Chapter LI
Alarm Design in Computerized Medical Equipment

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ABSTRACT

Alarms are frequently employed in safety-critical environments such as in aviation and nuclear power plants. Now that microcomputer technology has revolutionized the design of patient monitors for use in modern hospital operating rooms (ORs) and intensive care units (ICUs), alarms are used in countless medical products ranging from infusion pumps to ventilators. This is especially true in anesthesia/surgical and critical care environments. In this chapter we examine the use of alarms in the acute care clinical environment, focusing on their strengths and limitations in the setting of patient monitoring equipment.

INTRODUCTION

Alarms are frequently employed in safety-critical environments such as in aviation and nuclear power plants. Now that microcomputer technology has revolutionized the design of patient monitors for use in modern hospital operating rooms (ORs) and intensive-care units (ICUs), alarms are used in countless medical products ranging from infusion pumps to ventilators. This is especially true in anesthesia or surgical and critical-care environments. In this brief review, we examine the use of alarms in the acute-care clinical environment, focusing on its strengths and limitations in the setting of patient-monitoring equipment.

ALARM DESIGN

For a clinical alarm system to be helpful when an adverse clinical situation occurs, an alarm must be sounded, the problem identified and corrected, and the patient treated. The earlier

that an alarm occurs, the easier it is for the clinician to take actions to prevent patient injury (Schreiber & Schreiber, 1989).

Alarm systems in medical equipment should also be easy to (temporarily) silence, should offer power-on default settings to prevent the inadvertent use of settings meant for a previous patient, and should incorporate a display that enables the operator to detect problems or trends in its early stages. Also, the physical composition of auditory alarms should be designed to convey a sense of urgency that matches the actual urgency of the triggering clinical situation. Finally, the alarm should be nonstartling, instantly recognizable to the trained respondent, and designed such that it would not generally lead to anxiety in others, such as patients and their families (Quinn, 1989).

Alarms in medical equipment may be as straightforward as a simple threshold alarm such as an alarm that is activated when a patient's heart rate exceeds 120 beats per minute. Such simple alarm designs have the potential to be enhanced in several interesting ways. First, a duration condition might be added, such as the requirement that a patient's heart rate exceed 120 beats per minute for a period of, say, 30 seconds before alarm activation occurs. Note that such an arrangement has the potential to reduce the frequency of false alarms, but may also delay the detection of some important clinical events.

Second, the heart-rate data used for such an alarm system might be drawn from multiple sources, again in an effort to reduce the frequency of false alarms (sensor fusion). As an example, an alarm system might require that both the heart rate obtained from the electrocardiogram and the heart rate obtained from an alternate data source (e.g., pulse oximeter device, arterial catheter) exceed (or fall below) a particular number. (As a bonus, when the sources of information fail to provide similar numbers, the clinician can be informed that there is a data-quality problem, such as might result from movement artifacts or from other causes.)

New developments in intelligent or knowledge-based alarm technology have also been introduced commercially and experimentally with the hope of improving patient safety (Koski, Sukuvaara, Makivirta, & Kari, 1994; Westenskow, Orr, Simon, Bender, & Frankenberger, 1992). Such smart alarms combine expert-system techniques with alarm technology either to provide more informative alarms, to reduce the frequency of false alarms, or to provide initial suggestions about how to deal with the problem that triggered the alarm. These systems may offer the ability to change alarm priority with elapsed time (cascading alarms), or suppress secondary alarms that are the consequence of a primary alarm condition. Other smart alarm designs may suggest either a diagnosis or an operator intervention to tell the user more about how to handle the situation, or may offer a context-sensitive information display with specific clinical suggestions.

For instance, imagine a clinical monitoring system that was aware that the patient being monitored had severe coronary artery disease. Knowing that high heart rates are likely to produce coronary ischemia in such individuals, the monitor might offer a default high-heart-rate alarm of 85 beats per minute in such cases instead of a higher default heart-rate alarm (say, 120 beats per minute) that it might offer for patients with normal hearts. Similarly, alarms can be annunciated according to the urgency of the required response. Thus, a high-priority alarm requiring immediate response by a clinician might use a red indicator with a flashing frequency of 2 Hz, while a medium-priority alarm requiring prompt response to deal with a condition might use a yellow indicator with a flashing frequency of 1 Hz, and a low-priority