Information Dense Summaries for Review of Patient Performance in Biofeedback Rehabilitation

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ABSTRACT
In this paper, we present a novel visual design for information dense summaries of patient data with applications in biofeedback rehabilitation. The problem is important in review of large medical datasets where the clinicians require that both summary and all the performance details be shown at the same time. There are two main ideas (a) Summarizing data along the conceptual facets (accuracy / flow / openness) and the temporal facets (session / set / trial) in the biofeedback therapy. The conceptual facets represent key information needed by the experts to review patient performance. (b) Effectively present the data trends and the details in context of the entire performance. The summary incorporates ideas from graphic design and reveals the performance data at two time scales.

Categories and Subject Descriptors
H.5.3 [**Group and Organization Interfaces**] *Computer-supported cooperative work*

General Terms
Algorithms, Experimentation, Human Factors

Keywords
Summarization, multimedia, stroke rehabilitation

1. INTRODUCTION
This paper focuses on designing visual summaries of patient performance in biofeedback rehabilitation [1]. The biofeedback therapeutic process generates large spatial-temporal patient data. The fundamental challenge in summarizing these clinical datasets lies in the following observation – clinicians want *both* the summary (i.e. insight) and the details at the same time. This is because they want to focus on the details of the patient performance to determine the next stage of physical therapy. Importantly, since we have been using our tool with actual stroke patients, the clinicians do *not* want any details to be automatically removed from the presentation. This problem bridges the reductionist summarization problem in multimedia (e.g. [3]) with information dense displays found in Tufte's work [4] in graphic design Hence we term this problem as *information dense summarization*.

There has been prior work in faceted dataset browsing [5] and clinical data visualization [2,4]. In [2], the authors visualize temporal relationships in clinical data using novel silhouette representations. Tufte ([4], pp.111) summarizes patient data using non-linear time scales. There are several limitations of prior work: (a) handling multiple time-scales (e.g. 10 sec. – 2 hours) in continuous data; (b) handling different clinical data types (e.g. spatial / temporal data) simultaneously.

During the biofeedback therapy, an approximately two-hour *session* is organized into *sets*, where a set has consistent physical setup and media feedback. A set comprises *trials*, where the patient performs the reaching task. Subsystem adaptations are made between sets based on domain experts' understanding of patient performance. There are two main ideas: (a) Summarizing data along the conceptual facets (accuracy / flow / openness) and the temporal facets (session / set / trial) in the biofeedback therapy. (b) Effectively present the data trends and the details in context of the entire performance dataset.

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2. SUMMARIZATION CHALLENGES
The problem in information dense summarization is to reveal key variable changes while preserving the details of the patient performance. This is challenging because of the sheer magnitude of captured (e.g. hand trajectory) and derived (i.e. performance analysis such as reaching error) time-series data. A typical patient session can last two hours, with the patient performing 80~90 therapeutic reaches. For each reach (lasting a few seconds), we gather three-dimensional patient performance variables (raw observations), one-dimensional error variables (derived data) and one-dimensional media synthesis variables. We adopt faceted organization and efficient data ink in our design approach.

3. VISUAL SUMMARIZATION DESIGN
We now discuss our design of faceted organization and efficient data-ink, in summarizing the patient performance.

We organize the biofeedback dataset into *conceptual* and *temporal* facets. The conceptual facets in biofeedback rehabilitation are reaching *accuracy*, *flow* and *openness*. These facets represent the key information that the experts need to review patient performance. For each facet, we present the raw captured data and the derived errors. The temporal facets are *session*, *set* and *trial*. They reveal the procedural organization of the biofeedback therapy, at different levels of temporal granularity. Conceptual facets are organized vertically (Figure 1.A-F). Temporal facets are organized hierarchically and horizontally in the correct time order of the therapy (Figure 1.(α), (β),(γ)).

The main idea in our visual summaries is to reveal data trends in the patient performance *in context of the entire performance dataset*. In our clinical, experimental and exploratory setting, it is very difficult to develop a utility based summarization measure (e.g. as in [3]), as it is critically dependent on the domain experts (doctors, physical therapists, musicians, etc.). It is not sufficient to create a "summary curve", as this does not capture the highly detailed variations in the patient data. The experts are keen to see the entire dataset, at high detail and then draw conclusions on the patient performance. Indeed since we work with actual stroke patients it is critical not to make therapeutic mistakes. Hence we include the domain experts as integral to the process of

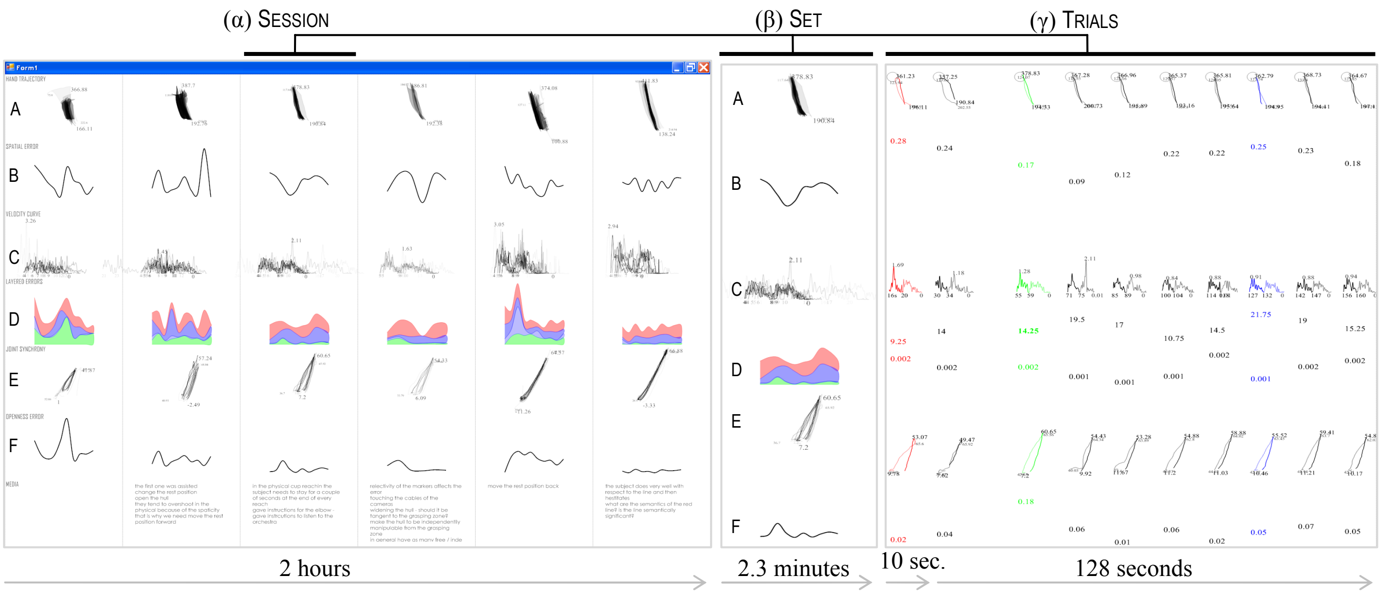

Figure 1 Screenshots of the visual summarizations that reveal key ideas in our design: *faceted organization and efficient data-ink.*

determining insights from the data and focus on developing effective data presentation techniques that help reveal data trends.

Our visual design is strongly motivated by Tufte's principles of designing statistical graphics on print media [5]. To overcome the low information density on electronic displays (72dpi vs. 1200 dpi for print), we must take advantage of their interactivity, to reveal details on demand. Importantly, the clinician time for data review is limited. Therefore we must design efficient data-ink, to reveal important data trends and details while avoid overwhelming the reviewers.

The faceted organization reveals data trends within a conceptual facet and enables efficient data comparison across temporal facets. Each temporal facet has a different data summarization / presentation design. At the set level, we have designed both a collapsed overview and an expanded detailed view of the set. On the collapsed overview, trials are aggregated with increasing transparencies in time order (Figure 1.(β)-(a),(c),(e)). The aggregated contours of hand trajectory / velocity curve / joint synchrony immediately summarize the spatial and temporal stylization in patient performance within a set. We reveal the subtle, dynamic correlations of the derived errors in the river of errors, allowing for comparison of errors over the set. (Figure 1.(β)-(d)). On the expanded detailed view, we use small multiples to allow for inter-trial comparisons (Figure 1.(γ)-(a),(c),(e)). Horizontal lengths on the expanded view are proportional to the actual time (i.e. trial duration / break), revealing the temporal stylization in patient performance, and highlighting any anomalies within a set. Within a set we show errors as numeric graphs – numbers themselves are used to mark data points, to help reviewers focus on the data ((Figure 1.(γ)-(b),(d),(f)). At the trial level, different trial segments (reaching, grasping, and returning) are colored with decreasing transparency, to reveal trial level segmentation (Figure 1.(γ)-(a),(c),(e)). We use primary RGB colors to highlight trials with critical errors, and show the error across all conceptual facets (Figure 1.(γ)).

Details are revealed on demand through user interactions. Double-clicking the collapsed overview of a set will expand it into an expanded detailed view (*semantic zooming*). Our application is realized using Piccolo.NET.

4. DEMONSTRATION SETUP

We will demonstrate the visual summary of patient performance from a typical patient session. The demo application will load the entire patient session data from our SQL Server database. It will present the set-level summaries on the collapsed overviews and the set / trial-level details on the expanded detailed view.

On the application, we will illustrate our design of: (a) faceted organization in both conceptual and temporal dimensions of the biofeedback therapy; (b) efficient data-ink that can reveal details and data trends in patient performance at different summary levels. We will demonstrate the user interactions with the application, i.e. pan, semantic zooming, graphical zooming and details on demand. In order to provide context of the biofeedback therapy, we will also prepare sample audio / video clips for play.

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