Knowledge-based Data Display Using $TrenD_X$

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Abstract

Exhaustive display of all available clinical data, particular in data-rich environments like the intensive care unit, can easily overwhelm the ability of clincians to comprehend the clinical status and evolution of their patients and may reduce their ability to detect pathological trends in a reliable and timely manner. SmartDisplay is a system we have designed that restricts the data sets displayed to time-lines of those parameters that are relevant to the patient context and to the particular care provider. The relevance criteria are provided by $TrenD_X$, a knowledge-based trend analysis system. SmartDisplay can also restrict the interval over which a parameter is displayed as a function of the pathological processes hypothesized.

Introduction and Background

The critical care data set provided for this symposium contains several parameters sampled approximately every 20 seconds for 12 hours. Simply presenting the data in line graph form and superimposing the oxygen saturation, heart rate, and mean systemic arterial pressure data does allow the clinician to observe trends and parameter interactions that are not otherwise obvious at the bedside. For instance. during the procedure of hand ventilation, a rise in heart rate clearly is associated with a fall in blood pressure on such a set of graphs. Most likely, (but not demonstrable with the available data) the hand ventilation was associated with higher mean airway pressures than those achieved with mechanical ventilation. High mean airway pressures, in the volume deficient patient, may cause a fall in systemic blood pressure. Knowledge of the data trends may provide the clinician with an opportunity to observe (even over multiple caregivers) such effects and therefore change therapy accordingly. A graphical summary of this data may permit rapid communication of these trends [1].

However, in routine clinical operation, multiple, collated real-time graphs of each measured parameter are inadequate (such as those available on several commercial ICU charting systems) and possibly confusing. The ICU data set provided for this symposium contains, at the most, 25% of the data which can be obtained on-line and in real-time [2]. Furthermore, a patient will be in the ICU for days or even weeks. Consequently, simply displaying a scrolling window over a two-week history of each measured parameter is likely to be unhelpful.

Consider one of the tasks of an ICU nurse. Typically, he will be intermittently watching the monitors for evidence of current or impending cardiopulmonary pathology and therefore will be interested in only the last few minutes of monitored data (e.g. the heart rate as measured from the ECG). However, there are some parameters that are worth tracking over the entire period the patient was monitored. For instance, prior to administering a specified dose of a potentially toxic, renally-cleared antibiotic, knowledge of how much of the antibiotic was administered over the past week and at what level of serum creatinine (an index of renal function) would

serve as a check to avoid erroneous dosing. The question this begs is: which parameters should be displayed and over what period of time should each parameter display cover? This paper provides one set of answers to this question.

Methodology

SmartDisplay is a program that we are developing that employs a trend analysis program called TrenDx [3] to determine which parameters should be displayed and with what temporal granularity. TrenDx has been successfully used to diagnose growth disorders [4] and we already have begun to explore its use in other domains [5] including intensive care. TrenDx represents monitored processes as value constraints over specified parameters. Typically there are several phases of each process and each phase will have a specified, possibly variable duration and its own specific value constraints. TrenDx attempts to match patient data to the Trend Templates which represent the various plausible alternate interpretations of the monitored data. A set of mutually exclusive, competing Trend Templates defines a *monitor set.* These Trend Templates are then ranked by how closely they match the patient data. If a Trend Template is ranked highly this can be interpreted to mean that the data monitored by that Trend Template matches or fits it better than other templates within the same monitor set. Figure 1 illustrates the monitor set for "hand bagging" ventilation. The monitor set includes the patterns of blood pressure changes, heart rate changes and oxygen saturation characteristic of several kinds of hand bagging. Two of these are "adequate" hand bagging without significant compromise of venous return and hand bagging associated with decreased venous return. This monitor set is described in greater detail in another paper in these proceedings by Haimowitz and Kohane.

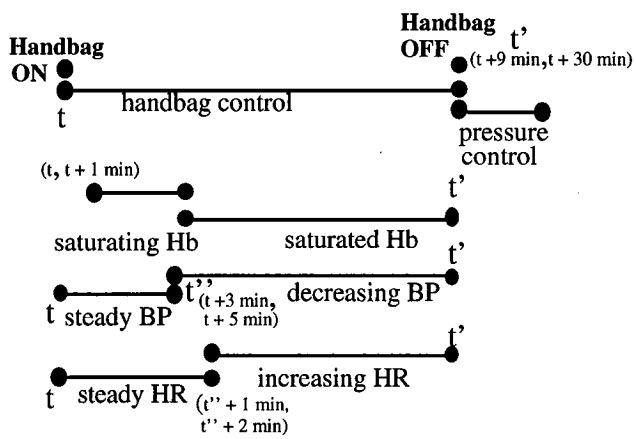

Figure 1(a): A trend template in the monitor set for hand bagging: Hand bagging with compromised venous return.

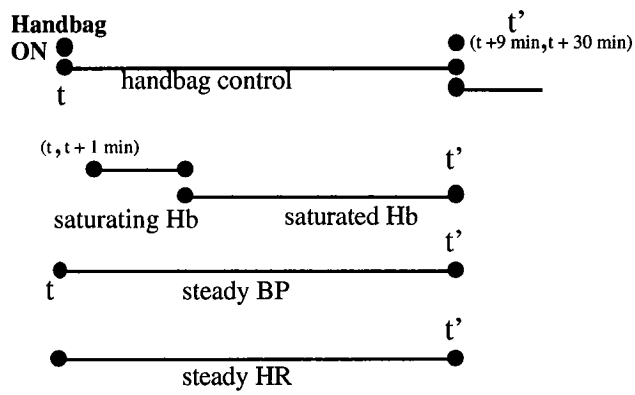

Figure 1(b): A trend template in the monitor set for hand bagging: adequate hand bagging.

Although, as shown in figure 1, there can be several parameters that are associated with each interval in the Trend Template, a clinician may only find a subset of these useful to display on a time-line plot. For example, a respiratory therapist may only be interested in monitoring oxygen saturation and blood pressure during the period of hand-bagging. Therefore for each Trend Template there must be a defined set of parameter display tuples *{Provider,Trend Template,parameter,TLspec}* which describe which parameters should be displayed for a particular class of care providers. The *TLspec* defines for each parameter display tuple, the characteristic of the time-line display for each parameter as described below.

Figure 1 shows that a parameter, such as heart rate, can be constrained on multiple intervals. By default SmartDisplay will generate a time-line for each displayed parameter that covers the maximum period containing all the time-segments over which the parameter is constrained in the Trend Template. However, this default time-line may be inappropriate for particular templates or clinicians. For example, the time-line of the heart rate parameter in the hand-bagging Trend Template may be most relevant and interesting around the time of transition from stable heart rate to increasing heart rate. Therefore, for each parameter in each Trend Template, SmartDisplay allows the knowledge-engineer or the user to specify the temporal extent of the time-line generated for each displayed parameter. This specification is defined in terms of a time-line language similar to that of Cousins and Kahn[6]. This language provides several operators for creating time-lines from one or two specified time-lines. For example, the SLICE operator selects the segment of a time-line between two specified events. In figure 1, a knowledge engineer can specify with the SLICE operator that the heart rate time-line should only span the period from onset of decreasing blood pressure to the present. We also plan to use the operators Cousins and Kahn have defined for the display characteristics of the time-lines (e.g. alignment and granularity) . All these time-line specifications are included in the *TLspec* of the parameter display tuples (described above) associated with each Trend Template.

For each patient monitored and for each clinician using the display system, SmartDisplay monitors the ranked list of Trend Templates generated by TrenDx. Every 30 seconds the top ranked Trend Templates from each monitor set is selected. The parameter display tuples which match these two Trend Templates and the bedside care provider are retrieved and the time-line specification of each tuple is executed. If there is more than one time-line for a given parameter, the OVERLAY time-line operator is used generate a single time-line for each parameter. If no Trend Template matches the data sufficiently well, then SmartDisplay

defaults to displaying the heart rate, blood pressure and oxygen saturation over the last minute.

The anticipated consequence of the SmartDisplay design is that clinicians will be provided with a view of the bedside monitor data set focused upon those parameters that are most clinically relevant to the current patient context (i.e. pertaining to the clinically significant processes hypothesized to be likely) and to the clinician's role in the ICU. Furthermore, the temporal extent of the time-lines displayed will be restricted to intervals deemed to be particularly important in alerting the clinician to a parameter trend in the hypothesized processes. We note that these expectations are based on the reasonable assumption that knowledge engineers will only build trend templates to monitor clinically significant processes.

Research Questions and Future Work

We are currently still implementing the SmartDisplay system and therefore have yet to answer several important questions. These include:

• Does SmartDisplay improve the rate at which clinicians accurately detect pathological processes? Is any change in performance related to the amount of data presented compared to commercial display systems?

• Does the scoring of the match of Trend Templates to patient data results in sufficiently stable ranking of Trend Templates. If the ranking changes rapidly and often, this may cause unwanted and distracting changes in the graphical display. If necessary, a carefully designed filter applied to the rankings will reduce the frequency of very transient displays. These performance issues will be explored by running SmartDisplay against the ICU test data set and larger data sets.

• Is there any additional benefit in displaying explicit diagnostic information? Would SmartDisplay be improved by including the names of the Trend Templates (which correspond to hypothesized pathological processes) from which the parameter display tuples are obtained?

Answers to most of these questions require testing SmartDisplay in conditions closely approximating clinical practice. In the short term however, we are working on implementing a robust version of the system including a sufficiently rich collection of Trend Templates.

References.

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