Research and Teaching Statements – Yue Zhang

My goal is to combine mathematical modeling, physics-based simulation, and advanced Computer Graphics techniques to provide computational tools to facilitate the data-to-knowledge process and enhance the education and training of our future generations.
Research: My early research focused on mathematical modeling of physical phenomena in solid mechanics and fluid dynamics, which resulted in six journal publications and three conference papers in mathematical modeling venues as well as 15 single-author technical reports at Michelin Americas Research Company (MARC). My research at MARC led to significant savings in tire fabrication and resulted in two invention records and one US patent. Since joining Oregon State University, I have expanded my research into scientific and information visualization, sound synthesis, and mathematical visualization. My research output at OSU includes 12 top venue publications (IEEE VIS and IEEE Transactions on Visualization and Computer Graphics) and computer graphics (ACM SIGGRAPH Asia) along with 27 other peer-reviewed conference and journal papers as well as six book chapters. My research has led to one NSF CRII grant and two subsequent REUs ($206,977) and three Oregon Department of Transportation (ODOT) grants for a total of $843,077, all single-PI. In addition, I have received a seed grant ($10k) from the Knight Cancer Institute at OHSU as a co-PI and an OSU Transdisciplinary seed research grant ($25K) as lead PI. Next, I will describe my main research directions since joining OSU.

<u>Network visualization</u>: Network data are prevalent, such as social networks, biological networks, and trade networks. Traditionally this data is modelled by binary graphs which become inadequate and cumbersome to describe polyadic relationships, e.g., a research paper with its authors. We address this by using hypergraphs, in which each polyadic relation is modelled as a hyperedge involving its entities. Hypergraph visualization research is relatively new and is limited to using variants of graph visualizations that produce cluttered layouts beyond tens of relationships. To enable readability for large data, I proposed the use of polygons to represent the hyperedges to leverage on the intuitive readability. This metaphor was published in (Qu et al. 2017). I then introduced energy definitions that were significantly different from commonly used force-directed methods and enabled an automatic layout algorithm on 2D plane (Qu et al. 2022). Subsequently, I led my team to produce a multi-scale framework (Oliver et al. 2024) and a topology-preserving decomposition (Oliver et al. 2025). My research vision and effort has established OSU as one of the leading institutes in network and hypergraph visualization. Our system is the first to handle thousands of data entities. My next step is to bring our tools to domain scientists and data stakeholders while developing interpretable visualizations to enrich hypergraph theories.

<u>Tensor field visualization</u>: Tensor fields are crucial and at the center of interest in applications that range from vehicle maneuver, building and bridge safety, 3D printing, material design, and earthquake modeling. However, common practice uses one scalar to represent the entire tensor and causes loss of information. This loss is exacerbated when going from 2D to 3D. I started my research on this topic to address these issues. Motivated by my tire research experience, I produced solid mechanics simulations to support the definition of a topological feature that captures shear. Prior work only focused

on extension and compression. This work further completed the definition of tensor field topology (Palacios et al. 2016). From there, we provided a robust method to extract tensor field topology (Roy et al. 2019), studied the interaction between different topological features (Qu et al. 2021), and introduced a graph network to model the global topological structures (Hung et al. 2024). When data practitioners use heat maps to show just magnitudes of a scalar, the type of motion is lost. Our work shows directions and types of motion. Tensors take on symmetric and asymmetric forms, e.g., Cauchy vs Piola stresses for solid mechanics. Specifically for asymmetric forms, we provided a multi-scale analysis in the 2D case (Khan et al. 2020) to handle large fluid dynamics data and defined the notion of topological features in the 3D case for both solids and fluids (Hung et al. 2022). For our groundbreaking research in the latter case, the paper received Best Paper Award from IEEE VIS 2021. This was the first Best Paper Award to tensor field visualization in nearly 30 years. Our research effort has firmly established OSU as the leading institute in tensor field visualization, and the datasets that I produced are being sought after by other visualization researchers in the community. My next step is to investigate ensemble simulations and apply our work to detect material damage while developing theory for higher order tensors.

<u>Sound modeling</u>: Acoustics data is known for its complexity. My goal is to develop automatic sound generation with realism for Graphics applications. My initial research in this area focused on extracting desired sound textures, i.e., salient from background, and retargeting them for videos and VR scenes. This initial research led to a SIGGRAPH Asia publication (Zheng et al. 2020). In addition, I have produced a rumble strip noise modeling report, FHWA-OR-RD-22-14, that is published by Federal Highway Administration and archived at National Transportation Library. This is the first report published by this venue on numerical modeling for tire and road interactions. I am working on a manuscript that models sound propagation using fluid dynamics that enables modeling of the air medium and ensures conversation of energy. I have submitted a manuscript on sound source counting using neural networks based on a novel visualization that I introduced. My next step is to combine physics modeling and data science for sound and then combine audio and visual for Graphics research.

<u>Math visualization:</u> Graphics techniques enhance teaching in virtual math and data worlds. Motivated by my own research problems and the need to teach my students to describe these worlds using our own eyes and ears as sensors, I produced two IEEE VIS papers: Optics-based Orbifold Visualization (Zheng et al. 2024) and Visualization of Branched Covering Space (Roy et al. 2018) for non-Euclidean spaces. My goal is to pioneer math visualizations for non-math majors to discover new knowledge that are in customized environments for them and that may not have been found by researchers who are in traditional math areas.

Teaching: My teaching philosophy is two-fold: (1) engaging the students by adapting my teaching style and assignments to their skills and interests, and (2) challenging the students with the state-of-the-art research results to broaden their views. My goal is to help our students gain confidence and skills for their next career stage.

I introduced CS419/519 (Numerical Modeling and Simulation). I re-designed CS458/558 (Information Visualization), CS499/551 (Computer Graphics), CS452/552 (Computer Animation) and ST/CS499/559 (Visual Analytics and Scientific Technology (VAST)).

For Information Visualization, I teach design principles that enable readability and clarity, information encoding with glyphs, hierarchical visualizations, network visualization for graphs and hypergraphs, and dashboard views with interactivity. For Computer Graphics, I teach light reflection, refraction and diffraction using geometric ray tracing models and physics-based energy formulations. For Computer Animation, in addition to Inverse-Kinematics (IK), I teach Finite Difference, Finite Element and Finite Volume methods for solving energy formulations used in solid deformation and fluid flow. This combination enables the students to become familiar with Physics-driven animations in modern computer games and entertainment products and to allow them to develop special effects themselves. For VAST, I teach design principles for interactive visual analytics systems for multivariate data analysis. I introduce non-Euclidean spaces and demonstrate examples on user-studies that are backed by task-driven questions. The courses have gained popularity among our undergraduate and graduate students as demonstrated by the steadily increasing enrollment.

Advising: I have graduated one Ph.D. student and eight M.S. students, who have found jobs at places such as Intel, Nvidia, Garmin, ESRI, AMD, and Amazon. My Ph.D. student, Shih-Hsuan Hung, is now an Assistant Professor at National Tsinghua University in Taiwan. For each of them, I developed projects to match their inspiration and passion. One of my M.S. students had a strong interest in ocean data. With my guidance and support, he received an NSF/NRT award working on a transdisciplinary topic with researchers from Otolith Chemistry and Seascape Ecology. This work resulted in a publication (Blasidell et al. 2021) and has garnered over 2,400 views. We developed a stress-scape visualization for Gulf of Alaska. I have three OSU invention records, two of them involving undergraduate students. One of the records was to create a checker game for vision-impaired individuals. A 14-year-old high school student with complete loss of sight tested our design that had sound-activated buttons as the checkers and played a checker game for the first time in his life.

I worked with the OSU sponsored Saturday Academy program from 2016 until the contract ended in 2023 by OSU. A female student who received Certificates of Merits from the committee that I was chairing for the Society of Women Engineers (SWE) joined the internship in our group subsequently. She mentioned she would stay in science and engineering fields in her college years. Another female student who also interned in our group is now finishing her Ph.D. at Cornell University. Recently, one female student joined University of Michigan to pursue her dream in Engineering along with focused courses from Computer Science.

Services: My services to OSU include serving on the Graduate Student Admission Committee (2019- 2020) and the Undergraduate Curriculum Committee (2020-present). I have served as a GCR on thirty-six graduate student committees. Externally, I have served on the Papers Committee for IEEE Visualization Conference (2022-2024) and PacificVis (2021-2025). I am Co-Paper Chair for IEEE TopoInVis 2024 and 2025. I was also the co-organizer for the Workshop on Novel Approaches to Visualizing Big Data Sets as part of the International Conference on Biological and Biomedical Ontology (ICBO) in 2016 and 2018. I have reviewed for SIGGRAPH, SIGGRAPH ASIA, IEEE Visualization, EuroGraphics, and EuroVis as well as the top journals in our fields: IEEE Transactions on Visualization and Computer Graphics, ACM Transactions on Graphics, and Computer Graphics Forum. I have served multiple times on NSF and National Science and Research Council Canada (NSERC) panels.