### Problem

- In modern hospitals, vital signs are continuously monitored with a variety of medical devices.
- Many devices are configured with threshold alarms, which are considerably limited:
  - Monitors only raise alarms when the threshold is crossed
  - Monitors are oblivious to each other
  - Monitors typically don’t use patient information to customize alarms
  - Monitors do not provide detailed rational for alarms

- As a result monitors produce many false alarms, which have been shown to have an adverse effect on patient care.
- Of false alarms generated by test data were suppressed using GSA.
- Many devices are configured with threshold alarms, which are considerably limited:
  - Monitors only raise alarms when the threshold is crossed
  - Monitors are oblivious to each other
  - Monitors typically don’t use patient information to customize alarms
  - Monitors do not provide detailed rationale for alarms

### Applications

**CABG Smart Alarm**
- Patients who undergo coronary artery bypass graft (CABG) surgery are high risk post-surgery, in the ICU.
- To mitigate the failures associated with threshold alarms, we implemented a rule-based system which monitors multiple vital signs to distinguish data artifacts from true patient distress.
- Combining vital signs in this way produced a 57.13% reduction in the number of false alarms generated without suppressing any true alarms.

**Closed Loop Control**
- Patient Controlled Analgesia pumps increase patient comfort, but are associated with a large number of adverse effects.
- Using multiple vital signs, respiratory depression can be detected.
- The PCA pump can be disabled for the duration of the distress state.

### Flexible Architecture

The system is a configurable pipeline of sensing, processing, and output elements. Each configuration can be instantiated on the GSA platform and executed with physical devices, virtual patients, or prerecorded patient data.

### Challenges

- **Interoperability:** To reduce false alarms, we should use multiple vital signs, from multiple devices.
- **Current devices are rarely interoperable.**
- **Differing data formats**
- **Differing data rates**

### Other Work

- Other projects in development utilizing this framework include:
  - Clinical decision support for vasopressor detection in subarachnoid hemmorage patients.
  - Closed loop insulin control using a diabetic patient model.

### Validation

- Deploy systems on top of a separately validated middleware platform.
  - Leverage the middleware’s safety properties of the system.
  - Validation can focus on checking:
    - Individual components
    - Coordination scripts
    - Rule set consistency
  - Simplifies validation procedures

### Other Work

- Other projects in development utilizing this framework include:
  - Clinical decision support for vasopressor detection in subarachnoid hemmorage patients.
  - Closed loop insulin control using a diabetic patient model.
Problem

- False alarms are commonly generated.
- Pump control is problematic.
- Multi-vital closed loop PCA is suppressed using GSA.

Applications

- CABG Smart Alarm: Monitored with a variety of medical devices.
  - Closed Loop Control
  - Patient Controlled Analgesia pumps increase patient comfort, but are limited: many devices are configured without suppressing any true alarms.

Challenges

- Interoperability:
  - Differing data rates
  - Differing data formats
- Coordination scripts

Validation

- Validate the following:
  - Safety properties of the middleware platform.
  - Interoperability:
  - Differing data rates and formats

Flexible Architecture

- Components can be configured to solve different problems. Each configuration can be tested on the GSA designer.

Other Work

- Rule-based system which issues threshold alarms, we implemented a statistical model, used to describe the patient's state; identifies combinations of vital signs which would be cause for concern.
- Statistical techniques. Choosing the right techniques is difficult. Models would aid in predicting the patient's future state.
- Biological complexity makes it difficult to calculate the best performance. Choosing the one with multiple models to check:
  - Rule set consistency
  - Coordination scripts
  - Interpretation of Data:
  - Some data sources are difficult to interpret automatically (e.g. EEG).
- Other projects in development utilizing this framework include:
  - Closed loop insulin control using a diabetic model.
  - Clinical decision support for vasospasm detection in subarachnoid hemmorage patients.