Experiencing the Vortex: An Immersive Exploration of a Natural Phenomenon

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Water is now sharp and now strong, now acid and now bitter, now sweet and now thick or thin, now it is seen bringing damage or pestilence and then health or, again, poison. So one might say that it changes into as many natures as are the different places through which it passes. And as mirror changes with the colour of its objects so this changes with the nature of the place where it passes: health-giving, harmful, laxative, astringent, sulphurous, salt, sanguine, depressed, raging, angry, red, yellow, green, black, blue, oily, thick, thin.[1]

—Leonardo Da Vinci, *Notebooks*

PREMISE

This interdisciplinary design and research project, resulting from a two-year collaboration between a group led by an architect and an engineer/physicist, two PhD students, two Masters' stu- dents, and one undergraduate student, presents a break away from designated disciplinary roles and embraces the premise of working on a truly inter and cross-disciplinary setting. In doing so, its primary motivation is to question the assigned roles one may take in a project, and work in common and through a lateral structure. Invested in making architecture an equal counterpart to science, our team worked with a research group focusing on Fluid Structure Interaction (FSI). While FSI problems have appli- cations in many scales of daily life, from brain aneurysms to wind turbines, and the original motivation for the architecture team has been to work hand in hand with the scientists on issues of energy harvesting and climate justice, it became apparent that meaningful long-term collaboration needed to start at a founda- tional level. In other words, the necessity of building a common language, creating common goals, and developing common methods of work became the foundational blocks for this work, which has so far only developed work that is focusing on the fundamental science problem and understand- ing what architecture, as a discipline with highly specialized methods of representation and thinking can offer to enrich it.

Architecture's most valuable representational tool, the orthographic projection, is one that is both extraordinarily simple and exceptionally complex.[2] In complex geometric designs, taking numerous sections through a formed object has proven to be a continually compelling design technique.[3] Further, in analyzing time-based processes, producing plans and sections of select moments allows an expansion and furthering of knowledge that would be otherwise inaccessible. This project relies on using orthographic architectural projections to analyze and interpret data from experiments done on a phenomenon. FSI is widely observed in the world that surrounds us and manifests itself in both extremely large (offshore structures) and infinitely small (laboratory size experiments) settings.[4] While in this work we focus on vortices observed in a fundamental problem in FSI, called Vortex-Induced Vibrations (VIV), vortices are observed in several natural phenomena: They are observed in the wake of a swimming fish, a rotating wind turbine blade, and within a cerebral brain aneurysm. With such far-reaching applications, the visualization method we discuss here can be applicable to several other systems and help highlight and illuminate otherwise invisible patterns of fluid movements in those systems. Developing a series of digital and spatial visualization processes, which aims to break down and clarify these patterns, provides ways for architecture, as well as other disciplines to spatialize and visualize data (which in this case is scientific) by revealing its invisible structures and cohering its patterns and meanings to a larger non-scientific audience.

METHODS AND PROCESSES

In VIV, a cylinder placed in fluid flow oscillates due to the shedding of vortices in its wake. In the lab, these wakes are tracked using hydrogen bubble visualizations and are quantified using Particle Image Velocimetry (PIV). With the use of Matlab, the positions of the bubbles were recorded and translated into excel files containing coordinates. The files were then fed through the Rhino plug-in Grasshopper and placed along the Z-axis interpreted as time. Together, our team studied this phenomenon by exploring the formation of vortices along the axes of time and space, extrapolating and intuiting patterns, and repetitions. By employing orthographic projections and translating data (primarily in the form of cartesian coordinates of the bubbles) into two-dimensional groupings, we were able to

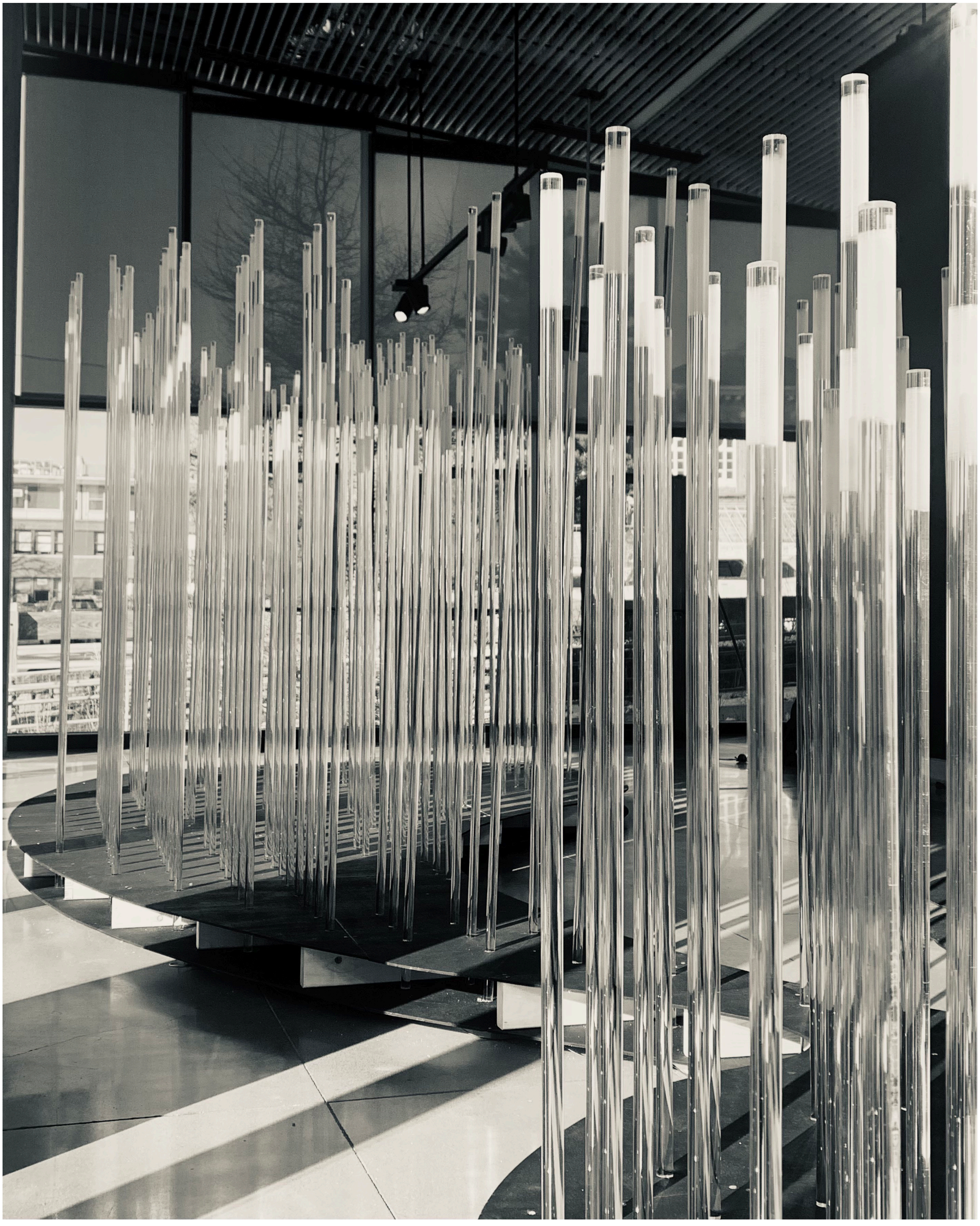

Figure 1. Partial view of the Final Exhibition, showing the etched acrylic rods in the gallery.

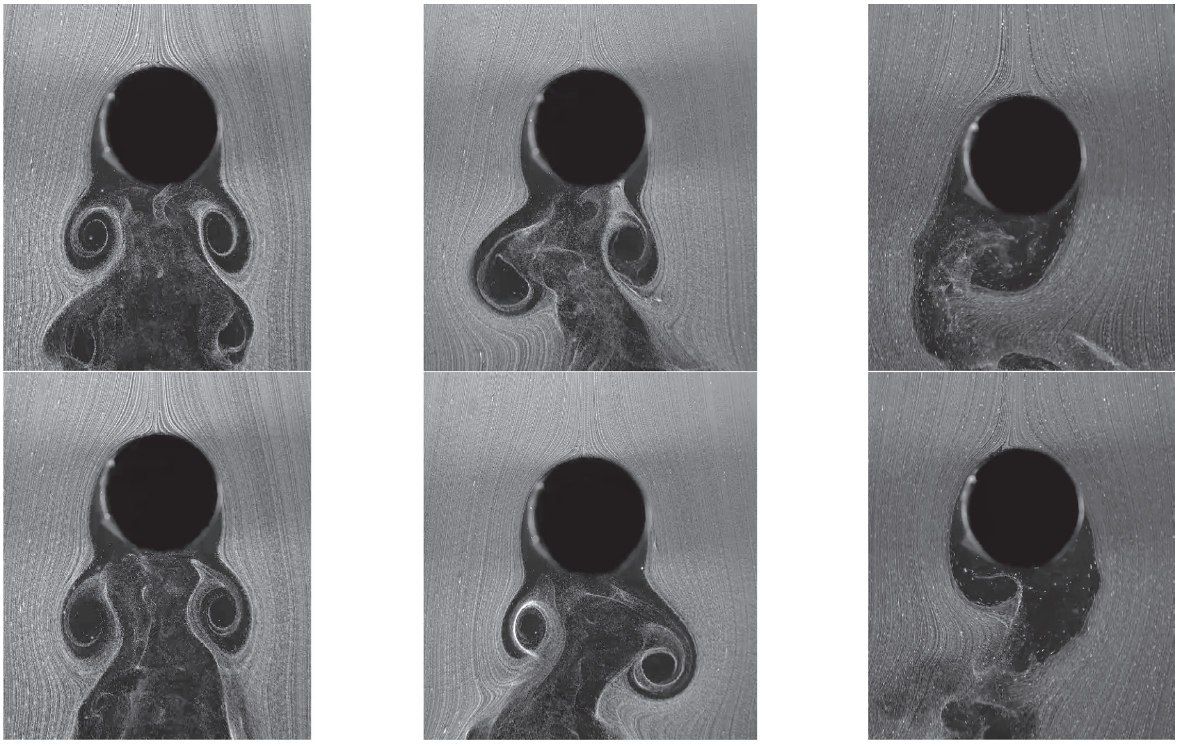

Figure 2. Photographic captures of Vortex-induced-Vibration experiments, where each column shows two snapshots of the wake at the same flow velocity. Symmetric, Alternating Symmetric, and Asymmetric Cases are observed as the flow velocity is increased from left to right.[5]

overlay, separate, and spatialize our interpretations of the data into different forms. Aware of our limitations for processing considerable number of data, we set forth to "extrapolate, generalize, infer or induct" the data sets to make sense of them.[6] Our goal was to make visible the otherwise invisible patterns of movement, to understand the large spatial implications for this phenomenon. We worked to create drawings and 3D constructs which would be informative for scientific investigations of this phenomenon[7] and simultaneoulsy engaging and interpretable to the non-scientist, helping the public gain a better understanding of this fluid mechanics phenomenon and the process of analysis itself.

To share and display our work and spark dialogues beyond our research groups, we made an immersive 3D installation in the Olver Design Gallery, Amherst, in early 2022. The breadth of our design creations consisted of 2D and 3D drawing sets, 3D printed experimental models, a series of layered and superimposed illuminated models, and a large, human scale, installation that the viewers could walk through. The 3D models and 2D drawings were created from data extrapolated from the hydrogen bubble visualizations and PIV to produce layers of lines or closed curves, stacked at vertical intervals to introduce time, and connected to create solid, spatial artifacts of various opacities and transparencies. The layered illuminated models highlighted moments of the moving wakes, by etching these planimetric forms in sheets of plexiglass, and lighted at measured intervals to again show the passage of time. Our walk-through vortex field, like our artifacts and drawings, aims at transforming 2-dimensional datasets into an immersive and affective experience, often used by architecture of larger scales.[8] To do so, we set forth to create a feeling of being surrounded within a large body of turbulent water, represented by transparent acrylic rods, presenting movements of the vortices over the duration of a VIV cycle. The rods, etched at specific intervals, track the movement of the vortices across time and space. As visitors walked through the structure, they experienced being inside a large body of moving water, and seeing vortices further emphasized by LED lights that illuminate the rods from a concealed base, forming and dissipating. In culminating this phase of our research, our aim was to translate and present a scientific phenomenon so that each person can experience and understand it. This multi-sensory rendition of the formation and dissipation of a vortex is evidence that building a common language and platform between disciplines is possible, but also comes with a true commitment to the idea of the common.

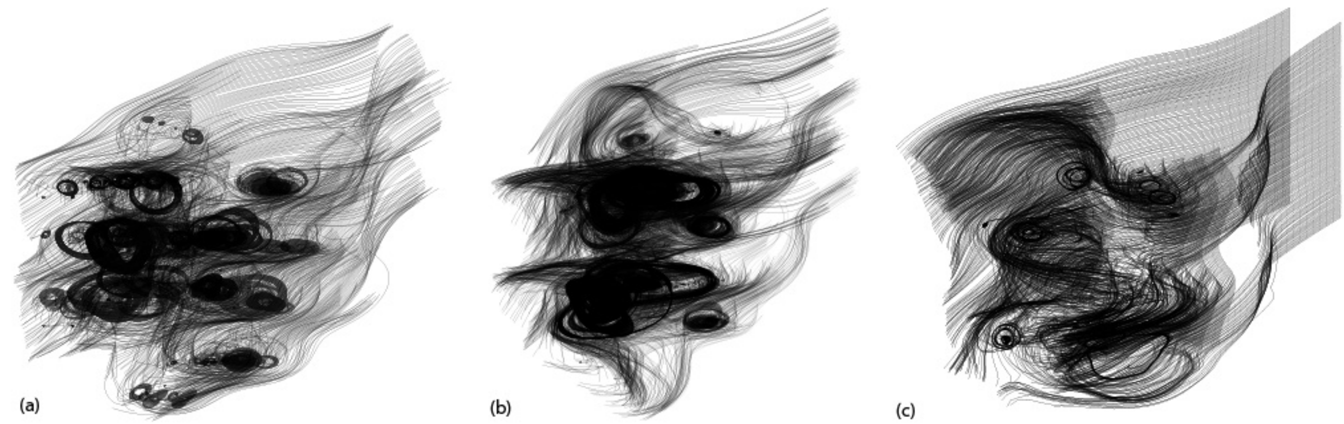

Figure 4. Axonometric Line Drawings of Streamline Vortex Models, Symmetric, Alternating Symmetric, and Asymmetric Cases (left to right).

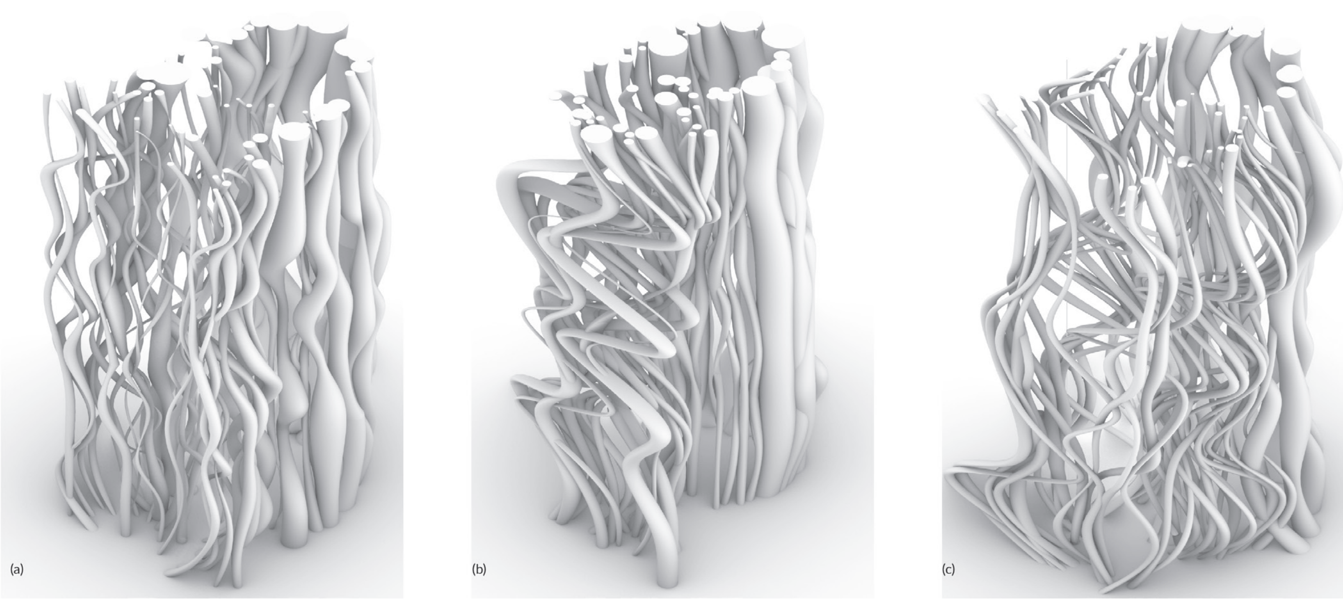

Figure 5. Models tracking density of vortex bubbles' movements using the z-axis as time. Symmetric, Alternating Symmetric, Asymmetric Cases (left to right).

Figure 6. Photographs of 3D printed Noodle Models. Scale allows for investigation and exploration.

Figure 7. Boxes depicting intervals of time in all three VIV cases. Acrylic and LED lighting helps to illuminate laser etching.

Figure 6. Vortex Perimeter Models of Alternating Symmetric Case (left) and Symmetric Case (right).

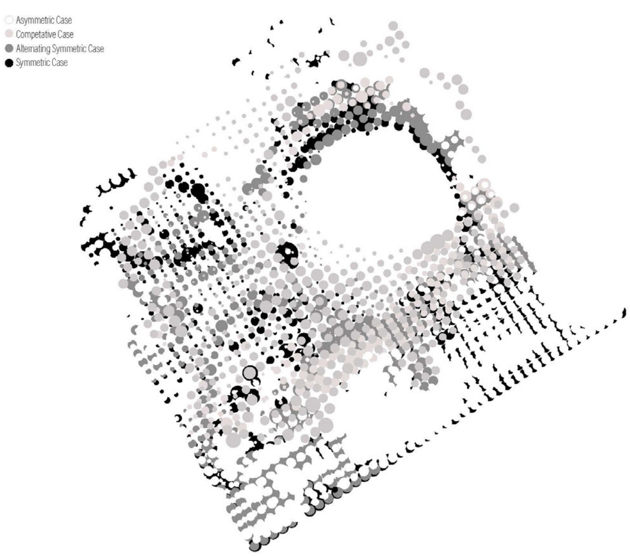

Figure 7. Layered Bubble Diagram, comparing the four commonly studied Fluid Dynamcs VIV cases. .

ENDNOTES

1. da Vinci, Leonardo, Notebooks, New ed. / Oxford ; New York : Oxford University Press / (Oxford world's classics (Oxford University Press), 2008, p.21-22.
2. Evans, Robin. Translations from Drawing to Building and Other Essays. Cambridge, MA: The MIT Press. 1997.
3. Iwamoto, Lisa. Digital Fabrications: Architectural and Material Techniques. New York: Princeton Architectural Press, 2009, p 10.
4. Modarres-Sadeghi, Yahya. Introduction to Fluid-Structure Interactions. Zurich: Springer Nature. 2022.
5. Gurian Tyler, Currier Todd, Modarres-Sadeghi, Yahya. Flow Force Measurements and the Wake Transition in Purely Inline Vortex-Induced Vibration of a Circular Cylinder. Physical Review Fluids. 2019, 4, 034701.
6. Carpo, Mario. The Second Digital Turn: Design Beyond Intelligence. Cambridge, MA: The MIT Press, 2017, p. 35.
7. Boersma, Pieter, DeWitt, Erica, Thurber Fey, Benner, Brigitte, Riahi, Pari , Modarres-Sadeghi, Yahya "On symmetric and Alternating-Symmetric Patterns in the Wake of a Cylinder Undergoing Vortex-Induced Vibrations in the Inline or Close to the Inline Direction", Journal of Fluids and Structures, 2022, Submitted.
8. Picon, Antoine. Digital Culture in Architecture: An Introduction for the Design Professions. Basel: Birkhauser GmbH, 2010, 201.