Personal Statement

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I am Yuchen Su, a passionate girl captivated by the interplay of computational science, mathematics, and physics. My academic journey, rooted in the rigorous **Tsien Excellence in Engineering Program (TEEP)**, has provided me with a solid foundation in **mathematical, physical and computational principles**. Through courses such as Mathematical Analysis, Advanced Algebra, and Computational Science and Engineering, I have honed my ability to apply complex mathematical tools. I have also excelled in advanced engineering subjects like Solid Mechanics and Fluid Mechanics. Additionally, with TEEP's emphasis on student research, I began engaging in research projects as early as my freshman year.

My current research, *Computational Design and Simulation of an Origami-Inspired Flier*, aims to optimize flier structures inspired by origami materials. In this project, I have reviewed numerous papers on flier simulations and fluid-solid interactions, and I largely proposed the current topic myself, with guidance from Professor Tao Du. To date, I have successfully developed a **rigid-body simulation** of an origami-inspired flier using the **Extended Position-Based Dynamics (XPBD) method**, validating its feasibility through **airfoil theory**. To improve precision and realism, I implemented a fluid model based on **stable fluid** using **Taichi**. I extended the primary model to 3D and added solid-fluid interactions, making it capable of simulating phenomena such as the Kármán Vortex Street. The simulation results can be visualized on my GitHub, which is done using **Polyscope**.Currently, I am coupling the rigid-body flier model with the fluid simulation framework to achieve a comprehensive simulation of the aerodynamics of the origami-inspired flier. I am also conducting real experiments on the fluid dynamics of a handmade butterfly flapping its wings.

In the future, I aim to enhance fluid simulation while maintaining both accuracy and speed by improving algorithms **physically and mathematically**, or by integrating reinforcement learning to build a robust flow field database. These advancements are expected to enable efficient and realistic simulations of complex flow fields surrounding origami-based fliers. By analyzing the behavior of fliers under various folding patterns and external forces, this research aims to provide the **optimal design** of origami fliers. Additionally, **reverse design** is expected to be realized, where, given a desired flight mode specified by the designer, the system would be able to predict the corresponding folding configurations and actuation strategies.

In parallel with this research, I contributed to the *Adaptive Visual Perception and Hardware-Software Acceleration for Micro Unmanned Aerial Vehicles* project. I handled most of the project independently, where I designed a **CUDA-accelerated Schur Complement Solver** within the Ceres Solver framework. This implementation leveraged **GPU parallelization and low-precision quantization** to enhance computational throughput while ensuring numerical stability. Building on this, I developed a precision-adaptive visual processing algorithm in C++, enabling dynamic adjustments to computational fidelity and effectively balancing visual accuracy and efficiency in real-time scenarios under varying environmental conditions. This was achieved by evaluating the data flow associated with the surrounding environment and incorporating **physics intuition**. I implemented **FP16 quantization** with minimal loss of accuracy. Furthermore, I conducted a comprehensive performance analysis of the Cholesky Solver and Schur Complement across various matrix sizes, computation precisions, and CPU/GPU setups, further deepening my expertise in numerical optimization and high-performance computing.

Furthermore, I gained exposure to large-scale particle simulations through the *Vacuum Microgravity Multi-scale Particle Flow* project, where I utilized tools like **LIGGGHTS** and **ParaView** for **particle flow** simulation, analysis, and visualization. This experience provided valuable insights into the scalability challenges of complex simulations, reinforcing my ability to tackle computationally intensive problems.

The objectives of this project, Multiscale Progressive Simulation, strongly resonate with my background in **physics-based modeling, GPU-accelerated computation, and mechanics**. My experience in developing precision-adaptive and GPU-parallelized algorithms uniquely equips me to address the trade-offs between computational speed and fidelity. Additionally, my expertise in **mechanics and mathematics** aids in understanding elastodynamics from a physics perspective.

The Progressive Dynamics method, with its focus on refinement and inter-level consistency, aligns with my expertise in efficient and accurate modeling of complex interactions. Similarly, the robustness of Vertex Block Descent in handling dynamic systems through vertex-level parallelism inspires me to explore its integration into multiscale simulations. These methodologies present exciting opportunities to tackle challenges similar to those I have addressed in my previous research.

With a strong foundation in mathematics, hands-on experience in computational implementation, and a genuine passion for innovation, I am eager to contribute to this project. This opportunity represents a pivotal step toward advancing computational science in physics-based simulation, particularly in its transformative applications in computer graphics. I am excited to explore how cutting-edge techniques can bridge the gap between fidelity and efficiency, enabling dynamic and visually accurate simulations that redefine interactive graphics and related fields.