Visual Development of Temporal Patterns for Medical Data Abstraction

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Abstract

In this paper we present a visual representation of temporal patterns in abstractions of numerical and timestamped data. We provide a curve-like acquisition tool which supports domain specialists to develop and refine temporal knowledge in an intuitive and effective manner. The resulting patterns can be used to detect artifacts as well as more complex phenomena, e.g., in order to derive intelligent alarms.

1 Introduction

The temporal development of numerical data and its interpretation, respectively, is of prime importance when monitoring patients in the medical domain, e.g., during surgeries or in the context of an ICU. Here, the automatic abstraction and interpretation of these continuously received parameter values can support the medical staff, e.g., anesthetists, with the tracking of the patient's status.

Furthermore, the interpretation of parameter values and their development is often difficult because they are superimposed by artifacts, e.g., an accidently dropped pulse sensor. In consequence, the validation of received parameter values preceding the actual interpretation is a crucial issue.

In this paper we present an approach for a visual representation of temporal abstraction and validation knowledge allowing for an intuitive and precise formalization. The applied visual patterns were adopted from knowledge engineering interviews taken with the domain specialists and were refined in order to allow for a formal and precise interpretation of the modeled temporal knowledge.

The visually acquired patterns will be translated to a textual representation in order to be integrated into a rule-based formalism. This enables a combination of temporal patterns and non-temporal rule conditions including conjunctions, such as *and*, *or* and *not* expressions.

The context of our work is an intelligent monitoring and alarm system to be used during surgeries or in IC units, there supporting the work of anesthetists.

The paper focuses on the development of high–level abstractions, i.e., deriving meaningful alarms or artifacts, although the handling of basic abstractions derived from raw data streams is also an important task.

The derivation of intelligent alarms is two-folded in our system: In the first step we try to detect defined states of artifacts within previously abstracted data streams and annotate the data with possibly found artifacts (thus enabling for a high-level data validation). In the second step we investigate the annotated data streams for defined alarm states, e.g. *insufficient anesthesia* and *hypovolemia*.

2 A Visual Representation for High-Level Abstractions

The manual definition of complex patterns of the particular parameter changes over time is a difficult and error–prone task. For this reason we introduce an intuitive and visual representation for describing such patterns, i.e., *Abstract Temporal Curves (ATC)*, which can be interpreted as conditions for temporal rules for deriving high-level abstractions, i.e. artifacts and alarms. The representation offers a curve-like description of the temporal behavior of parameters, thus describing certain phenomena.

2.1 Abstract Temporal Curves

In the following, we introduce simple graphical elements that enable a description of basic events occurring in abstract parameter courses. Thereafter, we define temporal constraints that can be applied to events in order to describe the temporal behavior. A more complex temporal pattern is described by a set of events, attached constraints and a maximum duration restricting the entire pattern.

The modeling basis of an ATC contains layers for each involved parameter (Figure 1). Horizontal lines denote the corresponding abstract parameter values. There exist two basic elements that can be combined in different ways in order to describe the possible events.

Edges are horizontal lines describing a persistent value the specified parameter may take. Parallel edges of the same parameter define alternative and possible values for the parameter.

Nodes are markers placed on edges at arbitrary positions. They define changes of parameter values and thus basically declare temporal constraints.

Changes in the specified parameter behavior must be separated by nodes. Additionally, further nodes can be placed at any position, as it has been done with the first defined node in Figure 1. Here the decrease of the abstracted parameter value *AP* (arterial blood pressure) is specified

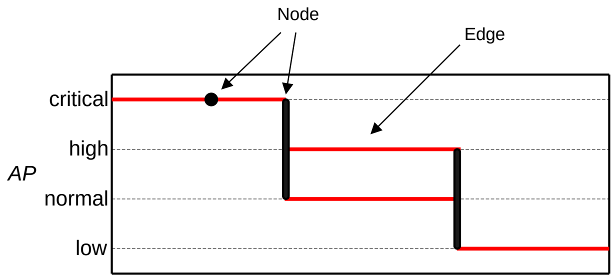

Figure 1: Edges and nodes in a parameter sequence in an ATC. Nodes can be defined at arbitrary positions on edges. They denote events expressing value changes and value persistence.

starting with value *critical* then falling to either *high* or *normal* and finally decreasing to the value *low*.

We extend the notation by *temporal constraints* between the nodes. A temporal constraint consists of a pair of nodes connected by a period. It denotes that the enclosed events need to occur within the specified time range. There are three alternatives to connect nodes by temporal constraints; Figure 2 depicts different types of constraints: A *sequence (c)* defines a time span for a certain event flow, occurring on a single parameter. It is required to occur within the given period. A second alternative for a definition of temporal constraints are *intervals (a)*. An interval connects two nodes of different parameter courses, which means that the corresponding events need to occur in the given time span. With the third alternative, i.e., the *point-interval (b)*, we directly connect nodes in order to express that the corresponding events are required to occur simultaneously. The

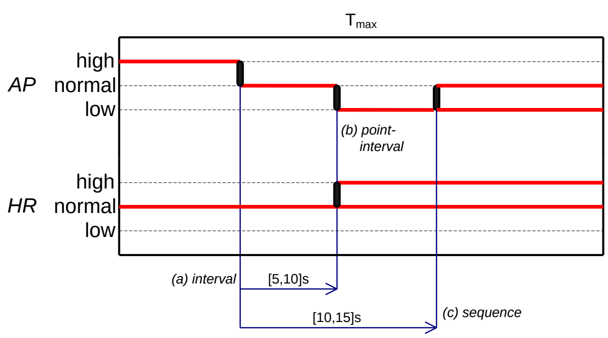

Figure 2: An ATC with temporal constraints defined between some nodes on the courses of the parameters *AP* (arterial blood pressure) and *HR* (heart rate).

additional global constraint T_{max} on top of the pattern description implies that the duration of the entire scenario is restricted to the time-interval $(0, T_{max}]$.

2.2 Translation of ATCs to Temporal Rules

The presented visual notation allows for an intuitive description of temporal events. These events will be compiled to a textual representation consisting of temporal events and expressions. The resulting temporal patterns can be combined with non-temporal rule conditions. Thus, they can be integrated into a rule-based formalism. For example, the rule framework of *d3web* [Baumeister, 2004] allows for a definition of complex rule conditions built up by non-terminal constructs, e.g. *and*, *or* and *not*. This enables the intuitive definiton of complex temporal patterns.

The presented work was implemented in the context of a medical project aiming for an intelligent detection of artifacts and alarms during surgeries. Two medical experts were involved with the formalization and refinement of the temporal knowledge including a variety of typical artifact and alarms. It turned out that the domain specialists got familiar very quickly with the meaning of the visual knowledge representation. This was not surprising since the representation was adopted from the observations made during knowledge acquisition interviews conducted with the domain specialists. In fact, similar curves were drawn on paper during the interview sessions to explain the particular events. Consequently, almost no training phase was required and the initial model was discussed and implemented in about 5 minutes for each pattern. However, the main effort consisted in testing and refining the collected patterns. The most complex task was the appropriate definition and refinement of temporal constraints included in the patterns. These adaptations required frequent testing cycles. For simple patterns, e.g., mostly artifacts, the refinement phase took about 10 minutes, whereas more complex patterns required more than 30 minutes for adaptation and testing.

In the literature, representations for high-level abstractions are mostly graph-based. A related approach to our visual representation can be found in [Chittaro and Combi, 2003]. There, three alternative visual vocabularies representing intervals and their relations (as subset of Allen-Relations), based on objects from the physical world, are presented. But, explicit temporal periods (e.g. $[10s, 30s]$) can not be modeled, as it is possible in our approach.

In the future we are planning to integrate a fuzzy definition of abstraction thresholds and temporal expressions, since an exact definition turned out to be one of the most difficult tasks. Visualizations of temporal uncertainty has been accomplished e.g. in [Kosara and Miksch, 1999]. Furthermore, we consider the semi-automation of the refinement process of the patterns by adapting discovery algorithms for this task.

References

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