Robust and Automatic Shock Detection and Processing in High-speed Flow Simulations

Aiden Woodruff[1] and Onkar Sahni[2]

[1]Department of Computer Science and
[2]Department of Mechanical, Aerospace, and Nuclear Engineering &
Scientific Computation Research Center

Rensselaer Polytechnic Institute, Troy, NY

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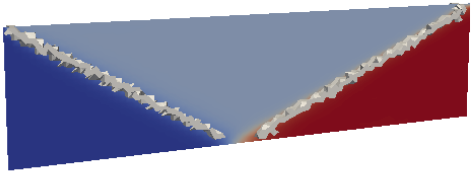
Introduction

- Shocks occur in high-speed flows
- They produce numerical difficulties and inaccuracies
- Robust and automated shock processing is highly desirable (for quantitative analysis)

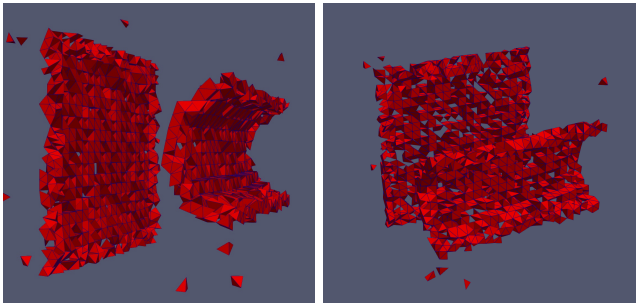
Shock Detection

- Input is the computed solution field (over a grid/mesh)
- Shock detection/sensor and filtering is applied (e.g., Lovely and Haimes 1999, etc.)
- Output is shock boolean information (e.g., cell/element-wise)

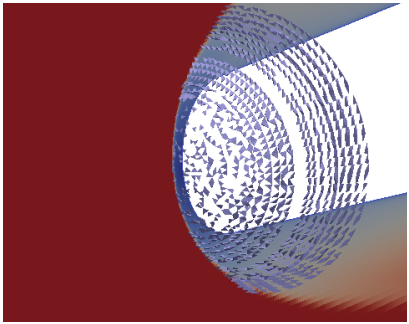


Motivation

- Current detectors/sensors produce noisy and fragmented surfaces
- A “cleaner” shock is necessary for automated processing, quantification, categorization, etc.



Results: HIFiRE-I



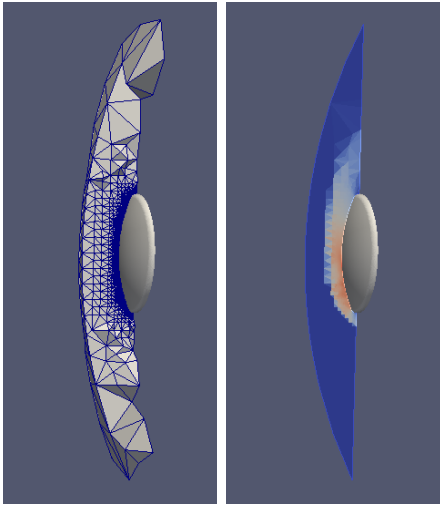
HIFiRE-I case: near-nose shock elements on a medium mesh

Results: HIFiRE-I

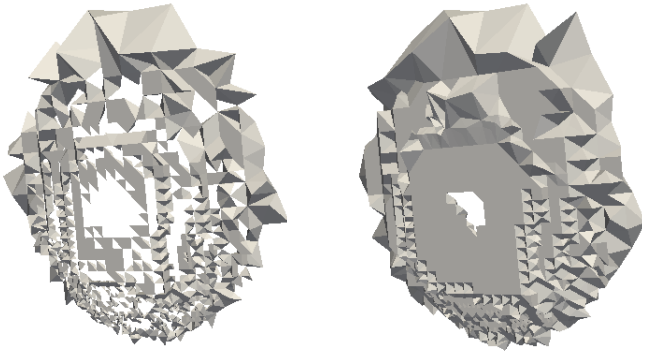
Shock elements for the HiFIRE-I case on a medium mesh: (left) before processing and (right) after processing

Results: Crew Exploration Vehicle Solution

Coarse mesh data for the CEV case: (left) mesh and (right) solution

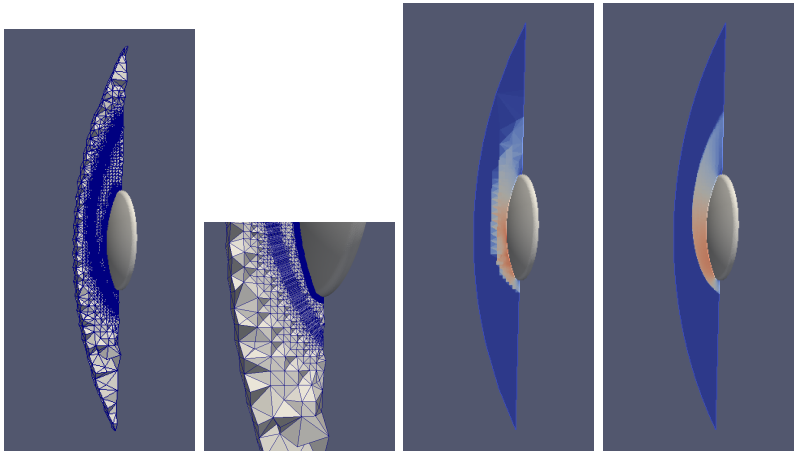


Results: Crew Exploration Vehicle: Shock Elements



Shock elements for the CEV case on an coarse mesh: (left) before processing and (right) after processing

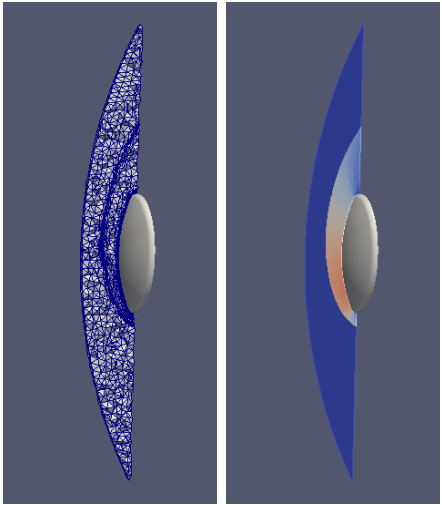
Results: Crew Exploration Vehicle: Shock-Fitted Mesh



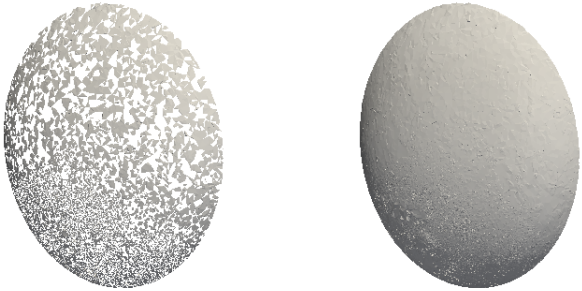
Shock-fitted mesh: (left) full and zoomed views, and (right) solution on coarse and fitted meshes

Results: Crew Exploration Vehicle (Fine Mesh – Multiple Iterations of Shock Processing)

Fine mesh data for the CEV case: (left) mesh and (right) solution



Results: Crew Exploration Vehicle (Fine Mesh – Multiple Iterations of Shock Processing)



Shock elements for the CEV case on an adapted mesh: (left) before processing and (right) after processing

Closing Remarks and Acknowledgments

Summary:

- Robust and automated procedure for shock detection and processing (including on coarse unstructured meshes)
- Key steps are de-fragmentation, labeling, and de-noising
- Numerical simulation datasets were used to showcase the utility of the current method

Acknowledgments:

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- Dr. Cameron Brown for providing some of the CFD simulation data
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More details

More details can be found in the conference paper:

 Woodruff, Aiden and Onkar Sahni (Jan. 3, 2025). "Robust and Automatic Shock Detection and Processing in High-Speed Flow Simulations". In: *AIAA SCITECH 2025 Forum*. AIAA SciTech Forum. American Institute of Aeronautics and Astronautics. DOI: 10.2514/6.2025-0916. URL: https://arc.aiaa.org/doi/10.2514/6.2025-0916.