Process Driven Guidance for Complex Surgical Procedures

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Problem: Surgical Team Procedures are often Inherently Complex and Error Prone

- Involve coordination among:
  - Multiple specialty teams
  - Different software applications
  - Suite of medical devices

- Problems with non-technical skills are a leading cause of medical errors
Goal: Support Human Performance in the Operating Room

Reduce preventable errors by providing guidance to surgical teams carrying out medical procedures (or processes)

• Model normative situations and non-normative (i.e. unusual or exceptional) situations where problems are identified and must be addressed

• Focus on support for non-technical skills
Limitations of Previous Approaches

• Process guides (e.g., checklists) often do not model some situations that are highly complex and high risk — e.g., non-normative situations, team communication

• Most guides are static so lack dynamic process context

• Dynamic guides hardcode the process so cannot be easily updated when that process changes

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Approach of This Work

Provide an automated process guidance system with a:

- **“Smart” Checklist User Interface** dynamically providing context-aware support during real-world situations (i.e. online)
- **Narration View** for supporting walking through selected training situations (i.e. offline)

Leverage a surgical process model that:

- Defines the recommended surgical process
- Has rigorous execution semantics
- After process improvements, update model to automatically update guidance
Contributions

• Developing a prototype process-model-driven guidance system for use by surgical team members in online and offline settings

• Building models for cardiac surgery processes

  Aortic Valve Replacement (AVR) and Coronary Artery Bypass Grafting (CABG)

• Evaluating this guidance system on highly complex and high risk portions of those models
  – Obtained positive feedback from the team members
Online Guidance: Smart Checklist System

• Automatically create a “smart” checklist user interface to help each specialty team understand:
  – its own dynamic process context
  – the contexts of the other teams

• Dynamically update the user interface by matching the process model against monitored process execution events
  – Store the process history to create post-procedure documentation
Example: Smart Checklist (Multi-Team)

**Smart Checklist**

**TEAM**
- Anesthesiology (A):
- Nursing (N):
- Perfusion (P):
- Surgery (S):

**PATIENT**
- Name: John Smith
- Gender: Male
- NUR: 945078

**Procedure**

**Anesthesiology**
- N, P, S: Perform wean from bypass safety checks
- P: Determine protamine dose
- A, N, P, S: Restart ventilation, wean from bypass, then assess heart and also determine protamine dose
- A, N, P, S: Start ventilation
- P, S: Wean from bypass

**Perfusion**
- N, P, S: Perform wean from bypass safety checks
- P: Determine protamine dose
- A, N, P, S: Restart ventilation, wean from bypass, then assess heart

**Surgery**
- N, P, S: Perform wean from bypass safety checks
- P: Determine protamine dose
- A, N, P, S: Restart ventilation, wean from bypass, then assess heart

**CPB Pump**
- HALF FLOW
- Ventilator:
- ON
- Baseline ACT:
- 140 s

**ISOLATED CABG**
- **In Progress**
- A, P, S: Initiate bypass
- N, P, S: Clamp aorta and deliver cardioplegia
- N, P, S: Anesthetize
- A, N, P, S: Separate from bypass

**Activity Log**
- Date: 14:45
- Task: N, P, S: Perform wean from bypass safety checks
  - Completion: 14:45
- Task: P: Determine protamine dose
  - Completion: 14:54
- Task: A, N, P, S: Restart ventilation, wean from bypass, then assess heart
  - Completion: 14:53
- Task: A, S: Restart ventilation
  - Completion: 14:53
- Task: A, P, S: Wean from bypass
  - Completion: 14:53
Example: Smart Checklist (Multi-Team)
Example: Smart Checklist (Surgery Team)

Perfusion

Surgery

Assess LV wall motion

A: Perform TEE to assess LV wall motion

S(A): Review TEE findings to assess LV wall motion

A,S: IF (Found LV wall motion abnormalities), Address LV wall motion abnormalities

A,S,P,S: Reduce CPB pump flow to 1 L/min
Example: Smart Checklist (Surgery Team)

Perfusion

Surgery

Assess LV wall motion

A: Perform TEE to assess LV wall motion

S(A): Review TEE findings to assess LV wall motion

A, S: IF (Found LV wall motion abnormalities), Address LV wall motion abnormalities

A, P, S: Reduce CPB pump flow to 1 L/min
Example: Smart Checklist (Surgery Team)

Perfusion

Surgery

Assess LV wall motion

A: Perform TEE to assess LV wall motion

S(A): Review TEE findings to assess LV wall motion

A,S: IF (Found LV wall motion abnormalities), Address LV wall motion abnormalities

A,P,S: Reduce CPB pump flow to 1 L/min
Example: Smart Checklist (Surgery Team)

Perfusion

Surgery

Assess LV wall motion

A: Perform TEE to assess LV wall motion

S(A): Review TEE findings to assess LV wall motion

A_S: IF (Found LV wall motion abnormalities), Address LV wall motion abnormalities

S: Confirm bypass graft patency

A_S: Provide inotropic/vasoactive support or else insert intra-aortic balloon pump

A_P_S: Reduce CPB pump flow to 1 L/min
Process-Model-Driven Guidance System

Process Model

- Open Integrated Clinical Environment (OpenICE)
- Process Execution Monitor
- Smart Checklist System
- Narration Generator

Smart Checklist User Interface

Process History

Narration View

Patient Device Data
Process-Model-Driven Guidance System

Open Integrated Clinical Environment (OpenICE)

Process Execution Monitor

Smart Checklist System

Narration Generator

Smart Checklist User Interface

Process History

Narration View

Patient Device Data
Models for Complex Surgical Processes

• Hierarchically decompose each process into steps/substeps

• Rigorous execution semantics based on state machines
Process-Model-Driven Guidance System

Wean from bypass
- Reduce CPB pump flow by \( \frac{1}{2} \)
- Assess LV wall motion if needed
- Make decision about assessing LV wall motion
- Assess LV wall motion
- Review TEE findings to assess LV wall motion
- Reduce CPB pump flow to \( 1 \text{L/min} \)
- Address LV wall motion abnormalities
- Confirm bypass graft patency
- Treat LV wall motion abnormalities
- Provide inotropic/vasoactive support
- Insert aortic balloon pump

Smart Checklist System

Open Integrated Clinical Environment (OpenICE)

Process Execution Monitor

Smart Checklist User Interface

Process History

Narration Generator

Narration View
Post-Procedure Documentation

- Automatically create a **process history view** summarizing the actual path through the **process model** completed and can edit to further customize it.
Process-Model-Driven Guidance System

Process Model

Open Integrated Clinical Environment (OpenICE) → Process Execution Monitor → Smart Checklist System → Narration Generator

Patient Device Data → Smart Checklist User Interface

Smart Checklist System → Process History

Narration View
Offline Guidance for Training

- Automatically generate a **narration view** providing a hypertext description to selectively explore the alternative paths through a given **process model**
Evaluation of this Process-Model-Driven Guidance System

• Held focus groups and conducted pilot studies applying the system to critical portions of the surgical process models

• Could see many benefits that improved surgical team understanding of the process contexts:
  – Highlights key shared data
  – Organizes by step hierarchy
  – Provides best practices guidance for complex and/or high risk situations (e.g., non-normative)
  – Reduces workload by automatically generating post-procedure documentation that can be further annotated
Future Work

• Continuing to develop the process-model-driven guidance system based on clinician feedback
  – Explore automated process execution monitoring techniques
  – Investigate process prospection to anticipate highly complex and/or high risk situations

• Further evaluating this system by conducting clinical human simulation studies
  – Collaborating with STRATUS Simulation Laboratory at Brigham and Women’s Hospital

• Complement surgical data science methods
Summary

• Automatically provide online and offline guidance to medical teams to reduce preventable errors

• Leverage a process model capturing best practices
  – Focusing on non-technical skills

• During focus group evaluations, clinicians could see many benefits of such guidance
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