Virtual parachute offers better design, deployment and accident diagnoses

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Stony Brook University researchers are developing a computational platform to mimic the complex "Inflation Dynamics" behavior a parachute's canopy undergoes as it travels through an airflow to help improve designs.

Flexible fabrics, such as the ones used in parachutes, are notoriously more challenging to model and study than their rigid counterparts. But now, researchers at Stony Brook University in New York are working to develop a platform to provide the U.S. Army—and the sports community—with a better and more reliable computational test bed for parachute accident diagnoses, design, and deployment planning.

The platform under development is based on the "front tracking method," which involves numerical algorithms, as well as the "mass-spring model" to describe the motion of the parachute's fabric surface.

During the American Physical Society's April Meeting, being held April 11-14 in Baltimore, Maryland, the researchers will describe their work and how it will help complement the traditional empirical understanding of the dynamic behavior of parachutes and optimize future parachute design and flight test processes.

What sorts of behaviors is the group exploring? For starters, they are looking at the effect of the parachute phenomenon known as "breathing" on the drag force and tension of the riser—the part of the chute that connects the parachute pack to the canopy above. They are asking how sudden turbulent flows (vortex) affect parachutes, the interaction of multiple parachutes, ways deployment angle can affect inflation and descending, and how parachute porosity can affect the stability of flow.

"We're also using parachutists for more interesting simulations," said Xiaolin Li, professor of Applied Mathematics and Statistics at Stony Brook University.

Why use the front tracking method? It's often used to handle the interaction between moving interfaces and fluids, such as Rayleigh-Taylor instability, Richtmyer-Meshkov instability, and phase transition problems, etc. "Such interfaces are usually closed manifold surfaces serving as the internal boundary for a different material," Li said. "But the surfaces don't have their own physics."

The spring-mass model "is used in computer graphics to enhance visually realistic motion," he added.

The group's work in this area is a new approach to simulating the parachute canopy. Most other researchers' work has "applied the finite element method, which is directly linked to continuum mechanics," Li explained. "But the computation involved requires the generation of unstructured mesh and the finite element, which is computationally more expensive in terms of memory and CPU time."

For example, a group led by two researchers named Tutt and Taylor simulated parachute fluid-structure interaction problems using the Arbitrary Eulter-Lagrange (ALE) finite element techniques within LS-DYNA software, which offers the ability to simulate nonlinear materials with large deformations.

Instead, Li and colleagues applied Delingette-based spring mass because this model "satisfies all the material properties—Young's Modulus and

Poisson Ratio—in the continuum model."

This type of model "can be immersed in the structured grid to simulate flexible inflatable structures such as airbags and parachute canopies," Li said. "It will reduce the costs of both structural modeling time and computational time involved in analyzing fluid-structure interactions—it's one order of magnitude faster than the finite element method."

On the theoretical side, the group's work adds a numerical proof of convergence via the classical mesh refinement process to the Delinguette-like mass-spring model toward a theoretically corresponding continuum-membrane model.

What's next? The group plans to add realistic parachutists to their model—in the forms of personnel and cargo—by using geometry. "This needs to be combined with CAD files," Li noted. One of his Ph.D. students has already begun working on it.

Code is another area for future improvements and enhancements. "We're in the process of 'parallelizing' our code for more refined simulation and the simulation of complex assembly," Li points out. "We can study complex systems entirely through numerical simulation by using a supercomputer. In the near future, we hope to set up the computational platform and compare it with the numerical results from the field operation."

Validation is also a key part of numerical study, so the group will continue to work closely with Army Scientist Richard Charles to do so.

Moving forward, the group's methodology is to "first establish the platform, then continue to improve it," said Li. "We're continuing our study of new numerical algorithms and computer technology, as well as physics—which enables us to make the fluid-structure coupling more accurate, the texture of the fabric more realistic, and the parachutists controllable."

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