Interactive Visualization of Time-Oriented Treatment Plans and Patient Data
THESIS SUMMARY

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March 15, 2004

Abstract

This thesis presents methods to support protocol-based care in medicine. Time-oriented treatment plans and patient data are represented visually providing various interaction possibilities to aid execution and analysis of medical therapy plans formulated in the representation language *Asbru*.

We introduce a two-view approach consisting of a *Logical View* and a *Temporal View*. The *Logical View* depicts therapy plans using a flow-chart like representation based on "clinical algorithm maps". The *Temporal View* on the other hand depicts plans as well as patient data in form of parameters and variables over time. The plan visualization method within the *Temporal View* is based on the idea of *LifeLines*. For being able to depict hierarchical structures and temporal uncertainties, we extended this concept and a novel glyph called *PlanningLine* has been developed.

The development is embedded into a 3-step evaluation process including a user study with eight domain experts (physicians) at the beginning to acquire users' needs, a design evaluation, and an evaluation of our software prototype at the end of the thesis project.

1 Introduction

The use of clinical guidelines and treatment plans has a profound history in the medical field and is widely used. The purpose of such representations and documents is primarily to enable discussion and communication among medical staff (physicians, nursing personnel, etc.) as well as improving the quality of care by setting up certain "standard procedures".

Most clinical guidelines are represented in plain text, rarely including tables and flow-charts. Computer support is desirable for various reasons: First of all obviously to ease document exchange, editing, and reuse. Furthermore, due to the semiformal structure of such documents, taking it a step further towards creation, runtime, and analysis support introduces a much higher level of aid. Tool support in this sense helps to cope with ongoing information overflow, eases quality assessment, and facilitates information respectively knowledge exchange. Clinical guidelines and protocols can be seen as skeletal plans as used in some planning approaches.

Planning techniques are well known in the field of Artificial Intelligence (AI). Various approaches and solutions to solve planning problems have been carried out by the AI-, respectively planning community since the 1960s. But most of these techniques can only be applied to well defined and limited problems. The real-world domain *medicine* requires much more flexibility: Well defined problems and processes are the exception rather than the rule, and uncertainty is an important factor. Traditional planning approaches are not able to support these requirements. Therefore, special techniques for medical plan management, like the *Asgaard/Asbru* [Miksch, 1999] approach (this work is part of) and others [Wang et al., 2001], have been carried out.

Most of the scientific projects dealing with medical treatment planning concentrate on the knowledge representation and acquisition as well as the implementation of that knowledge in real world environments. From a human-machine point of view, they focus almost entirely on the "machine end" of the *human-machine chain*. Very little work has been carried out to bridge the gap between the formal AI methods used "behind the scenes" and real consumers: physicians, nursing and other medical personnel. This work is intended to fill this gap. It aids physicians during plan execution by providing an easy-to-use, intuitive interface approach towards medical treatment planning, starting from the user's point of view.

The top level goals of this thesis are to:

- provide a considerable treatment documentation,
- offer better analysis support by using appropriate visualization methods,
- merge various information sources,
- improve therapy, and
- help to concentrate on the essentials in the daily routine.

These goals represent vital improvements and advantages for the work process of physicians.

2 The Plan Representation Language Asbru

The underlying plan representation language used for this work is *Asbru* [Seyfang et al., 2002, Miksch et al., 1997] which is a time-oriented, intention-based, skeletal plan-specification representation language that is used in the *Asgaard* Project to represent clinical guidelines and protocols.

Visualizing *Asbru* plans imposes six fundamental problem characteristics on the representation that have to be considered:

- time-oriented data from the past to future planning data including a rich set of time attributes allowing to depict uncertainties
- logical sequences
- hierarchical decomposition
- flexible execution order (sequential, parallel, unordered, any-order)
- non-uniform element types
- state characteristics of conditions

Based on the identified basic issues, we investigated related work in medical treatment planning, information visualization, medicine, and commercial medical software products.

3 Related Work

The related work presented here is only a part of the state-of-the-art research carried out in this thesis, but represents the most important and most influential ones:

There is a number of scientific projects dealing with protocol based care in medicine present (see [Peleg et al., 2003, www.openclinical.org, 2003]), but only some of these projects provide graphical tools at all, and most of them only for authoring plans. They use a flowchart- or workflow-like presentation depicting the elements used in their formal representation.

The most widely used visual representation of clinical guidelines in the medical domain are so-called *flow-chart algorithms* also known as *clinical algorithm maps* [Hadorn, 1995, Society for Medical Decision Making, 1992]. But these clinical algorithm maps were intended to be used on paper only and have never been enriched by computer support as for example navigation or versatile annotation possibilities. Furthermore, flow-charts cannot straightforwardly be used to represent temporal data, concurrent tasks, or the complex conditions used in *Asbru*.

A simple and intuitive information visualization technique representing processes respectively states over time are so called “Life Lines” [Plaisant et al., 1998] which have previously been used to depict patient histories.

Because none of the existing visualization methods fulfilled all the requirements defined, we framed out a new conceptual design.

4 Design and Implementation

We took a **two-view approach** introducing a *Logical View* and a *Temporal View* for representing plans, parameters, and variables (see Fig. 1). For the *Logical View* we created a flowchart-like representation based on *clinical algorithm maps*. For depicting plans within the *Temporal View*, we extended the *LifeLine* concept and developed a novel glyph called *PlanningLine*. A *PlanningLine* is able to represent incidents having temporal uncertainties. Moreover, this glyph is not limited to the medical domain, but can be used for a variety of applications.

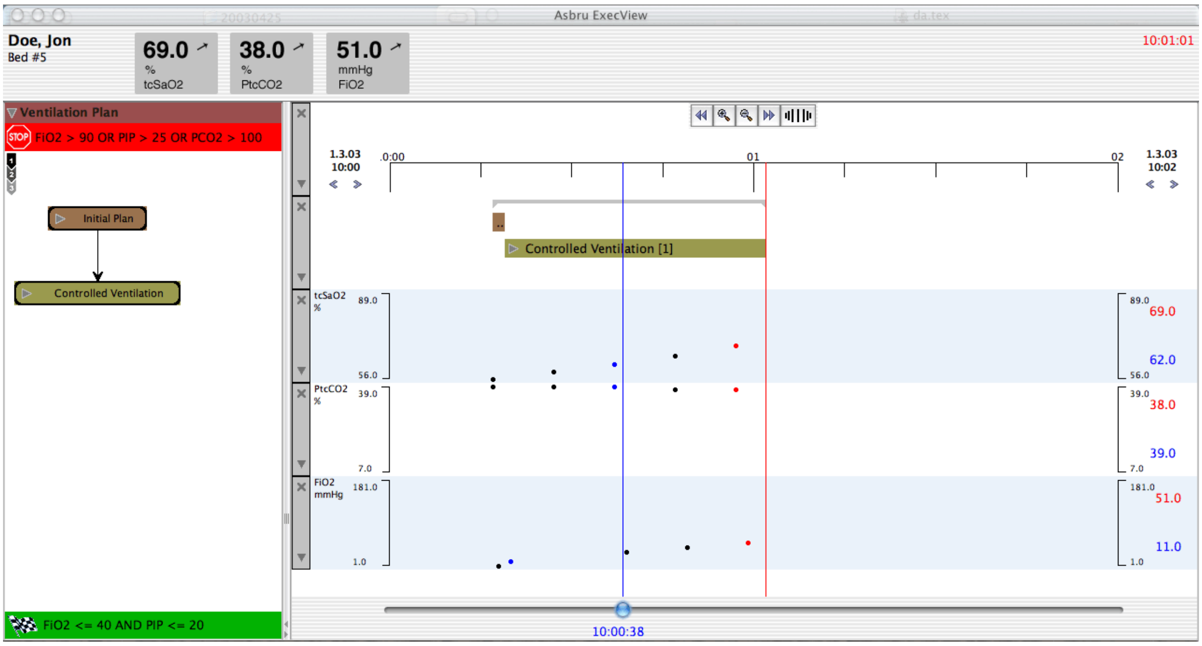

Figure 1: Application window showing the execution of a plan (Mockup).

In order to proof our concept and give as well as get a better impression especially of interaction issues, we implemented a Java prototype. For displaying the flowchart-like part of our representation to depict plan step elements, we use the graph drawing framework **JGraph** [Alder, 2002a, Alder, 2002b]. This is a flexible, small, and powerful package using the Model-View-Controller paradigm and is structured analogous to the standard *Swing* component *javax.swing.JTree*.

5 User Involvement

We applied a user-centric approach when developing our visual representation: We involved real consumers from the very beginning by carrying out a user study and evaluated our design as well as our prototype thoroughly. This increases the quality of design, the user acceptance, and serves as an indicator of the maturity of development.

The first step of major importance for requirement analysis in our development process was to conduct a user study with eight physicians to gain deeper insights into the medical domain, work practices, application of guidelines in daily work, users' needs, expectations, and imaginations. When summarizing and evaluating the results of our user study the following desired fundamental characteristics can be recognized: a simple and transparent structure, intuitive interaction (easy to learn and comprehend), a cleaned up interface, a high level of application safety (undo where possible), time saving (allowing quick and effective work), fast, and flexible.

We have examined and proven the usefulness of our two-view approach (*Logical View* and *Temporal View*) by performing a **3-step evaluation process** including the user study, design evaluation, and prototype evaluation as described in detail in Chapters 7 and 8 of the thesis.

6 Conclusion

The use of software in contrast to paper allows us to support the process of exploring and understanding treatment plans at a higher level. It enables a meaningful navigation, providing annotations on demand for not overwhelming the viewer, and keeping orientation by using Focus + Context techniques, thus increasing the flexibility in working with treatment plans. The interaction is carried out intuitively by applying well known techniques from standard software supported by different Focus + Context techniques for keeping an overview. The most important user requirement of being time-saving is achieved by combining intuitive navigation and rich information presentation including annotations and linked documents in a structured way. This is in contrast to working with paper-based treatment protocols that are often a mix of text, tables, and graphics, scattered over various pages, making it hard to keep an overview and conceive the logic of a guideline.

An additional value besides communicating plans to domain experts became apparent during development: The visualization of plans helps to spot problems, bugs, and ambiguities in the formal plan representation which are hard to see and detect otherwise. Furthermore, the visualization serves as an important basis for the communication between medical domain experts and computer scientists.

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