Research Statement for Valerio Pascucci

The main goal of my research is to develop tools and techniques that help scientists extract knowledge from massive amounts of data. This requires computing multi-scale representations of features extracted from raw data in a reliable, unbiased way, which is best accomplished with a formal mathematical framework not influenced by the user's interpretation of the input data. Therefore, the primary focus of my research has been the development of data analysis and visualization techniques based on Morse theory. This involves deriving combinatorial algorithms that can be applied to real world meshes while retaining key characteristics of the idealized smooth models of well understood topology. In particular, in the past decade I have been actively pursuing the development of novel algorithms for robust computation and visualization of topological structures such as Reeb graphs, Morse-Smale complexes, and Jacobi sets. While mentoring and collaborating with students, I have studied not only new efficient methods for computing these topological structures, but also pursued ways to apply them to scientific data analysis allowing scientists to gain insight in a variety of applications. Examples include the study of Rayleigh-Taylor instabilities emerging in supernovae explosions and inertial confinement fusion, the analysis of combustion simulations for the design of clean energy production, or the investigation of the structural properties of porous materials under failure.

To deal with the typical size of massively parallel scientific simulations, my research often involves new methods to manage and process large data even when accessed from a regular workstation. Successful solutions include the introduction of hierarchical space filling curves as a storage scheme to enable cache friendly use of modern memory/disk hierarchies without knowing the characteristics of the hardware available (cache oblivious approach). To achieve efficient computations of datasets in movement I have been pursuing data streaming techniques and the use of modern processing components such as GPUs. I have developed the first vertex shader to compute the geometry of isosurfaces and developed the first streaming method for extracting Reeb graphs of massive models in any dimension. This line of work has more recently yielded the development of a generic data steaming framework for multicore architectures that we are extending to support hybrid distributed parallelism and is a pivotal component of my new petaapps project supported by NSF.

In support of my research activities, I also share the goal of my colleagues in the School of Computing to improve the visibility of the University of Utah as a preeminent program in our field. I believe we are making great strides towards this goal with an aggressive publication record in top venues and participation in leadership positions. My near term research focus is in extending the topological analysis techniques from scalar to vector valued data while retaining the robustness of the general approach. Major challenges will involve dealing with dynamic models and quantification of uncertainty, which is essential for the future trends in exascale computing. I will continue with my commitment to include students and postdocs in my research and encourage them to take the initiative and publishing as lead authors in joint papers.

Scholarly Accomplishments

I have published 34 papers in peer reviewed journals and 68 papers in peer reviewed conference proceedings in top venues such as IEEE Transactions on Visualization and Computer Graphics and SIGGRAPH. I have also edited a book that is now in press and published 13 book chapters. Since joining the University of Utah I have established a strong research group in data analysis and visualization and I have brought significant research funding sufficient to sustain my research activities

Teaching Statement for Valerio Pascucci

The University of Utah is the lead educational institution in the state and , therefore, must feature a modern curriculum that reflects the latest advances in the field of computer science. Graduate and undergraduate students need exposure to the most recent techniques in computer science while still developing a solid formal foundation that will allow them to flourish in their future careers. In short, they need to be trained into becoming resourceful thinkers and effective doers. In each course I teach I strive to introduce the latest material appropriate for the level of the students and gauge their progress with early feedback so that I can adapt the class plan. Since joining the University of Utah, I have taught the following courses:

- Computational Topology (spring 2009), which received the Dean's letters for excellence in teaching.
- Scientific Visualization (fall 2009)
- Introduction to Computer Graphics (spring 2010)

The first course I taught after joining the University was an advanced graduate class in Computational Topology with applications in data analysis. This new course was designed from the ground up and was particularly challenging since this topic requires a strong mathematical background that most computer science graduate students do not have. Building new material for each class has been extremely stimulating and rewarding. I was able to take advantage of the smaller class size by engaging the students to solve exercises at the blackboard with the help of their colleagues. This also allowed me to monitor the progress of each student and adapt the material accordingly. I also presented a good part of the material in form of questions to be answered instead of information to be memorized. Overall, the students adapted very well to this level of participation in class and in many cases steered the lessons in unexpected directions of greater interest for them.

The second class I taught was in dual level Scientific Visualization (CS5630/CS6630). This course was redesigned from the previous years to focus on introducing recent techniques for effective presentation of scientific data. I also provided greater emphasis on techniques that are traditionally classified as Information Visualization. The class was structured to primarily allow the students to master a large portfolio of advanced visualization methods. At the same time, this course enabled the students to develop the critical skills necessary for choosing the best approach for presenting given datasets. After learning the foundations of scientific visualization, the students were exposed to some of the most advanced and popular visualizations and required to act as reviewers providing commentaries that highlight the effective components and the limitations of the different approaches. Even for the final project the students were strongly encouraged to propose applications needing an advanced visualization approach and then provide the solution. The students responded very well and proposed an incredible variety of problems that would have been hard to plan in advance. Ownership of the proposed projects lead inevitably to a wealth of creative solutions.

Last semester I also completely restructured the Introduction to Computer Graphics class with updated material and an adjusted target based on the feedback provided from the previous year. I

adopted the "Red Book" as the primary text, which is the main source of documentation and examples in OpenGL. In addition to revising and updating the material I have introduced a number of review sessions during the semester that the students found very effective as a way to prepare for various exams.

Overall, I believe that my professional experience at LLNL allows me to offer the students a unique combination of research focus and practical experience that is very effective in motivating their studies. Learning through the solution of real problems is effective for both undergraduate and graduate students. For this reason, I believe that education and research should be closely interconnected, since they also allow maintaining an updated curriculum. I do not believe in lecturing from the book but in providing examples and working with the class to develop solutions to problems that exemplify the important concepts. In this way the students can more easily reach their potential through analysis, critical thinking, and problem solving.