In situ Viz Unlocks Unsteady Dynamics at Extreme Scale

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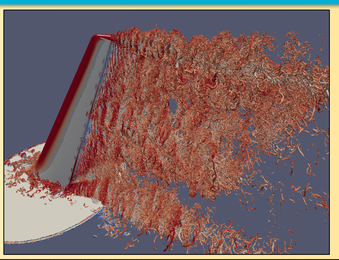
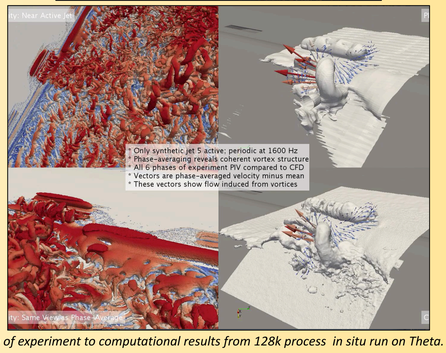
Unsteady synthetic jet flow control simulations create data streams so large that dynamics are only practical to access with in situ visualization.

In Situ Analysis and Visualization

In situ analysis and visualization allows comparison of instantaneous vortical structures with phase averaged quantities from experiment and simulation.

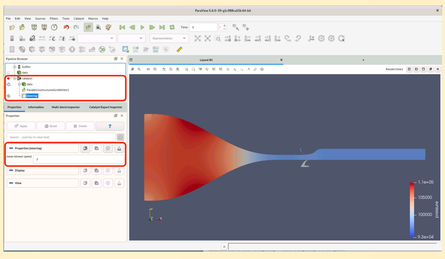
- In order to get insight promptly, in situ analysis and visualization can be used to reduce the cycle time in examining different designs for favorable performance.
- Animations of images help engineers understand how jets improve flow and scale that improvement to flight/turbine conditions.
- Catalyst compiled into PHASTA, provides isosurfaces at every time step at 3% overhead to simulation – far less than writing full data.





Comparison of experiment to computational results from 128k process in situ run on Theta.

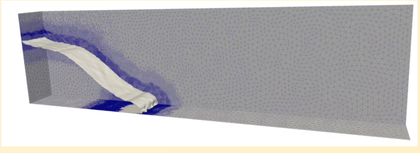
Computational Steering



***Top Red Box**: This is ParaView's Live pipeline browser with Catalyst Live end-points to both the current simulation data and the simulation parameters exposed for steering. **Bottom Red Box**: The graphical user interface for manipulating the exposed steering parameters such as mean and amplitude of the flow control. Visualization pipeline can be reconfigured live during ongoing simulation whose problem definiition parameters are being changed in the same GUI.*

Our computational steering infrastructure evolves the traditional in situ analysis and visualization model to accommodate a set of computational steering use cases. It leverages in situ analysis and visualization capabilities to decrease time to solution, reduce the dependency on storage capacity and improve the overall quality of scientific and engineering analysis.

- It enhances analysis by inserting an engineer (human) in the loop using the in situ computational monitoring and steering workflow supported through SENSEI, Catalyst and Catalyst Live software.
- Communication of parameter changes back to simulation (computational steering) allows for interactive exploration of a parameter space .



Multiphase flow problems require fine meshes at interfaces. Catalyst is used to support in-memory adaptivity and yet provide in situ visualization of the solution that would otherwise require writing hundreds of mesh files. Live, reconfigurable visualization also guides/steers adaptivity.

Future Plans

- The optimization of airfoil performance through flow control injection placements and wing geometry leads to a large number of simulation runs producing hundreds of terabytes of simulation results requiring petabytes of storage. We plan to enable interactive exploration of the design space by engineers to determine the most useful patterns and locations to actuate the injectors.
- The team is also collaborating on data compression wherein hundreds of solution time steps are stored within the slower RAM of an ongoing simulation, compressed in both space in time, and then either analyzed via Catalyst or exported after the run is completed for deeper, offline analysis of the simulation dynamics.

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