Figure 2: The sample "No. 12/11 W4 102 1", inorganic concrete foam, as photographed and archived in the lab.

The aforementioned sample then became one of 25 samples that the research team chose based on their distinct physical and symbolic characteristics to act as models for producing tangible interfaces for rendering perceptible unnoticed and often indistinguishable qualities of the city (see figures 11 and 12). The sample, as much as the 24 others, has undergone a process of sensoasthetic and techno-driven transformation from heterogeneous data to tangible as an experimental method of data materialization.

3.3 Translation to 3D Model

The 3D-scanned sample has been re-meshed with Blender, so as to keep its original surface topology while mending small mistakes on the surface grid, and also to prepare the model's grid for 3D printing later in the process (see figures 3 and 4). So far, a 3D model has been created on the basis of the found piece of concrete foam from a street in one of Shenzhen's urban forests.

4 REINTERPRETING LOCATION SOUND

4.1 Location Audio Recording

On the location where sample No. 12/11 W4 102 1 was found, audio data was recorded weekly over the course of the 8-week fieldwork, using a 360-degree spatial audio microphone as well as a set of surface contact microphones that were fixed to the street surface. The 360-degree microphone recorded the environmental sonic atmosphere at the sampling location, while the surface contact microphones captured the vibratory energy felt in the street at the sampling location. These audio recordings represent the found sample's larger environmental context; they shed light on how contextual and environmental forces informed the found sample. The recordings show traces of human activity, such as hikers, bikers, and rarely also cars passing by on this mountain pathway. The

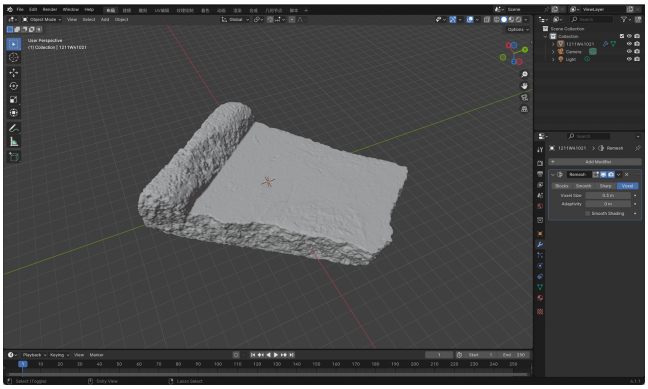

Figure 3: 3D scan of "No. 12/11 W4 102 1".

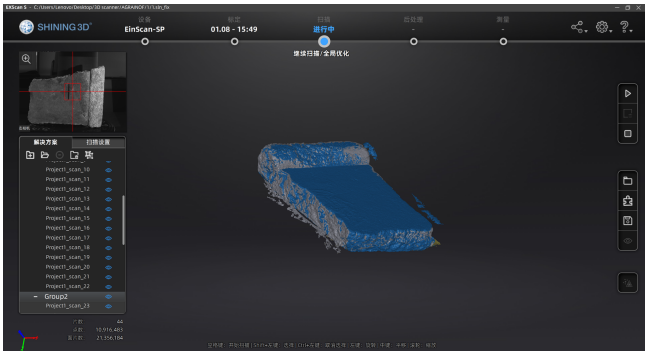

Figure 4: Re-meshing of the 3D file, shown in Blender.

surface contact microphones also exhibit distant low-frequency vibration, most tentatively forces of industrial and technological origin from the city parts that surround the mountain, as well as vibrational energy from human footsteps, which are commonly found below 100 Hz [18]. This data hence represents in part literally the human and technological forces that have shaped the sample in its qualities, for example the vibration of the ground, on which the sample was found and which has most likely left visible traces on the sample shape – given it has been lying there for a long enough period of time. And in part, other influences on the sample, like the human passers-by chatting or airplanes flying by, are more hypothetical and metaphorical in their nature, yet nonetheless are representative of the found sample.

4.2 Sound Pre-Processing

A specialized parametric equalizer, FabFilter, has been used in the lab to filter the recorded audio to a frequency range of 200-1000 Hz – a frequency domain that is an approximation to other ranges that commonly contain signatures of human activity such as speech, motion and footsteps [9]. In addition, in Ableton Live, the audio has been prepared for further processing by creating a short 1-minute compound sound file out of the many from the hour-long audio recordings, a selection process that has been realized under the principle of what bears most human and technological traces (see figure 5). The compound audio file, spectrally, is a sum of the

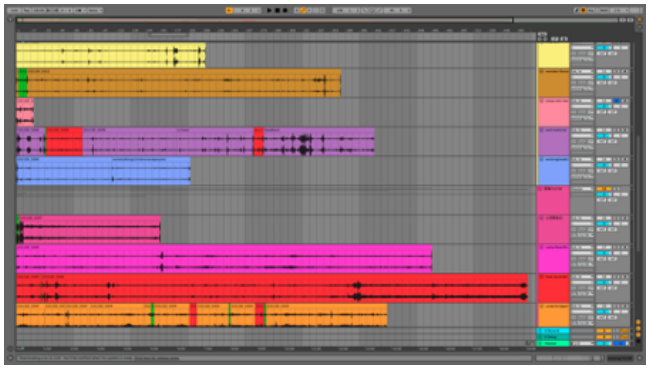

Figure 5: Audio pre-processing in Ableton Live.

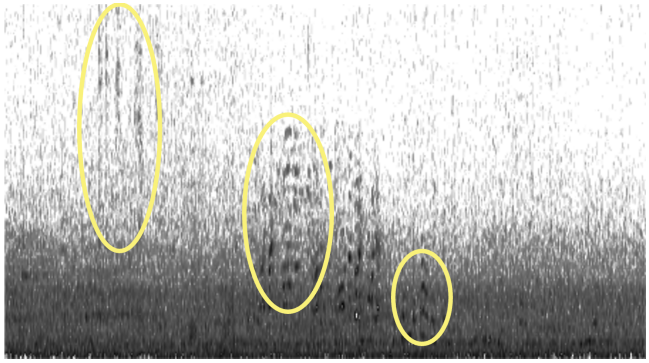

Figure 6: Spectrogram of combined environmental and vibration recording at the sampling location, spectrogram made with Sonic Visualiser, yellow circles indicating the presence of human and technological activity.

low-frequency rumbling from the surface contact microphones as well as the full-range sound spectrum recorded on the 360-degree microphone.

4.3 Spectrogram

With the app "Sonic Visualiser" by the Queen Mary University of London, the pre-processed compound 1-minute audio file was translated, with the use of Fast Fourier Transform (FFT), into a gray-scale spectrogram, representing the audio data in the frequency domain. Time is shown on the x-axis and low to high frequency on the y-axis, while brighter color within each time frame represents higher energy in the respective frequency band (see figure 6). The spectrogram clearly shows a more continuous, quite regular background noisescape, contrasted by temporary, short peaks in sound energy, which might be indicative of human or technological activity at the sampling location (see figure 6). Using a spectrogram as a form of visualizing audio data is not new, but what is idiosyncratic of the method described in this paper is the fact that the spectrogram itself is not made visible directly to the visitors, but instead acts as an intermediary step for integrating audio data with the sample's shape.

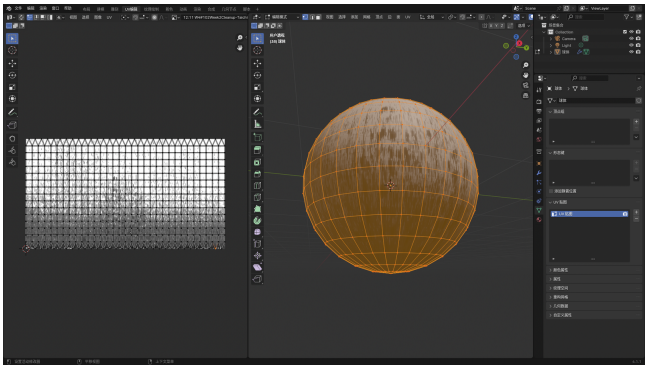

Figure 7: Spectrogram (on the left) on UV Map (on the right in orange) in Blender.

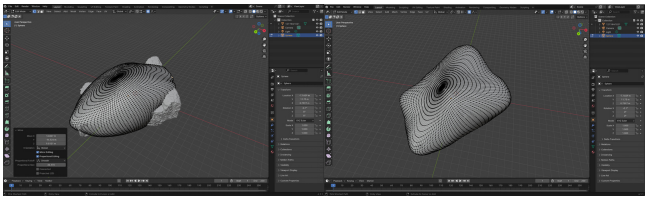

Figure 8: Adjusting the UV Map to match the object.

5 INTEGRATING 3D MODEL WITH AUDIO DATA

The generated gray-scale audio spectrogram, as a two-dimensional pixel-based image, is imported into Blender, where it is applied to the 3D model through UV mapping; a process in Blender that enables users to select the ways in which a 2D image gets wrapped around a 3D object [4]. UV mapping allowed us to use the imported spectrogram image as a 2D texture that wraps around the 3D model in a complex way. First, the spectrogram image was wrapped around a perfect sphere (see figure 7).

Subsequently, the orange sphere was moved onto the 3D model. Then, individual points on the spherical surface were manually dragged out to match the 3D model's shape; hence through manual deformation, the UV map was rendered an approximation of the 3D model's initial shape as exactly as possible (see figure 8).

Once the UV map is quite closely wrapped around the 3D model, the spectrogram image is applied to the UV map as a topological texture map (see figures 8 and 9), so that darker pixel areas in the image, representing louder sound energy, result in three-dimensional peaks on the object's surface. Ultimately, this process changes the surface topology of the initial 3D model: the primary mesh is physically displaced by the audio's amplitude (darkness of spectrogram) and the highest values are adopted as a falloff map and marked by a different shader. In other words, different forces collide in this process of UV mapping: the force of sound physically meets the surface of the 3D object; and the collision thus produces a topology that is idiosyncratic to the data it is based on. The resulting artifact (see figure 1) thus combines various sources of data within it in the sense of a collision of forces – a static freeze of a long process of translation: while it bears the shape of the found piece of inorganic

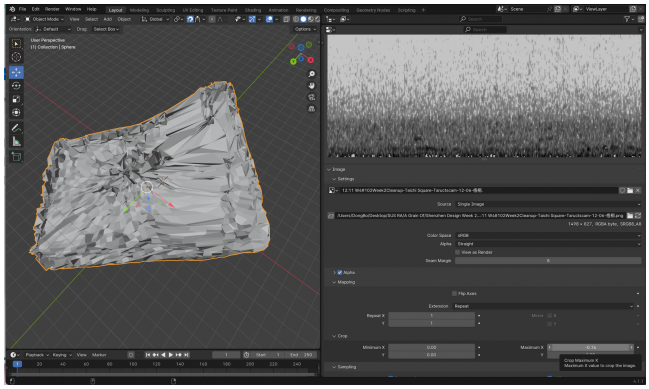

Figure 9: Spectrogram applied as the texture to the object.

foam, its textural surface shows the audio energy recorded at the sampling location, which is a way of visualizing on the 3D object the sound energy resulting from natural, human and technological forces that have most likely shaped the found sample of city material.

6 MANUFACTURING THE ARTIFACT

In order to translate the digital object into a tangible artifact that can be exhibited in a museum, we 3D printed the resulting model with black resin. The manufacturing process and decisions are crucial aspects of the proposed method. The materialization procedure consists of adopting a digital technology (additive manufacturing) and a human-made material with a synthetic and intriguing aesthetic whose even properties make it "impartial" to materialize any kind of data that defines its new qualities.

This process helps us materialize as a physical object an artificial compound created through manifold processes of interpretation and translation, as described afore, and present it as a physical artifact – an interface that visitors can see, touch, and even hear, as we will describe in the following.

To foster interaction between the 3D-printed object and the visitors, the manufactured artifact was then extended by inserting a miniature loudspeaker of 20 mm diameter onto its surface. A small-scale amplifier and sound player based on self-built electronics circuitry (see figure 10) was hidden on the ceiling of the exhibition hall, while the artifact hung on a thin electric wire with the double function of holding the artifact floating in the air, minimally letting it move with small air movements, and feeding the amplified sound to the built-in loudspeaker. This is why we call this artifact an "extended" 3d print – extended with small electronics such as the loudspeaker and cable.

The sound to be played through the artifact was not the location audio from the sampling site, because that sound is already presented to the visitor through the artifact's topological map. Instead, the original collected material sample – the piece of inorganic foam – was activated in the lab and recorded as a source of sound: an oval rotation shaker was used to shake the material sample regularly under controlled lab conditions and let it collide with the shaker's plate, so as to produce a studio recording of its sonic material properties as activated through physical-mechanical motion.

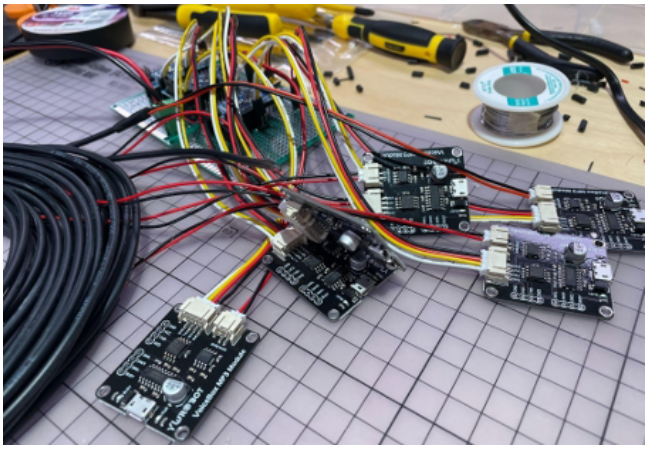

Figure 10: Electronic circuitry for sound extension of the artifact.

The resulting sound is textural in its quality and of high energy – which has the advantage that this sound source is capable of vibrating the manufactured artifact. Through the built-in loudspeaker, the lab sound recording, as a loop, is played and can be heard by the visitor, yet in addition, even though it is a miniature loudspeaker with little power, the loudspeaker will also vibrate the 3D print minimally – just strong enough for the visitors to feel the sound texture recording as a vibration on the artifact when they touch it.

7 PUBLIC DISPLAY OF THE ARTIFACT AND AUDIENCE OBSERVATION

What ultimately results from this method is a physical artifact, hanging from the ceiling in the exhibition gallery, shaped on the basis of the original found sample No. 12/11 W4 102 1, with a topological surface texture representing the location audio energy that has shaped it, emitting the sound of a mechanically activated version of its original material sample (concrete foam shaken in the lab), while softly vibrating driven by that same sound playback (see figures 11 and 12). The audience sees the rough shape of the original sample, hears its textural material properties, and feels the topological surface texture of the environmental audio data from the found location. The shift of senses shifts the priorities: the material properties are less important for us to present to the audience than is the environmental surroundings of the sample, so as to present the samples in their environmental and cultural embeddedness.

At the Shenzhen Design Week, the discussed artifact was on display alongside other 24 hanging extended 3d prints (seen in figures 11 and 12); each of them following the same method yet representing a different data point out of our database. The visitors could look at, hear, and touch this "assemblage" [16] of hanging artifacts, and they were free to move around, and even in between them. We use the term "assemblage" here to point to the fact that the series of hanging artifacts in its entirety represents how the city, too, is an assemblage of single components, as is described as "urban assemblage" by Renaud et al. [2019]. The visitors then engage with this assemblage – and what is particular for our choice

Figure 11: An assemblage of hanging artifacts of "A Grain Of" at the Shenzhen Design Week 2024

Figure 12: Studio photograph of "A Grain Of' installation, showing visitor interacting with the assemblage of hanging, sound-emitting artifacts

of display is that they encounter these hanging, city-based "data materializations" on eye- and ear-level, allowing for a corporeal, sensory experience rather than a museum-like situation where exhibits are normally behind glass vitrines and not meant for direct bodily engagement. In "A Grain Of", this produces a kind of "theatricality" [5] (that has been critically discussed by Michael Fried [1998]), which ultimately helps the extended, 3D-printed hanging artifacts enter into a sensory-driven experience with their audience while at once representing, as data materializations, the city's hybrid and complex materialities.

Observing audience members, we find that many were tempted to touch the hanging artifacts, to rotate, push, and play with them. They walked through them and clearly explored the haptic as well as spatial dimensions. They put their ears close to hear the emitted soundscape. Several visitors spent time with the objects and seemed attracted by their sensual tactility. Yet, many questioned what it is that they are looking at. We believe that the exhibited version doesn't offer a clear, accessible layer of information about the data that we materialized but instead follows Starrett and Reiser [2024] in creating a sensory experience. Our first iterations used straight-forward one-to-one mappings of surface properties to surface properties, and these were discarded as not interesting enough, as our focus was on the integration of heterogeneous data, including audio, instead of solely the material properties. We believe there is potential for future work.

8 CONCLUSION

The manufactured artifact No. 12/11 W4 102 1, a hanging 3D printed object with sound and vibration, produced for the Shenzhen Design Week, presents a novel method of rendering data and found materials – in this case from the city of Shenzhen – perceptible for a public, general audience. Integrating multiple senses into this experience, allows for more complex, multi-dimensional, as well as poetic and corporeal experiences of interaction with the hanging artifact. Integrating sound speakers and sound-driven vibration directly into the artifact further demonstrates the close relationship between materialities and sound – given that the research project "A Grain Of" understands both the city and sound through a material, physical lens. We used the visualization of intangible sound waves and frequencies, transforming them into a tangible form via our manufactured artifact that integrates the physical aspects of sound. "A Grain Of" offers us for one, as discussed elsewhere, a path to theorizing the "grain" of the city through an interdisciplinary, speculative framework [14] – yet for two, it in itself presents a novel method for a multi-modal, artistic reinterpretation of city data.

Ultimately, the method presented in this paper offers novel avenues for creatives to materialize data as a form of multi-sensory, public exhibition-oriented data visualization based on state-of-the-art technological trends. Technology, then, becomes a crucial part of the proposed method – technology in itself is rendered an interface through which we gain a novel, additional understanding of a piece of material from the city, and more specifically, of the site it was found at. "A Grain Of", thus enables us to look at, touch, and "listen to a site through technology" [19], and to gain a novel understanding of it, which lies beyond the artistic-poetic engagement that "A Grain Of" allows its visitors. It is part of the contribution of this work that the senses and modalities get swapped or even confound, so that environmental audio data is presented as surface property, while the original material's surface property is emitted as auditory information from a miniature loudspeaker within an artifact, which in turn is roughly shaped according to the source sample's outlines. We created a unique, even destabilizing, connection with the source to offer fresh perspectives on the relationship between the human and their urban environment, as well as a deeper understanding of the latter. This work went beyond just providing information and instead proposes an empathic connection with urban life – even in its seeming ordinary aspects. Nonetheless, we are aware that in order to enhance the audience's awareness and connection to urban ecology through fragmented materialities, we may need to develop a more sympathetic orientation map.

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