Resource- and Task-Driven Visualization Adaptation

David S. Ebert
School of ECE
Purdue University
West Lafayette, IN USA
ebertd@purdue.edu

Yung-Hsiang Lu
School of ECE
Purdue University
West Lafayette, IN USA
yunglu@purdue.edu

Edward J. Delp
School of ECE
Purdue University
West Lafayette, IN USA
ace@purdue.edu

William Cleveland
School of Statistics
Purdue University
West Lafayette, IN USA
wsc@purdue.edu

Ahmed Elmagarmid
Department of Computer Science
Purdue University
West Lafayette, IN USA
ake@cs.purdue.edu

Alok Chaturvedi
School of Management
Purdue University
West Lafayette, IN USA
alok@purdue.edu

Mourad Ouzzani
Department of Computer Science
Purdue University
West Lafayette, IN USA
mourad@cs.purdue.edu

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Abstract
We believe that for the most effective information communication to the user, the content and visual representation of the content needs to be adapted based on the task the user is performing and the resource capabilities of their display, including battery life, memory, display resolution, and communication bandwidth. By adapting the content that is presented and the visual representation (rendering) of the content, the user can more effectively complete tasks and make decisions.

Keywords
Information visualization, visual analytics, resource adaptation, display adaptation, task-driven visualization.

ACM Classification Keywords
H5.2. Information interfaces and presentation; I.3.8 Visualization.

Introduction
In creating effective visual representations, abstraction is fundamental and the abstraction must match at both the data and visual representation levels. Illustrators, designers, and cartographers have a rich history of the effective use of abstracted information depiction and have developed a toolbox of principles for concisely conveying complex information. These depictions simplify reality,

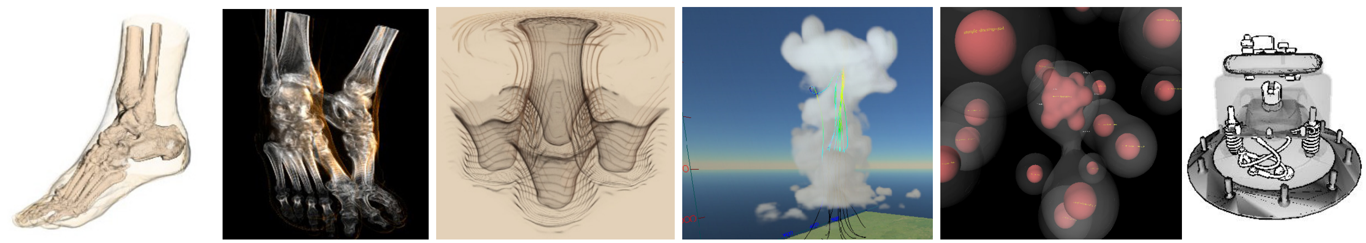

Figure 1: Examples of our perceptually-driven, task-specific representations of datasets, including simplified and detailed anatomical renderings of a CT foot dataset, non-Newtonian convection in a box, multivariate, multisource cloud dynamics data, document and corpora visualization, and a PocketPC repair rendering of an aircraft component.

speed comprehension and allow greater richness of complexity to be effectively conveyed. We are exploring the use of both perceptual and visual abstraction principles to ensure the appropriate abstraction levels for the user's task. For solutions to be effective for real visual information analysis, visual analytic problems, we must also develop techniques that allow analysis across scales within a dataset. Again, we will utilize abstract techniques (data and visual) to provide scalable solutions. Inspired by the effectiveness of science illustrations to concisely show multi-scale systems (e.g., atom to cell to body), we are investigating illustrative inset, blow-up, focus plus context, and designed composite visualization techniques to provide multi-scale visualization solutions. We will also explore varying the abstraction and representation level within an image to help the viewer attend to important information, reduce visual search time, create perceptual layering of information, and enable quicker decision making in time-critical environments.

Visual abstraction and representations are only successful when they are appropriately and effectively mapped to relevant information. We need appropriate metadata information, data categorization and aggregation mechanisms, and task, user, and data characteristic driven mappings to visual representations. Therefore, this work must be tightly integrated with our data management research.

We have utilized varying rendering styles and combinations of illustrative and 3D perception-aiding (e.g., texturing, shading) rendering techniques to harness the power of visual abstraction, reduce the complexity of three-dimensional, time-varying data, and more effectively convey information [Rheingans 2002, Svakhine 2005a, Svakhine 2005b], as shown in Figure 1. We are exploring the adaptation and extension of these techniques to non-spatial, combined spatial/non-spatial, and higher-dimensional abstract data spaces. So far, we have only adapted a small portion of the illustration/design toolset to effective visualization. We have explored novel visualization methods for document and corpora management, and network security analysis, which allows the simultaneous visual analysis and discovery of both local (e.g., document similarities) and global traits (e.g., trends, anomalies). We will utilize this experience to adapt these novel rendering techniques and create effective large scale information analysis spaces.

Adapted Content Visualization

For effective analysis, decision making, and action, the visual representation needs to be adapted based on **all** of the following: the user, the user's task, and the device resources (power, network capability, and screen resolution). We are exploring novel methods, based on traditional, illustrative, and image-based rendering, to display information that is not only tailored to user preferences and task, but also best uses the capability of their device. This visual rendering/content adaptation must be addressed for effective collaboration in heterogeneous environments. As mentioned in the introduction, user and task adaptability drive all of our visual representation methods. For user adaptability, we need to accommodate users with different levels of expertise, perceptual preferences (e.g., form dominance), and perceptual capabilities (e.g., color vision deficiencies) to create effective visual representations.

We will make our methods adaptable to device resources and develop alternative representation/ rendering methods (e.g., sketch vs. image) for power, resolution, and bandwidth limited displays that are common to many application, including first responder and emergency management field personnel. For example, in emergency response, mobile command centers may have the capabilities to display 3D renderings of burning buildings, augmented with chem/bio hazard information and weather model data. These centers with large displays need to provide visual representations appropriate for the large field of view as well as to enable collaboration among decision makers. The battalion chief's display would have the fire-fighter locations augmented onto the display, while individual GPS-located firefighter displays would show their location within the building's floorplan, as well as dynamically updated fire-spread and control information. Traffic/crowd control personnel would have projected spread estimates to enable them to guide evacuation routes and traffic. In this example, device, location, user, and user-task adaptation are all required to create the effective solution.

In adapting the representation to mobile devices, we first need to consider how to effectively communicate the information given the small screen area. Some studies have already shown that low-resolution caricature sketches of faces are more effective than down-sampled picture of individuals in user facial recognition tasks, providing motivation for illustrative and sketch-based representations on small screens.

The second important factor is the graphics capabilities of the devices and the power requirements of each graphics operation, since battery life is a precious resource, especially in emergency response and management situations and most field applications of visualization and decision making.

Finally, the frequency of use of the system is also an extremely important factor for effective analysis and performance. For instance, if the system is used infrequently, as in the case of emergency response situations, the affordance of the representation becomes critical because of the time between uses.

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