USER-INITIATED NOTIFICATION: A CONCEPT FOR AIDING THE MONITORING ACTIVITIES OF PROCESS CONTROL OPERATORS

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Monitoring activities in a process control environment are quite unique depending on the current situation and the operator's current understanding of that situation. Furthermore, the operator may be required to monitor multiple simultaneous events over potentially long periods of time. Currently, operators must periodically scan displays to gather such information, or manipulate the alarm or control system in ways not originally intended in order to gather that information as appropriate. Furthermore, if the monitoring activities span multiple operating shifts, then there is the potential for operators to forget to communicate these requirements at shift change. Despite the uniqueness of the situations that will require process events to be monitored, it is hypothesized that there is a limited set of conditions that can be pre-defined in a tool that will allow operators to set up their own monitoring "agents" according to their current diagnostic needs. Such a tool is predicted to decrease the working memory load of operators, and reduce the time it takes them to detect important process changes (or lack of them). Furthermore, it is proposed that this concept is extensible to other plant personnel and to other domains that have similar monitoring requirements. Although some potential pitfalls can be predicted with the introduction of this tool, the number of predicted benefits warrant the further exploration of this concept. This will be the next step in our design process.

INTRODUCTION

In process control or other environments requiring supervisory control of automation, operators need to monitor both significant events in the process as well as what the automation is doing to control the process (Woods, 1994). Monitoring activities take place in both normal and abnormal situations, particularly when an operator makes a set of control moves to change the state of the plant (e.g., either in response to normal plant operations requirements, such as changing the levels and kinds of products being manufactured, or in response to an anomaly situation to move the plant back to a safer state). In both types of situations, the operator needs to get feedback as to whether the intended effect of the control move has indeed taken place. This is primarily done by periodically checking overview, process and trend displays, talking to field operators, and by relying on the alarm system to alert the operator that the plant has reached an unsafe state. In several field studies of normal and abnormal operations, we have identified shortcomings of today's technology in supporting operations teams (Soken, Bullemer, Ramanathan and Reinhart, 1994). The purpose of this paper is to describe an interface design concept that would allow operators in a process control plant to initiate monitoring events based on their current diagnostic needs, thereby having a means to use the computer as a monitoring tool and notify them that the event has occurred instead of having to do the monitoring themselves. We call this concept *user-initiated notification*.

PLANT OPERATIONS

Normally, a process control plant is functionally divided into a number of units, such that an operations team is responsible for each unit of the plant. Each operations team consists of two to five field operators and one or two board operators (depending on the size of the unit). The field operators work on the unit itself, manually changing valves, watching for leaks, etc. and the board operator(s) monitor and control the unit through the use of a distributed control system (DCS) (Zwaga and Hoonhout, 1994), which is a computerized control system that has a number of operating displays, such as schematics, alarm summaries, and trend graphs. With this system, each automated controller or sensor is given a tag name, such as FI-201 (Flow Indicator 201). For each of these tags, the control system contains information about the sensed state of the process variable (PV), the setpoint (SP) and the output (OP) of the controller. Although operators monitor the plant through schematic, group, trend, and alarm summary displays, it is generally plant engineers who are responsible for designing and implementing the control system, as well as all of the operating displays used and seen by each shift team.

The majority of communications that occur are between the field operators and board operators of a particular unit, but cross-unit communication is sometimes necessary, since products generally flow from one unit to another. Another important communication flow is during shift change, when the previous shift team must communicate important events to the next shift team. This information is passed verbally from one operator to the next, and the head operator out on the unit will write notes in a log book located on the unit and the board operator will write notes in a log book located in the control room. Finally, in some plants, operators will rotate their positions, such that one day an operator will be out in the field and the next day that same person may be operating the board, or responsible for a different position in the field. This cross-training has benefit for mutual understanding of roles and responsibilities and how each part of the job affects the other.

MONITORING ACTIVITIES

Field operators will conduct periodic rounds of their part of the plant, and check for any leaks through observation and check that pumps are operating correctly by sound and touch (field operators will touch a pump to feel for heat and vibration that is abnormal). Field operators also rely on the board operator to monitor process states that need to be checked in the field, such as a regulator or a valve being stuck. Sometimes, a field operator will call the board operator to tell him about an abnormal process state (e.g., “The wet gas compressor sounds like it’s cavitating!”). Sometimes, a DCS display is available in “the shed” on the unit, from which field operators can monitor, but not control the unit. Sometimes, a field operator will see an alarm on this display that is relevant to his area that he will respond to even before the board operator has a chance to contact him.

Board operators will monitor the plant from the control room primarily through the displays available to him on the DCS. There can be hundreds of such displays, and 6-8 screens can be seen at a time (depending on the number of monitors he has). Generally, operators will leave 3 or 4 overview displays up at all times, and change the views seen on the other screens as necessary.

Board operators will rely heavily on the alarm system (and to a less extent field operators) to notify them of abnormal states, and respond to those as necessary. Board operators may also need to monitor particular plant states more carefully, based on their current tasks (such as following a procedure, changing the operating conditions of the plant, etc.).

In our own field studies of petrochemical operations and in a field study of nuclear power plant operators conducted by Vicente & Burns (1995), a number of interesting observations were made about the ways that operators of a plant will manipulate their environment to support their monitoring activities, thus “finishing the design” of the tools available to them. For example, Vicente & Burns (1995) observed operators leaving the doors open on strip charts that needed closer monitoring to remind both themselves and operators on later shifts that these particular process variables deserved closer attention. Another observation was that operators would sometimes manipulate alarm limit setpoints during operations, not because the previous alarm limits were inappropriate, but because a situation had occurred which required them to monitor a particular process variable for certain characteristics that were not necessarily an alarm state.

In our own observations of plant operators, such manipulation of alarm limits is a rare event (since a shift supervisor usually needs to physically turn a key to allow for this capability). What should be noted, however, is that since the alarm system is designed for orienting of abnormal states, operators will sometimes manipulate the alarm system to support orienting of other kinds of states that the operator feels are informative. That is because appropriate, dynamic mechanisms are not currently available to support this functional requirement of plant operations. The following situations were identified where such a strategy might be useful:

- increasing the setpoint after an initial alarm to get a "second chance" (since the process value may continue to increase after having "passed" the alarm limit and one would like to monitor for that).
- changing the alarm setpoint to a value at which time an action needs to be taken (as in following a procedure).
- manipulating the setpoint on a variable that is correlated with one that needs to be monitored but is not alarmed.

Once the event of interest has happened, the intent is to set the alarm limits back to where they were. However, operators may forget to take this step, thus risking the lack of alarms when appropriate, a situation which can become worse at shift change, since the next operator will have no idea that the previous operator has forgotten to reset some of the alarm limits.

USER-INITIATED NOTIFICATION

Since much of the information necessary to monitor the plant is centrally located in the DCS, it becomes possible to use this information to the operator's advantage. The idea behind user-initiated notification is to design a tool that will give the operator of a distributed control system a means to easily generate information about the process related to their current diagnostic needs. Thus, it gives operators more flexibility and control over what types of information they would like to hear about, rather than having to rely on the pre-defined alarm limits set up ahead of time by plant engineers. This is useful since alarm limits are set up based on "steady state" operations (and are thus not as helpful in other situations, such as startup). Moreover, there are significant, situation-specific needs for notification events that do not qualify as alarm events, (i.e., a vessel filling to the halfway mark is informative and important to know in the current task context but not an alarm condition).

The initial concept was based on the idea that there are a set of alarm-initiated activities, taken from (Stanton, 1994): 1) Observe (hear) alarm 2) Accept alarm 3) Analyze alarm message 4) Investigate cause of alarm 5) Take corrective action 6) Monitor that the corrective action has had the desired effect. In other words, operators will often make a control move (such as opening a valve) that they think will have the desired effect (e.g., increasing flow to another area of the plant). However, in order to ensure that the desired affect has indeed taken place, the operator must actively monitor those values. People are not very good at vigilance and monitoring tasks and there is a cost to sampling — attention will have to be diverted away from some other activity (Stanton, 1994).

The intent, then, for the user-initiated notification tool, is to provide the operator with an easy means to ask the computer to monitor various process values for certain conditions (e.g., reaching a particular value, increasing, decreasing, high rate of change, etc.) and be notified of that condition when it occurs. The potential benefits of such a display are the following:

- Avoids the "inappropriate" use of the alarm system to generate this type of information.
- Offloads operator's memory by providing a tool to do specific types of monitoring.
- Allows for "temporary" monitoring activities that are only in effect until the event is triggered or the operator deletes that monitor.
- Allows operators to have control and flexibility over what type of information is displayed.
- Could be used as a "handoff" tool at shift change (one operator could discuss the monitors that are currently in place and why, giving the next operator a context of what kinds of important things are happening in the process).

- Gives operators a way to be more "proactive" in their monitoring activities without lots of effort.
- Can be used as a knowledge acquisition tool - of what kinds of information operators feel they'd like to see.

When this user interface concept was described to plant engineers and operators at a couple of petrochemical companies, they instantly saw the value of the display and could think of many situations in which this kind of a tool would be useful:

- To monitor that a control move has had the desired effect.
- To monitor for certain constraints in the process (e.g., the operator often increases the rate of feed input until certain constraining limits are reached. The operator could have the computer monitor for these conditions).
- To aid in transferring the operating task at shift change (since the next operator could see what monitors had been initiated by the previous operator).
- To aid in following procedures (e.g., since procedures often are of the form, "Bring the level to 20%, then start pump X - the operator could have the computer monitor for this condition, so the operator would know when it was time to move to the next step).

In fact, plant personnel suggested uses for the tool that far exceeded the original intent of the concept:

- To facilitate coordination between board operators, field operators, instrumentation men, and plant engineers (e.g., the board operator could tell the computer, "If this value gets to X, tell the field operator to take a sample.")
- Plant engineers could use it to "look over the shoulder" of board operators to see if they are employing good standards of practice.
- Plant engineers could set up generic monitors that are specific to a particular situation, such as startup, and save and call up a set of these reminders as appropriate.
- Operators and/or engineers could use it to set up periodic reminders (e.g., certain pieces of equipment need to be tested every two weeks).
- Plant supervisors could use it to see if plant goals were being reached.

What was interesting was that the original intent of the concept was quite simple, but plant personnel could immediately envision multiple, diverse extensions to the concept. The common theme was that a tool like this could be designed for each type of person in the plant (field operator, board operator, supervisor, engineer, etc.) to monitor for their information requirements. In fact, this concept appears to be generic enough that it could be applied not only in the process control domain, but in many domains that have similar monitoring requirements.

OPENING UP PANDORA'S BOX?

In the brief period of time that we have explored this interface concept, it could already be envisioned that such a monitoring system could actually have a dark side. What if operators set up a number of monitors that the next operator does not want? Perhaps there should be a time-out for these monitors, or they are personalized to each operator. While the initial concept was for operators to initiate a small set of temporary monitors, plant engineers could envision thousands of these monitors being set up to monitor for various plant characteristics. If so, then perhaps the alarm flood problem will only be added to with a "notification flood". What was originally designed as a concept to aid the monitoring activities of operators could potentially increase the problem of information overload. Perhaps there should be a limit to the number and kind of monitors that can be invoked at one time. Finally, if engineers could use such a system to "watch over the shoulders" of operators, it could be used as a method to assign blame to operators for poor performance. Perhaps these kinds of options should not be designed into the monitoring system, so such capabilities are not possible. On the other hand, displays that support monitoring of group activity are needed. The very intriguing aspect of this concept is that it enables others to see more of the formerly hidden monitoring activities of plant personnel. Despite some of the foreseeable problems with this interface concept, the number of foreseeable benefits certainly warrants exploring this concept further, while considering design features that will limit the potential negative consequences that this tool could introduce.

CURRENT DEVELOPMENT

Based on the initial positive response we had to the concept of user-initiated notification, we are currently developing a test prototype of this kind of a tool in a petrochemical plant. This is a tool in addition to the current alarm system, that will eventually allow operators to set up to 20 monitors at a time. These are either event-based logical, event-based analog, or time-based. Event-based analog monitors can check for whether the setpoint, output, or process variable of any flow, level, pressure or temperature is equal to, greater than, or less than either a particular value (such as 100°) or another process parameter (i.e., “Tell me if this flow equals another flow”). Logical combinations allow for two values to be combined with AND or OR. Logical flags for each process parameter can also be checked, such as, “Tell me if this value goes out of alarm”. This is particularly useful when bringing a piece of equipment back on line. When the level in a tank reaches the low alarm limit, for example, you know that it is filling up as intended.

Currently, the system is working for most of these cases, for a particular board operator. Further planned functionality includes having time-based monitors which can either be one-time events, such as, “Remind me at 1:00 to take a sample” or periodic, such as, “Remind the field operator every Monday morning to take these samples.” The next step in our design process will be to design a front-end interface to allow operators to specify these monitors in an easy-to-use format. As a first step, operators will be able to specify a query by choosing from a list of options, and have the ability to turn monitors on and off or erase them completely. They can also specify how they would like to be notified, whether as a sound, or in a message list on the alarm summary. This simple version will be tested for user acceptance and utility before extending the concept to be more integrated with their current operating displays. For example, it may be possible to set up monitors directly from trend graphs and other schematics and utilize different means for notifying operators, such as marking flags directly on schematics. These concepts will be explored further as we learn more about the actual use of this tool by operations.

CONCLUSION

Monitoring activities taken by operators in a process control environment are quite unique depending on the current situation and operator's current understanding of that situation. Furthermore, the operator may be required to monitor multiple simultaneous events over potentially long periods of time. Currently, the operator must periodically scan displays to gather such information, or manipulate the alarm or control system in ways not originally intended in order to gather that information as appropriate. Furthermore, if the monitoring activities span multiple operating shifts, then there is the potential for operators to forget to communicate these requirements at shift change. Despite the uniqueness of the situations that will require process events to be monitored, it is hypothesized that there is a limited set of circumstances that can be pre-defined in a tool that will allow operators to set up their own monitoring "agents" according to their current diagnostic needs. Such a tool is predicted to decrease the working memory load of operators, and reduce the time it takes them to detect important process changes (or lack of them). Furthermore, it is proposed that this concept is extensible to other plant personnel and to other domains that have similar monitoring requirements. Although some potential pitfalls can be predicted with the introduction of this tool, the number of predicted benefits warrant the further exploration of this concept. This will be the next step in our design process.

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