Interactive Visual Analysis in Engineering: A Survey

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Abstract

Interactive visual analysis has become a very popular research field. There is a significant body of literature on making sense of massive data sets, on visualization and interaction techniques as well as on analysis concepts. However, surveying how those results can be applied to actual engineering problems, including both product and manufacturing design as well as evaluation of simulation and measurement data, has not been discussed sufficiently to date. In this paper we provide a selection of demonstration cases that document the potential benefits of using interactive visual analysis in a wide range of engineering domains, including the investigation of flow and particle dynamics, automotive engine design tasks and change management in the product design process. We attempt to identify some of the proven technological details such as the linking of space-time and attribute views through an application-wide coherent selection mechanism. This paper might be an interesting survey for readers with a relation to the engineering sector, both reflecting on available technological building blocks for interactive visual data analysis as well as exemplifying the potential benefits on behalf of the application side.

CR Categories: I.6.6 [Simulation and Modeling]: Simulation Output Analysis; I.6.9 [Simulation and Modeling]: Visualization—Applications

Keywords: interactive visual analysis, engineering, simulation, coordinated multiple views

1 Introduction

Making sense of the massive amounts of data from engineering design, simulation or measurement processes is by no means an easy task [Hauser 2006]. Traditional analysis procedures are based on computing various statistical properties of the data. Interactive visual analysis [Thomas and Cook 2005] is a relatively new alternative that has already gained a lot of interest. It allows the gradual exploration of data in a guided human-computer dialogue. Interactive visual analysis takes full advantage of the advanced human visual and cognitive system to find unknown or unanticipated details that could otherwise go unnoticed. The interactive nature of the analysis can often reveal more information than complex, but static visualizations. In fact, it calls for simple and effective visualization techniques that can be rapidly adjusted to provide the exact piece of information that the analyst needs at a given stage of the exploration.

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Data in engineering application domains usually stems from measurements, or, more typically, from simulation. These data sets are large, complex, multidimensional and multivariate. The data is often time-dependent and dependencies in the data are intricate. During analysis, experts working with these data sets want to understand the behavior of the simulated or measured system, discover relations, create and support hypotheses. They often look for features and phenomena that they cannot exactly describe before the analysis. Interactive tools can assist them in the process of making sense of their data. This constitutes a domain where one can expect interactive visual analysis to be of great added value.

There is often no single visual representation that can encode all of the important information contained in the data. Interactive visual analysis systems can show different aspects of the same data in several distinct views [Baldonado et al. 2000]. Each individual view can be textual (e.g. a table) or graphical (histogram, scatter plot, etc). The views can differ in the data they depict or in the visual representation of the data. The data displayed in one view can be a subset or an aggregate of the data depicted in another view, or it can be completely different information, e.g. a map that provides geographical context. Using multiple views in a visualization system can be advantageous when the data attributes are diverse, when different levels of abstraction need to be represented or when the users of the system exhibit different levels of expertise. Different views can highlight different properties and correlations in the data. They can help the user understand intricate, often surprising and unexpected relations in the data. The visualization system can follow a "divide-and-conquer" approach and present partitions of the entire data set in individual views. This avoids the cognitive overload that users could face when they need to consider the entire data set at one time. Efficient interaction with the visualization is crucial in the analysis procedure. There are several concepts of coordinating multiple views, including linked navigation, focusing, brushing and linking [Buja et al. 1991; Becker and Cleveland 1987]. There are numerous well known visualization systems based on these principles, including XmdvTool [Ward 1994], GGobi [Swayne et al. 2003], Snap-Together Visualization [North and Shneiderman 2000], WEAVE [Gresh et al. 2000] and Improvise [Weaver 2004]. Please refer to the paper by Matkovic et al. for a list of academic and commercial visualization tools [Matković et al. 2008a].

After more than a decade of related research, there is a significant body of literature. Roberts provides an overview of many research publications related to coordinated and multiple views or one of the many associated boundary sciences [Roberts 2007]. He discusses developments in data preparation, concepts of creating and linking views, exploration techniques, window and sessions management, usability and perceptual issues and various display mediums. The book by Thomas and Cook [Thomas and Cook 2005] covers many aspects of visual analytics. We do not attempt to present another overview of the very broad topic, but rather focus on a very limited subset: interactive visual analysis in solving engineering problems. That means we do not discuss any of the very interesting developments in medical visualization [Gresh et al. 2000; Oeltze et al. 2007], gene expression analysis [Weber et al. 2007; Saraiya et al. 2004] or visualization in software engineering [Bohner et al. 2007; Gračanin et al. 2005], either.

The remainder of the paper is organized as follows: Section 2 deals with analysis in product and manufacturing design. In Section 3

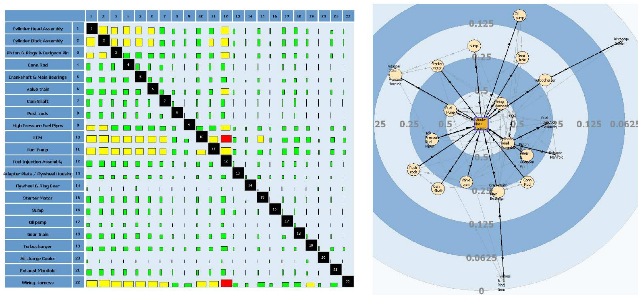


Figure 1: Linked views for the investigation of changes in the engineering design process. *Left*: Combined risk plot. *Right*: Change propagation paths. *Image courtesy of Keller et al.*

we focus on interactive visual analysis in flow simulation. Section 4 discusses several applications in automotive engine design. Section 5 mentions systems for the analysis of particle simulations. Section 6 briefly covers the exploration of sensor data. Finally, Section 7 contains a collection of thoughts about the future.

2 Engineering Design and Project Planning

Data sets from a wide range of engineering problems follow a very similar model [Tweedie et al. 1995]. This model includes a set of *parameters* (P) that the designer can directly influence. There is a set of dependent variables termed *performances* (F) that depend on P. The requirements of the design are typically formulated in terms of subsets of F. The dependencies of F on P are usually complex and non-linear, but can be computed. This computation is generally termed *simulation*. However, the mapping from F to P cannot be computed. The Influence Explorer [Tweedie et al. 1995] is one of the early visual analysis systems that assists the designer in exploring the complex relations between P and F in either direction. The user can select a range in one of the dimensions of F and the corresponding data items are highlighted in the linked histograms of the other dimensions of both F and P. The rapid brushing and studying of the linked views helps in the development of a mental model of the parameters' impact on the performances. Ultimately, it allows identifying the parameters which yield the required performances.

Keller et al. propose a visual analysis framework for engineering change management [Keller et al. 2005] (see Figure 1). Complex products consist of tens of thousands of interlinked components. Most products are designed by modifications of existing products, therefore change is an integral part of the design process. Changes to a component can have a dramatic impact on others, either direct or indirect. Their system visualizes the results of a change prediction method. Each direct link in the change propagation model is assigned an estimated likelihood value (probability of the change propagating between the two components) and an estimated impact value (severity of the change to the receiving component). The risk value is the product of those two. The prediction method computes the risk value of a change propagating from any component to any other component. The authors propose two types of views for the visualization of the change propagation. The Design Structure Matrix can show direct linkages or change likelihood and impact values. It is powerful in highlighting high-risk connections. However, it fails in depicting indirect links. They also use the Propagation Tree, a network graph representation with radial layout where the part that initiated the change is in the center. Other components are displayed at a distance inversely proportional to the risk of a change propagating from the initiating component. Each branch

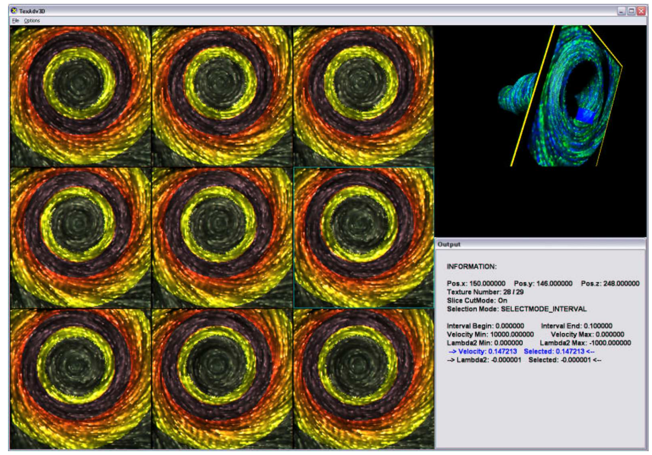


Figure 2: Linked 2D (left) and 3D (right) texture advection views reduce occlusion problems and provide enhanced spatial cues. *Image courtesy of Schafhitzel et al.*

of the tree represents one change propagation path and the lengths of the branches are proportional to the probability of this propagation path. This tree is suitable for studying the effect of change propagation to all components, thereby complementing the Design Structure Matrix. A collapsed version of the tree with a different layout allows the visualization of all propagation paths from one component to another. The Propagation Tree offers a fisheye-style focus and context approach, too.

Actors collaborating in design and construction activities in architecture constitute an "adhocratic" (as opposed to hierarchical) organization. Coordination management in an adhocratic organization can be a challenging task. The *Bat'iViews* concept [Kubicki et al. 2007] integrates views manipulated everyday by the construction stakeholders to highlight relations between them.

3 Volume and Flow Visualization

Volume and 3D flow visualization is a vast and actively researched field of scientific visualization. Application areas of flow visualization include meteorology, oceanography, computational fluid dynamics (CFD), ground water flow and medical visualization. The applications are diverse, but many of the tasks and challenges are similar. Specification and localization of flow features like vortices and flow reversal is one of the recurring tasks. Analysis often involves finding relations of different flow attributes. Occlusion in 3D flow visualization is another omnipresent issue.

Schafhitzel et al. suggest using linked 2D and 3D texture advection views (Figure 2) to improve the interactive exploration of 3D flows and alleviate occlusion problems [Schafhitzel et al. 2005]. The 3D texture advection view provides spatial context. In addition, texture advected flow visualization on several parallel 2D slices through the data set is also displayed. In the 2D slices, a further scalar flow attribute, the *feature attribute* (e.g. pressure, temperature or velocity magnitude) can be represented by color coding. A range of feature attribute values can be brushed in the 2D slices to define a focus domain. Saturation of color distinguishes focus and context areas. The focus and context are immediately linked to all other views. Spatial cues are provided by a kind of navigational slaving. The current position in a 2D view is indicated by a traditional mouse pointer. The corresponding position in the 3D display is marked with a little box. Furthermore, the location of the 2D slice under the mouse is indicated by a rectangular frame in the 3D view.

Feature-based flow visualization attempts to visualize interesting flow patterns or regions like vortices, flow reversal or flow separation. These features must be found and extracted from the flow data before they can be displayed. Automatic or semi-automatic flow feature extraction has a long research history [Post et al. 2003]. Automated approaches need a priori specification of criteria defining the features of interest. unfortunately, proper definition is often impossible because the feature is poorly understood, thus interesting flow features can be overlooked. Therefore, there is a lot of work on interactive feature specification. Henze described one of the early multiple linked view systems for interactive feature specification [Henze 1998]. The proposed *linked derived spaces* concept uses an arbitrary number of linked *portraits* that are essentially extended scatter plots. Each portrait can display pairs of flow attributes. The points in the portraits are connected with respect to the connectivity information of the physical simulation grid. A selection of brush types including axis-aligned rectangles, wedges and parabolas can be used to select regions of interest in each portrait. All views are linked and the brushed set is highlighted in all other views.

Doleisch et al. have developed a system called SimVis for interactive feature specification and localization in 3D flow data [Doleisch et al. 2003]. They propose scatter plots and histograms linked via advanced brushing for specification of flow features. Linked (but passive) 3D glyph displays provide spatial information. Flow simulation data often exhibits a rather smooth distribution of attribute values in space. This smooth nature is reflected in *smooth brushing*, which results in a continuous degree-of-interest (DOI) function. The DOI can also be interpreted as the degree of being in focus. The continuous DOI function is used for opacity modulation in the linked views, thereby smooth focus and context visualization is achieved. Complex features can be described by composite brushing. The feature definitions are expressed in an XML-based feature definition language and are persistent across analysis sessions. The paper describes localizing features in the simulated air flow around a car and finding backflow regions and possible vortex cores in a catalytic converter.

Bürger et al. have suggested a multiple views framework where local feature detectors can complement each other [Bürger et al. 2007]. This enhances the credibility and combines the advantages of several detectors in an interactive visual analysis system. This concept is used for the analysis of combustion in a two-stroke engine. The authors investigate the mixing process inside the combustion chamber and the connection between turbulent motion and mixing.

Features in time-dependent volume data can be explored in a linked system of time histograms, parallel coordinates and volume rendering, too [Akiba and Ma 2007]. This approach (see Figure 3) effectively partitions the three factors contributing to the complexity of the data into three views: (1) The *time dependent nature* of the data is displayed in the time histograms. (2) Parallel coordinates display *multivariate* data. (3) The volume rendering provides the *spatial* details. The transfer function for the volume rendering can be defined directly in the parallel coordinates. The time histogram assists user in finding time steps of interest and in the classification of time-varying data. Furthermore, a temporal transfer function can be defined. Linking between those two views is two-fold. The subset of voxels defined in the parallel coordinates is displayed in the time histogram. In addition, the transfer function widgets are also linked. Any changes to those two views are immediately reflected in the 3D volume rendering. The authors present an analysis of combustion simulation. The simultaneous visualization of mixture fraction, mass fraction of OH radicals, local mixing rate and the flame surface collaborate to reveal the interactions between mixing and reaction. The actively burning flame surface can also be identified.

4 Automotive Engineering

Virtually all aspects of an automobile are simulated before the first physical prototype is built. Testing new designs in simulation is more cost effective and allows shorter development cycles than making measurements on prototypes. The massive amount of data that automotive engineering simulations produce calls for advanced analysis methods. In this section we introduce several visual analysis tools used in automotive design.

There are many (often conflicting) goals of engine design, including the need for high power and good fuel efficiency, meeting emission regulations and reducing noise levels. The fuel injection system in diesel engines is the key component to achieve those goals. Matković et al. have presented an approach to finding optimum design parameters for a fuel injection system [Matković et al. 2005a]. The procedure involves the simulation and visual analysis of several thousands of different parameter combinations. Linked histograms, scatter plots and parallel coordinate views are used for the simultaneous display of design parameters and simulation results. Instead of a single highlight color, the brushed items are assigned a color gradient which establishes visual links between the corresponding data items in different views. Through brushing in any of the views, the engineer can acquire insight into the correlations between design parameters and results. The paper captures the exploration and analysis process and the set of optimum design parameters are identified.

This work has been extended by incorporating the analysis of detailed time-dependent injection simulation data [Konyha et al. 2006] (see Figure 4). The complete fuel injection process takes less than 0.01 seconds. Simulation computes several time series, including injection rate and pressure, in fine resolution over this short time period. The time-dependent data is displayed in function graph views and the authors introduce a novel technique for brushing them. The investigation focuses on the temporal parameters of the injection system and their impact on the injection process. Complex composite brushes spanning multiple views reveal correlations and dependencies in the data and the authors identify the means of achieving the desired temporal patterns in the fuel injection process.

Simulation models often have many design parameters that can be varied over a large range with fine resolution. In other words, the dimensionality and granularity of the design parameters constitute a very large space. The number of parameter combinations can be so large that exhaustive simulation and analysis is impossible in practice. Fortunately, this is not necessary, because most of the design variants are uninteresting and only a small subset of them is close to the desired optimum. The paper by Matković et al. [Matković et al. 2008b] exploits this in the context of fuel injection system design. In their workflow, the simulation results are investigated in an interactive visual analysis session similar to the one described in their previous work [Konyha et al. 2006]. The findings from the analysis are then used as input for the iterative refinement of the simulation model and its parameters. The concept of introducing a feedback loop into the workflow allows quick prototyping and design optimization by saving unnecessary simulation computer time and reducing the amount of data that the engineer is confronted with in each cycle.

A linked dual view system for the visual exploration of *engine char-*

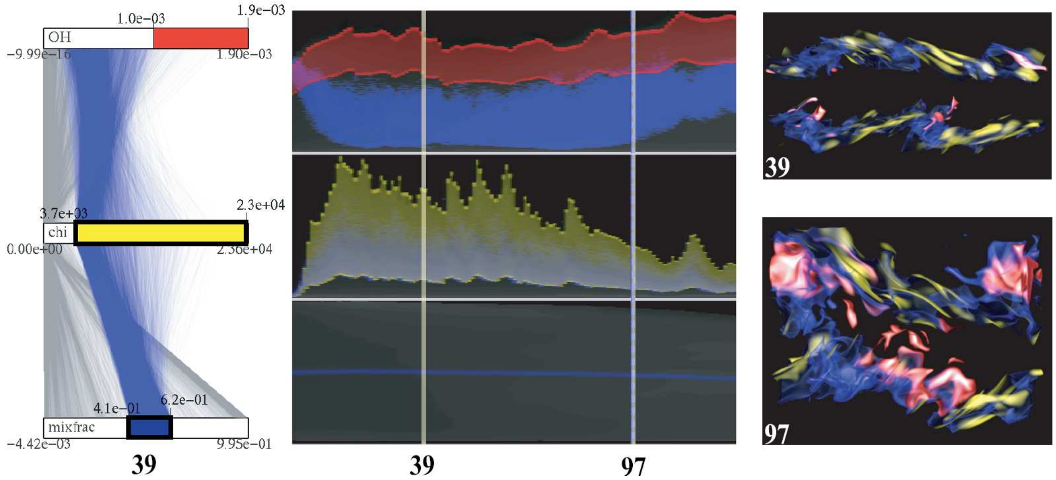


Figure 3: Visual analysis of a combustion dataset using linked parallel coordinates, time histograms and volume rendering. *Image courtesy of Akiba and Ma.*

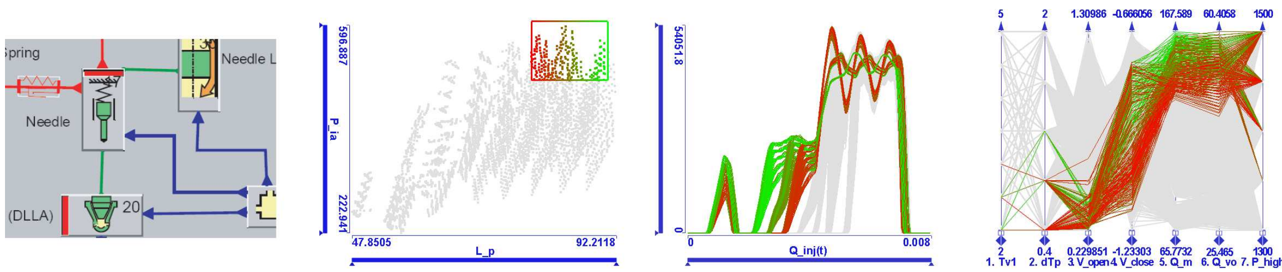


Figure 4: Linked views in the analysis of a diesel fuel injection system [Konyha et al. 2006]. The brushed rectangle in the scatter plot represents conditions when fuel is injected deep in the combustion chamber and with high power. The linked injection rate function graphs show that this requires boot shaped main injections. The desired needle opening and closing velocities are highlighted in the parallel coordinate view.

acteristic diagrams has been proposed [Matković et al. 2005b]. The data set consists of a 2D attribute space, for example, engine speed and load signal. For many points of the attribute space, time series data is computed in simulation that represents the amount of fuel injected over time, for instance. The attribute space is displayed in a 2D scatter plot. The time series are shown in a function graph view. The user can explore the various function graph shapes by simply hovering the mouse pointer over the attribute domain. The function graph that belongs to the point under the mouse in the attribute domain is highlighted while all other graphs are drawn as context. If there is no data point directly under the mouse pointer then the displayed time series is interpolated from the data associated with the neighboring points. Both views can be brushed using traditional rectangular brushes. In addition, a polyline brush can also be defined in the attribute space. The polyline brush is especially useful because engine operation cycles like accelerating from standstill can be represented by a continuous line in the attribute domain. This line can be approximated by the polyline brush. Therefore all function graphs pertaining to an operation cycle can be intuitively selected.

Motion of certain engine components, including the valvetrain, can be modeled by simulation based on rigid body dynamics. The process of finding optimum design parameters for a timing chain using interactive visual analysis has been published [Konyha et al. 2007]. A variety of views, including histograms, scatter plots and parallel coordinates are used during the analysis, together with a novel segmented view for discontinuous series data. The segmented view manages to simultaneously highlight focus and preserve outliers. The investigation is aided by iterative composite brushing. Data in all views can be brushed and composite brushes can span multiple views.

SimVis (see Figure 5) has been successfully adapted for the analysis of time-dependent simulation data of a diesel exhaust system [Doleisch et al. 2004]. Each view can either show data of one time step or accumulate the data of many successive time steps. A two-level focus and context visualization is implemented. The first level is a traditional focus and context view for data in the currently active time steps. The second level of context displays the data of all time steps. A combination of linked 2D/3D scatter plots [Piringer et al. 2004] can be used to specify flow features. The authors describe the analysis of a diesel exhaust system consisting of a diesel oxidation catalyst and a diesel particulate filter. They find answers to several questions related to the particulate filter regeneration process that are of interest to the designer, including: (a) do all soot deposits in the particulate filter oxidize completely during the filter regeneration phase? (b) where and how fast does the soot oxidize? (c) how high is the thermal stress of the particulate filter? Much of the analysis focuses on the changes in soot mass value over time, which requires visualizing the gradient. The authors have implemented a framework to compute several derived data attributes like differences, normalized values, etc. to cope with this requirement.

The same approach has been applied to the visual analysis of combustion in a diesel engine [Doleisch et al. 2005]. Several aspects of

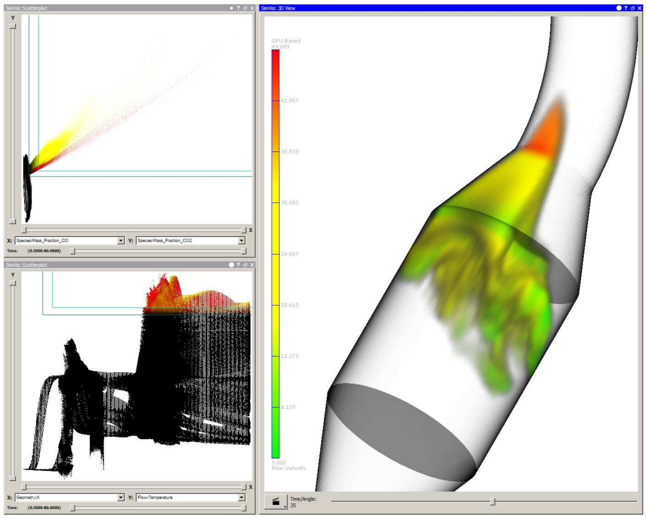


Figure 5: Snapshot of the visual analysis of a diesel particulate filter. *Left*: high CO and CO_2 mass fraction values and high temperature are selected via smooth brushing in the scatter plot. *Right*: the linked 3D view show gas velocity in those cells at 35 seconds into the particulate filter regeneration process. *Image courtesy of Doleisch et al.*

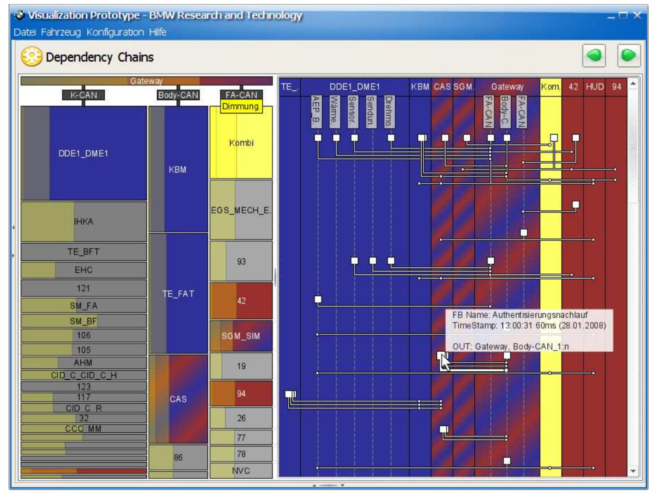


Figure 6: A tool for the visual analysis of communication between in-car electronic control units. *Left:* the ECU-Map shows a treemap-like view of the control units. *Right:* the sequence chart displays the communication sequence initiated by the selected component. *Image courtesy of Sedlmair et al.*

the combustion are of interest to the engineers, including questions like: What are the regions of incomplete combustion and what are the reasons for the incomplete burning? How much soot is produced and what does the amount of soot depend on? The paper provides a detailed description of the analysis procedure using the linked 2D scatter plots and 3D views.

Laramee et al. present the visual analysis and exploration of fluid flow through a cooling jacket [Laramee et al. 2005]. The cooling jacket is a part of the engine block where coolant circulates and transfers heat away from the cylinders. Some of the cooling jacket designing goals are expressed in terms of coolant flow characteristics like even flow distribution, avoiding stagnant flow, etc. Further important goals include minimizing the amount of coolant in order to reduce weight and allow the engine to reach its operating temperature quicker. The paper describes a combination of 2D scatter plot and 3D flow visualization views. Features can be specified by brushing the scatter plots. The linked focus+context 3D view provides spatial information.

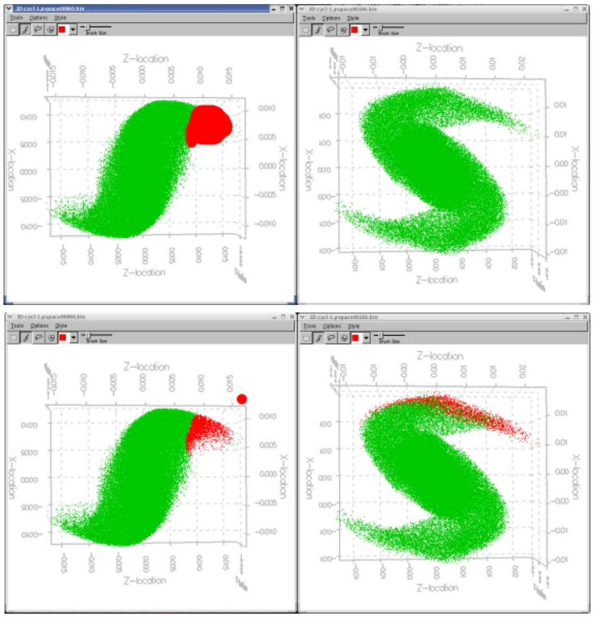
A modern car contains up to 70 electronic control units that control various emission, safety and convenience features of the automobile. Typically, each unit performs a variety of functions. Complex operations like lifting a power window require the cooperation of functions in several units. Therefore, the units are linked via bus systems to exchange data and messages. Fault diagnosis and root cause analysis in these systems is an integral part of automotive development. The dual-view approach presented by Sedlmair et al. [Sedlmair et al. 2008] supports automotive developers in the process of analyzing and diagnosing dependency chains within erroneous in-car communication processes (see Figure 6). A treemap-like diagram displays the entire physical layer of the in-car communication network. The area of each rectangle in the treemap is roughly proportional to the amount of functionality implemented and activated in the given control unit. The user can select a specific functionality within one control unit. The linked *sequence chart* depicts the dependency chain of the selected function, similar to UML sequence diagrams. Other functionalities in the dependency chain can be selected directly in the sequence chart to display their dependency chains. The user can navigate through the already explored dependency chains by using a web browser like history. Detailed information like full component names are provided on mouse-over. Furthermore, semantic fisheye zoom along the horizontal axis is implemented in the sequence chart: vertical lines that belong to one unit can be collapsed.

5 Analysis of Particle Simulation Data

Prior to construction of a particle accelerator, simulations of particle beams are developed to produce the best possible accelerator design. The large, time-dependent and multivariate simulation data represents complex physical phenomena. Researchers analyzing the data are often unsure what features of the data are meaningful, especially since physical phenomena hidden in the data may have never been observed before. A system of linked 2D and 3D scatter plots has been proposed for such tasks [Co et al. 2005] (see Figure 7). Rich brushing capabilities in 2D scatter plots including rectangular and lasso selections as well as an intuitive paint brush tool are offered to support interactive feature specification. The 3D scatter plots are enhanced by rendering small disks instead of dots. The orientation and the color of the disks encode the momentum vector of the particle. Time is represented via animation.

Jones et al. have also proposed tightly coupled heterogeneous views for the analysis of gyrokinetic particle simulations [Jones et al. 2008] (see Figure 8). Features can be brushed in a binned parallel coordinates view. The time-dependent particle data can be displayed by multivariate glyphs or pathlines in a lined 3D view. They offer two different strategies for preserving selections when moving to a different time step. The user can preserve the currently selected set of particles in order to track their temporal behavior. Alternatively, the selected attribute range in the parallel coordinates can be preserved so that the evolution of features over time can be explored.

The paper by Navrátil et al. describes a very different approach based on resampling the particle simulation data to a regular grid [Navrátil et al. 2007]. The resampled data is imported into an



(a)

(b)

Figure 7: Using the paint brush selection tool in the analysis of particle beam simulation data. *(a)* Particles in a spiral arm are selected. *(b)* The marked particles can be seen in a later time step. *Image courtesy of Co et al.*

existing scientific visualization system for analysis where ionized regions are displayed by isosurface extraction. This procedure can highlight properties of the data that are more difficult to discover with previously used methods.

6 Analysis of Sensor Data

Kim et al. describe an approach for the analysis of sensor data from pipeline pigs [Kim et al. 2006]. Pipeline pigs are devices that are inserted into and travel (driven by a product flow) throughout the length of a pipeline. Geometry pigs make measurements of the inside surface of the pipe. The measurement data is analyzed to find conditions such as dents, wrinkles, ovality, bend radius and angle, and occasionally indications of significant internal corrosion. The data includes the displacements of several radially arranged fingers over time. The resulting 1D multivariate data is displayed using a combination views including line graphs, 3D height maps and dense pixel displays. Fisheye view is used to help users focus on specific regions of interest. Ivanov et al. have addressed several issues related to the real time visual analysis of sensor data [Ivanov et al. 2007]. The application domain presented in their work is not engineering, however, the formulated design principles are quite relevant for other real time sensor data analysis systems.

7 Conclusion

In this paper we provide an overview of opportunities and applications of interactive visual analysis tools in engineering contexts. Some of them are certainly impressive. Interactive visual analysis has been considered a success story already [VisSuccess 2009], but

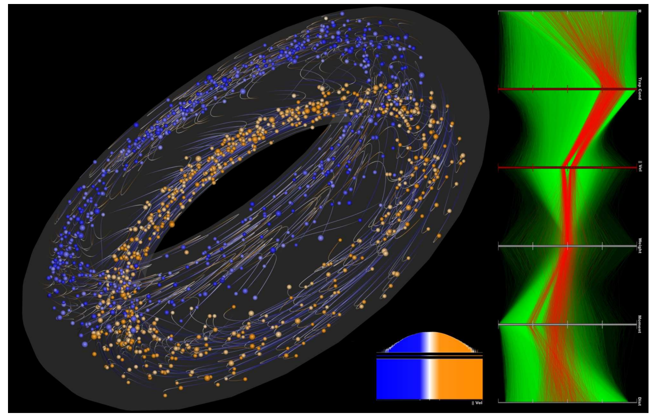


Figure 8: A multivariate exploration interface for the analysis of gyrokinetic particle simulations. Parallel coordinates can be brushed to select features of interest. The 3D view provides spatial information. The color coding can be controlled by the transfer function editor (bottom middle). *Image courtesy of Jones et al.*

there is still a long way to go and there is a lot of room for innovation.

Some of the proposed visual analysis tools work with a data model that can be represented by a single table. This is definitely insufficient when one needs to represent complex dependencies in design and manufacturing processes, for example. We suggest that more work should be invested in dealing with heterogeneous data sets as opposed to a single table.

Interactively linking displays of substantially more than 10^5 data items can be a challenge [Andrienko and Andrienko 2007]. Pixel oriented techniques can work up to a few million items, limited by the available screen space. Unfortunately, practical data sets exceed that limit. Methods that rely on aggregation to reduce the data set need careful tuning of the aggregation parameters in order not to miss important features. We claim that an interactive visual aggregation procedure before starting the actual analysis of the data can be useful, analogous to interactive flow feature extraction.

Often, information describing interesting features is not directly available in the data set. They are more easily found in some transformed or derived version of the data. Do current visual analysis tools offer adequate support for interactive definition of transformations of the data set?

Proper handling of erroneous or missing data is still not widely supported [Roberts 2007], even though it is essential for the analysis of data acquired via measurements. In fact, measurement data can pose further challenges. Real-time processing and visual analysis of streaming data from test bed systems, for example, is an interesting topic.

The management and visualization of the analysis workflow are especially important in collaborative analysis. They facilitate the reproduction and documentation of the analysis procedure. Furthermore, they allow the efficient sharing of analysis workload and also the exploration and comparison of different analysis paths. Understanding the analysis results is also made easier if the path leading to them is represented. Do we provide consistent solutions for that?

Finally, we claim that professionals working on systems that support visual analysis must never forget the utmost importance of cooperation and communication with the experts of the specific application domain—the potential users. Visual analysis tools should be smoothly integrated in their workflow and existing software suites. This is the only way to build really usable advanced visual analysis solutions.

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