Visualization of Flow Past a Marine Turbine: A Multi-field Challenge

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Overview

• Motivation for marine turbine research
• Basic questions posed by engineers
• Description of multi-field simulation data
• Some experiments & attempts visualizing multi-field data

Multiple-Coordinated Views:
  Histogram table, Velocity histogram, Parallel coordinates, Streamline graph, Distortion

• Some Observations
• Open questions
Marine Turbines: Motivation

• Renewable, green, and sustainable energy
• Converts kinetic energy from tidal water
• More predictable than wind
• Less environmental impact
  ○ Deep
  ○ Slow
• Higher Installation and Maintenance Costs
Marine Turbine Simulation: Questions

- What is the optimal Pylon (turbine support) and blade design?
- Goal: maximize energy drawn + minimize impact on flow
- How does the flow past a marine turbine behave?
- To what spatial extent does a marine turbine affect passing flow?
- How closely can turbines be packed in a given region?
Marine Turbine Visualization Challenges

• Adaptive resolution, unstructured mesh

• High dimensionality of CFD data:
  • Flow Velocity $v(x,y,z)$
  • Relative Pressure (to boundary)
  • Density (can vary due to pollutants)
  • Turbulent Kinetic Energy (energy associated with rotational flow)
  • Turbulent Dissipation Rate (rate kinetic energy is converted into heat)
  • Turbulent Viscosity (diffusive mixing of flow turbulence)
  • Derived Attributes

• Commercial off-the-shelf tools may not provide enough insight
Visualization Application: Features

- Multiple-coordinated views for interactive visualization
- Information-Assisted Multi-field Histogram Views
- Interactively multi-select or brush any attributes deemed interesting
- Information and knowledge-assisted streamline seeding
- Knowledge-assisted distortion
- Multi-threading
Visualization Application: Overview
Visualization View: Histogram Table
Visualization View: Polar Histogram
Visualization View: Parallel Coordinates
Visualization View: Streamline Graph

Streamline ID

Curvature Plot

Curvature

0 1,000 2,000 3,000 4,000 5,000 6,000 7,000
Visualization View: Scientific

TKE
TDR
Blade
Velocity
Pressure
Visualization Application: Experiments
Observations, Discussion

- Engineers responded favorably to multiple-views, including parallel coordinates and distortion
- Visualizations highlighted a problem in simulation
- Streamline graph obviates periodicity of swirl flow
- Engineers surprised by asymmetry of tangential velocity
- Engineers want more than just visualization
Question Remaining

• What improvements can be made to histogram table to provide a better overview of multi-field data?
• What alternative scientific or informations visualizations can be used to provide overview of multi-field CFD data?
• Are there any simple techniques to order parallel coordinate axes?
• Can detailed, multi-field views be coupled more closely with the spatial domain?
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Any Questions?

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