Generic Smart Alarm

Andrew King, Alex Roederer, Sanjian Chen, Philip Asare, Oleg Sokolsky, Insup Lee

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Problem

•In modern hospitals, vital signs are continuously monitored with a variety of medical devices.

Studies have shown up to **75%** of alarms are false positives.[1]

57% of false alarms generated by test data were suppressed using GSA.

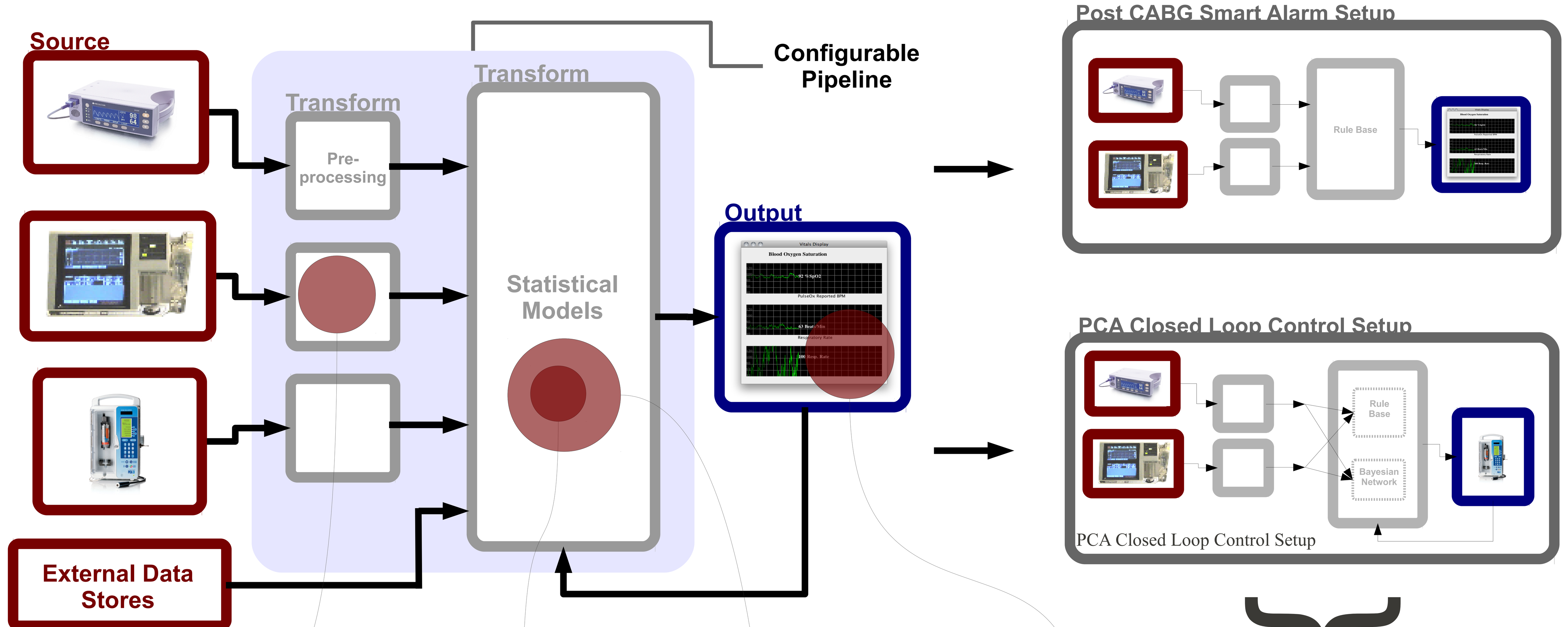
•Many devices are configured with threshold alarms, which are considerably limited:

- 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 rational for alarms

•As a result monitors produce many false alarms, which have been shown to have an adverse affect on patient care.

Flexible Architecture

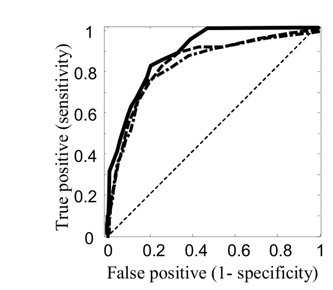
The system is a configurable pipeline of sensing, processing, and output elements. Each configuration can be instantiated on the GSA platform and executed with physical devices, virtual patients, or prerecorded patient data.



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



ROC Curve: It is feasible to compare the performance of multiple models to choose the one with the best performance.

•Intelligence:

- Biological complexity makes building patient models difficult. Models would aid in predicting the patient's future state.
- We can approximate models utilizing statistical techniques.
- There are many different techniques. Choosing the right one is difficult.

•Interpretation of Data:

- Some data sources are difficult to interpret automatically (e.g. EEG).
- Application of time series analysis or similar will likely be required.

•Data Display

- The most effective method to deliver information to medical professionals is unknown.

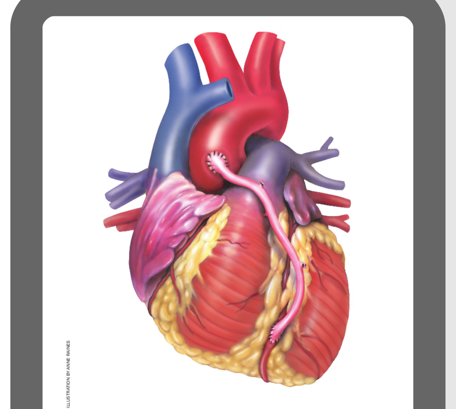
Applications

CABG Smart Alarm

•Patients who undergo coronary artery bypass graft (CABG) surgery are high risk post-surgery, in the ICU.[2]

•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..



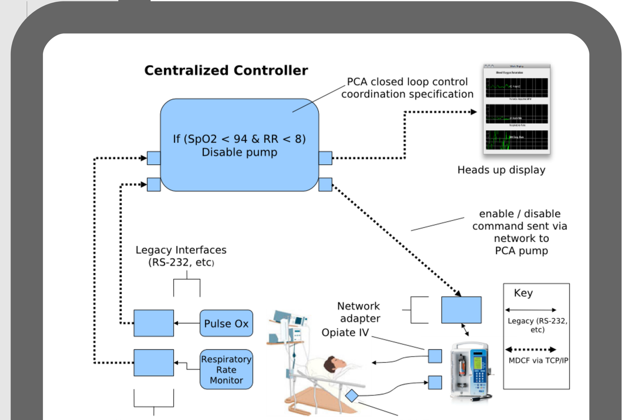
Heart with coronary artery bypass graft.[2]

Closed Loop Control

•Patient Controlled Analgesia pumps increase patient comfort, but are associated with a large number of adverse effects.[3]

•Using multiple vital signs, respiratory depression can be detected.

•The PCA pump can be disabled for the duration of the distress state.



Multi-vital closed loop PCA pump control

BP	HR	SPO_2	RR	Alarm Level
Normal	Normal	Normal	Normal	0
High	Normal	Normal	Low	1
High	Low	Normal	Normal	2
Very Low	Normal	Normal	High	3
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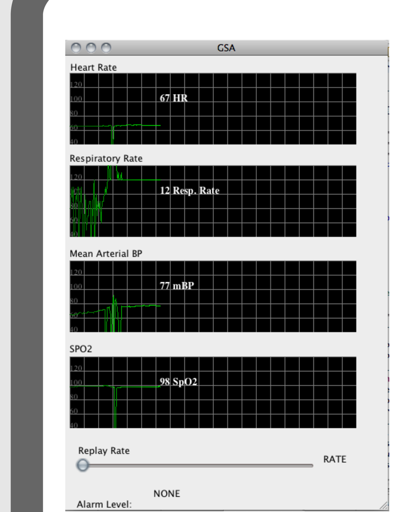
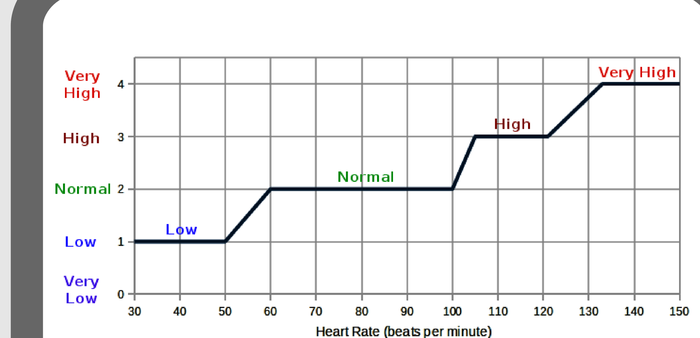
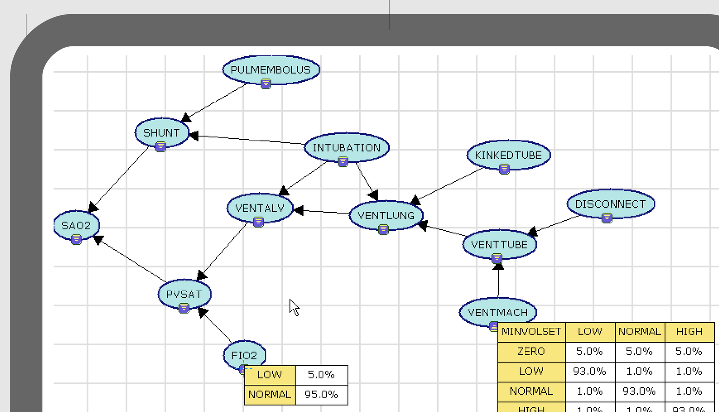
Rule Set: the simplest type of statistical model, used to describe the patient's state; identifies combinations of vital signs which would be cause for concern (based on interviews of medical experts).



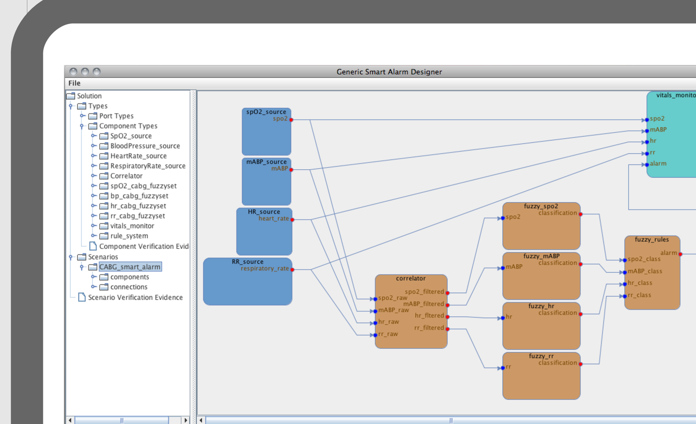
(Figure 3) Output: The components responsible for delivering information to the medical professional, or for relaying an actionable decision message to a medical device.



Preprocessing: Some vital signs require preprocessing for analysis.
In this demo, classifiers break continuous vital signs into discrete classes (established through medical expert interviews).



Inference Module: The inference module receives vital sign information, and uses a model or models to perform a useful transformation or answer a question. Here, four vital signs are transformed into an alarm level.

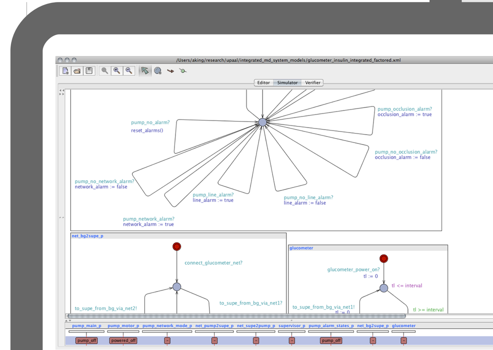


Design: CABG Smart Alarm System modeled in the GSA designer; system models can be exported and instantiated.

Validation

•Deploy systems on top of a separately validated middleware platform.

- Leverage the middleware's safety
- properties to prove the safety properties of the system.
- Validation can focus on checking:
  - Individual components
  - Coordination scripts
  - Rule set consistency



Model check individual GSA configurations

- Simplifies validation procedures

Other Work

•Other projects in development utilizing this framework include:

- Clinical decision support for vasospasm detection in subarachnoid hemmorage patients
- Closed loop insulin control using a diabetic patient model

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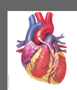

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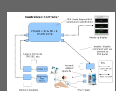

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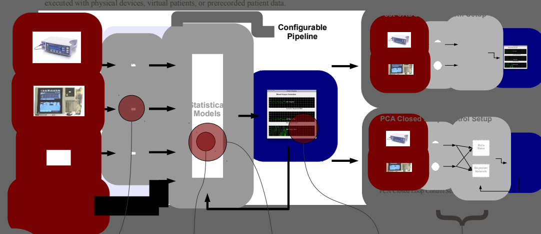

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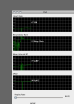

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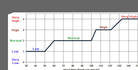

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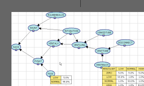

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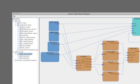

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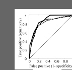

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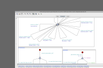

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