

Abstract ICCFD 2012: Generalized Box-Plot for Analysis of Unsteady CFD Solutions

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Abstract: The functional box plot is generalized to provide a holistic view of the four dimensional space-time field data resulting from unsteady Computational Fluid Dynamics simulations. It displays the variation of five common statistics - minimum, first-quartile, median, third-quartile, and maximum – projected onto the three-dimensional spatial sub-space. Visual analysis using the generalized box plot is demonstrated for the unsteady flows past a swept cylinder and a wind turbine.

Keywords: Visualization, Box-Plot, Unsteady Flow, Computational Fluid Dynamics, Vortical Flows.

1 Introduction

The visual analysis of four-dimensional (x, y, z, t) unsteady flow is an active area of research. Ultimately, the data must be mapped to a two- or three-dimensional display in a way that is meaningful to the user. Standard CFD post-processing of unsteady flow is an animation, which is intuitive to the human visual cognition system. Unfortunately, it is difficult to visually synthesis global statistics from a long animation. Our strategy takes the functional box-plot, a statistical technique used to visualize ensembles of one-dimensional functional results, and generalizes it to the projection of four-dimensional data statistics to the one-, two-, or three-dimensional subspaces.

2 Problem Statement.

The basic box plot symbol is shown in Figure 1. First developed by Tukey [1], it shows five descriptive statistics for a set of data values. The central line in the box is the median value, the lower and upper extend of the box is the 25th and 75th percentile values, and the ends of the line (also known as the whisker) is the one of several possible measures of the extent of the data. In some cases, this is the minimum and maximum values. In others, it is the 5th and 95th percentile. Throughout this paper, we will utilize the minimum and maximum values in our generalized box plot.

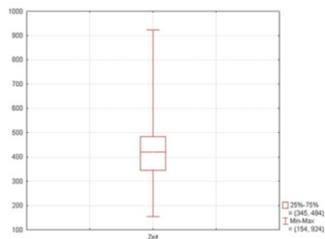


Figure 1 (left). Box-plot symbol.

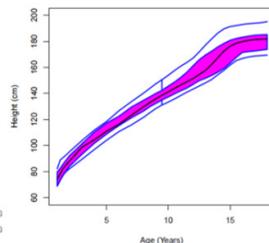


Figure 2 (right). One-dimensional functional box plot

A one-dimensional functional box plot is shown in Figure 2 [2]. The functional box plot is an extension of the box plot concept to ensembles of one-dimensional functions. In this example, it was applied to measurements of height versus age of boys in France. The box plot is ultimately based on sorted data and the main difference between variants of the functional box plot is in how the data is sorted. In the simple case, the function is discretized, the results of the functions at the same value of

the independent variable are sorted, and the values for the five statistics are used to create the next segment of the lines for the five statistics. In other cases, the entire functions are sorted first.

In [3], the authors generalized the functional box-plot to the visual analysis of high dimensional aerodynamic meta-data. This requires performing the statistical analysis over the inactive (not on axes) independent variables in the aerodynamic database. Figure 3 shows example results for the high-lift prediction workshop data. It contains lift versus angle-of-attack two-dimensional carpet plots and one-dimensional line plots of statistics averages over all cases submitted to the workshop.

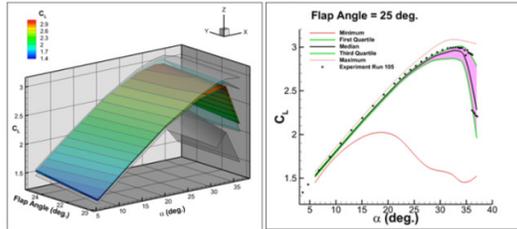


Figure 3 Generalized functional box plot: Lift versus angle-of-attach for HiLiftPW-1 data

For four-dimensional unsteady data visualization, the generalized functional box plot shows the variation of the same five statistics (minimum, first quartile, median, third quartile, and maximum) within conventional one-, two-, or three-dimensional plots. Figure 4 shows the generalized functional box-plot for X-component of momentum on a slice aligned with a swept cylinder. The degree of unsteadiness in the wake is demonstrated by the distribution of the statistics surfaces downstream of the cylinder. In the final paper, many more box-plot examples will be shown for unsteady flows. In particular, the unsteady flow around a wind-turbine will be analyzed with the generalized functional box-plot.

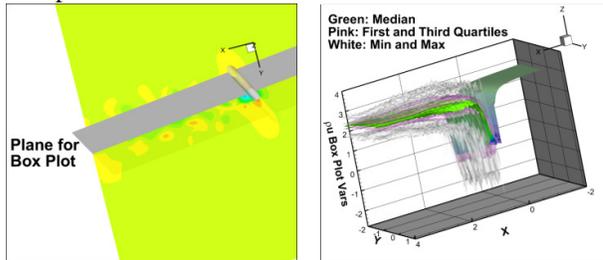


Figure 4 (left) Unsteady flow past a cylinder, (right) x-mom box plot on plane

3 Conclusions and Future Work.

The generalized functional box-plot provides a holistic view of the statistics for an unsteady flow. The Min/Max, quartiles, and median over time at each point in the flow are displayed simultaneously on conventional one-, two-, and three-dimensional plots. This data is very difficult to obtain from a conventional animation of the unsteady flow. The final paper will contain several more examples of functional box-plots for unsteady flows.

References

- [1] J. W. Tukey. Box-and-whisker plots,” Exploratory Data Analysis. Addison-Wesley, Reading, MA, 1977, pp. 39-43.
- [2] Y. Sun and M. G. Genton. Functional Boxplots. Int. J. Comp. and Graphical Stats., 20:216-334, 2011.
- [3] S. Imlay and C. Mackey. Generalized Functional Box Plot for Visual Analysis of High-Dimensional Aerodynamic Meta-Data. AIAA-2012-1262, Jan. 2012.