Developing Efficient Uncertainty Visualization Algorithms in VTK-m

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Introduction

- **Motivation**
  - The majority of visualization techniques neglect inherent data uncertainty, which can lead to inaccurate analysis
  - Including uncertainty in analysis leads to a computational overhead
- **Goal**
  - **Develop uncertainty visualization algorithms using VTK-m**
    - Reduce execution period, Integrate in ParaView

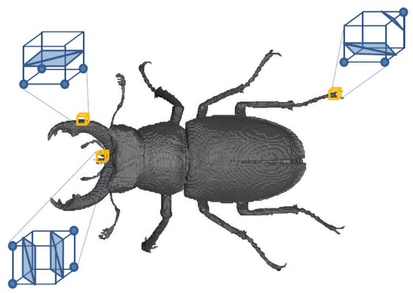
Background

- **Marching Cubes Algorithm**

  Extracts isosurface and fiber surface
  - **Isosurface**

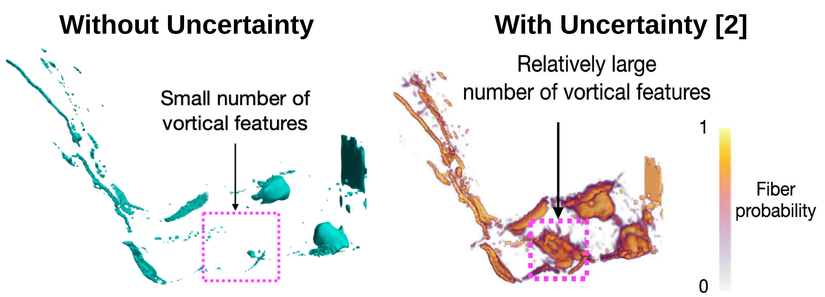
    3D points with equal data value
  - **Fiber surface**

    Extension of isosurface to bivariate data

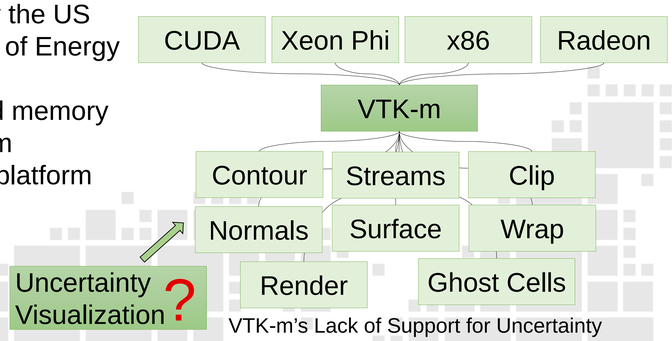


Surface extraction for Stag Beetle* dataset using marching cubes [1]

- **Marching Cube Algorithm with Uncertainty Propagation**



- **VTK-m**
  - Visualization toolkit for many multi-core processors
  - Funded by the US Department of Energy
  - **Features**
    - Shared memory parallelism
    - Cross platform portability



VTK-m's Lack of Support for Uncertainty Visualization

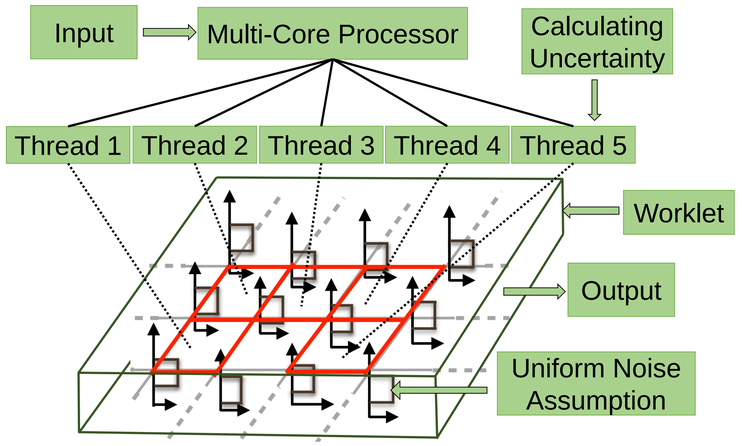
Research Gaps

State-of-the-art surface-based uncertainty visualization algorithms are sequential

- Unable to exploit hardware accelerators
- Lack of support from production tools

Research Contributions

- **Embarrassing Parallelism**

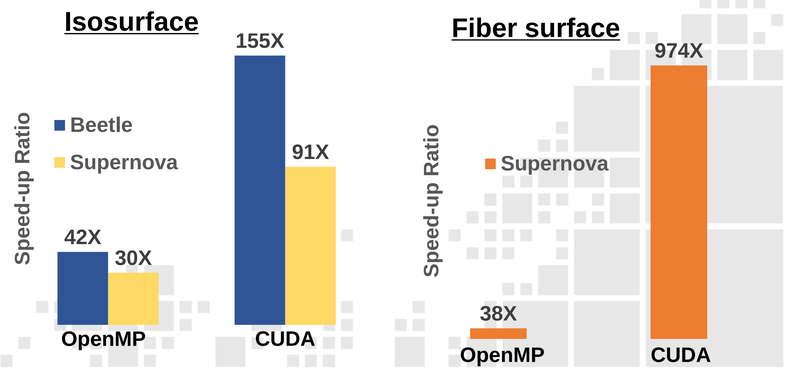


VTK-m's shared memory parallelism for faster uncertainty computation

- **Integrating in ParaView**
  - VTK-m seamlessly integrates with ParaView
  - Enhances our VTK-m uncertainty module

Results

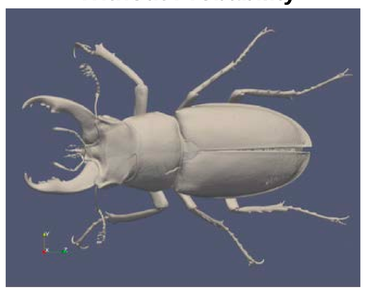
- **Performance Gains on Summit Supercomputer [3]**



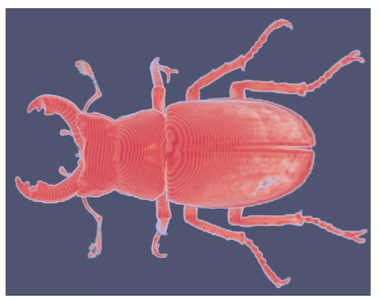
- **Performance Tests**
  - Serial and OpenMP [42 threads] tests on IBM Power9 CPU
  - CUDA [42 threads] tests on Nvidia Volta GPU

- **Uncertainty Visualization in ParaView**

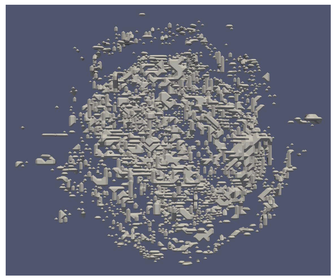
Isosurface — Without Probability



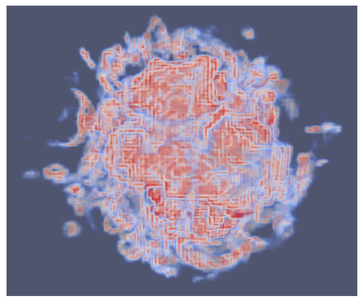
0 Probability 1



Fiber surface — Without Probability



0 Probability 1



Serial	9618 (ms)	Serial	1.06E+06 (ms)
OpenMP	230 (ms)	OpenMP	27849 (ms)
CUDA	62 (ms)	CUDA	1084 (ms)

Conclusion

- Achieved significant speed up for uncertainty computation using VTK-m on Nvidia GPU
  - Isosurface: **155X** faster on Beetle* dataset
  - Fiber surface: **974X** faster on Supernova[II] dataset
- Displayed Seamless Integration in ParaView
- **Future Work**
  - Extend uncertainty algorithms to Gaussian noise assumptions
  - Develop uncertainty visualization method for multivariate data

Acknowledgments

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References

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[3] Wang, Z., Athawale, T. M., Moreland, K., Chen, J., Johnson, C. R., & Pugmire, D. (2023). FunMC²: A Filter for Uncertainty Visualization of Marching Cubes on Multi-Core Devices.

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