USING SOFTWARE ENGINEERING TO HELP REDUCE MEDICAL ERRORS

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How did I get here?

- BA, mathematics, University of Rochester
- Programmer, U of R Medical School
- PhD, CS, University of Colorado Boulder
- Faculty, University of Massachusetts Amherst
Research Focus

• Most of my career has focused on Software Engineering Research
  – How to make software systems more reliable
    • Automated testing techniques
    • Automated reasoning techniques
    • Better approaches for representing requirements
  – How to better support developers
    • Object management
    • Software architecture
Software Engineering

• A wonderful, rich area for research
• Systems are always getting more complex
  – Sequential to distributed
  – Internet-based to cloud-based, client-server
• Safety and security concerns are increasing
• But one day...
Medical Errors

A crisis in healthcare!

Could techniques developed for analyzing software systems be effectively applied to medical procedures to reduce errors and improve outcomes?
Question

- Leading causes of death in the US?
  - Heart disease ~611,000
  - Cancer ~584,000
  - Medical Errors ~440,000
  - Accidents ~130,000
What this means?

If 3 B747 airplanes crashed everyday, for an entire year, it would be equivalent to the number of deaths due to medical errors a year.
Medical Procedures

• 2009 National Research Council Report
  • "persistent problems do not reflect incompetence on the part of health care professionals - rather, they are a consequence of the inherent intellectual complexity of health care taken as a whole and
  • a medical care environment that has not been adequately structured to help clinicians avoid mistakes or to systematically improve their decision making and practice.”
Medical Procedures Are Complex, Distributed Systems

- **Human-Intensive Systems** that involve coordination among software applications, hardware devices, and human performers
  - Humans are central decision makers, but
  - Humans may be exhausted or distracted and may make mistakes
Our approach

**Model**
the medical procedure

**Evaluate** the model for:
- Sequence Errors
- Safety vulnerabilities
- Inefficiencies

Working with domain experts, **improve** the model/process
Model the medical procedure

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Little-JIL graphical view

Single-Unit Transfusion Process

Bedside Checks
Prepare for Infusion

Verify Patient ID
Product Verification

Administer Unit Blood Product

Begin Transfusion
Assess Patient

Suspected Transfusion Reaction
Stop Transfusion
Handle Adverse Reaction

Post Transfusion Work

Discard Transfusion Materials
Record Infusion Info

*Exception: Adverse Reaction
Perform Blood Specimen Obtaining Process
The following agent may be involved in this (sub)process: nurse

The following may be utilized in this step: specimen-container, label, agent: ma/nurse, specimen-collection-equipment.

To "perform Blood Specimen Obtaining process", the following need to be done in the listed order:

determine the need for blood test
order test(s)
recognize some tests have been ordered
collect labels
gather equipment for specimen collection
walk to patient
verify the correct patient to get specimen
obtain and label specimen
send blood specimen to lab

E If Info Not Match, report this error.
E If Patient Has Multiple ID Bands, report this error.
E If Info Not Found, report this error.
E If Patient Has No ID Band, report this error.
Sequence errors

Can event a happen before event b?

Use model checking techniques to verify if the property holds or provide counter example traces.
Model the medical procedure

**Evaluate** the model for:
- Sequence Errors
- Safety vulnerabilities
- Inefficiencies

Working with domain experts, **improve** the model/process

**Sequence errors: representing properties**

1. Confirm presence of ID band
2. Infuse a unit of blood product
3. Confirm presence of ID band

1. Confirm presence of ID band
2. Confirm presence of ID band
3. Confirm presence of ID band

Diagram showing the sequence and confirmation steps.
Safety Vulnerabilities: Fault Tree Analysis
Model the medical procedure

Evaluate the model for:
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Efficiencies: Discrete Event Simulation
Results

- Mostly found problems in our models and properties
- BUT, after those problems are removed, found important errors in the processes
  - Single points of failure
  - Deadlocks
  - Use of stale data
  - Etc.
- Case studies: Blood transfusion, Emergency room flow, Cardiac surgery, Chemotherapy
  (saw a 70% reduction in errors that reached patients)
Dynamic Guidance and Analysis

- Using the validated models to provide context sensitive, dynamic guidance and feedback
Geary, Margaret

Gender: female
Birthdate: 07-03-1926
Age: 89
MRN: 12345678
Room: 204

HR 78
TEMP 37.0° C
SYS / DIAS 116 / 80
SpO2% 95

ADMINISTER A SINGLE UNIT OF BLOOD PRODUCT *in progress*

- **administer a single unit of blood product**
  - **perform pre-infusion work**
    - **assess patient**
      - review patient history
      - evaluate patient clinically:
        - Perform all of the following in any order
          - perform clinical evaluation
          - check vital signs
            - obtain vital signs
            - document vital signs
        - confirm presence of IV catheter
          - **check vital signs**
            - obtain vital signs
            - document vital signs
          - confirm presence of IV catheter

  General Notes
Geary, Margaret

Gender: female
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TEMP 37.2 C
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ADMINISTER A SINGLE UNIT OF BLOOD PRODUCT
Successfully completed

13:57 General Notes

▸ perform pre-infusion work
▸ infuse unit of blood product
▿ perform post-infusion work

▿ evaluate patient clinically:
Perform all of the following in any order

▸ perform clinical evaluation

▿ check vital signs

▸ obtain vital signs
idious vital signs

record infusion info

discard infusion materials
# Administer A Single Unit Of Blood Product


<table>
<thead>
<tr>
<th>Client Name: John Doe</th>
<th>MRN#: 12345678</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Activity</strong></td>
<td><strong>Date</strong></td>
</tr>
<tr>
<td>perform clinical evaluation</td>
<td>Mon Mar 21, 2016</td>
</tr>
<tr>
<td>confirm presence of IV catheter</td>
<td>Mon Mar 21, 2016</td>
</tr>
<tr>
<td>gather infusion materials</td>
<td>Mon Mar 21, 2016</td>
</tr>
<tr>
<td>verify patient ID to ID band</td>
<td>Mon Mar 21, 2016</td>
</tr>
<tr>
<td>verify blood product information</td>
<td>Mon Mar 21, 2016</td>
</tr>
<tr>
<td>begin infusion of blood product</td>
<td>Mon Mar 21, 2016</td>
</tr>
<tr>
<td>perform clinical evaluation</td>
<td>Mon Mar 21, 2016</td>
</tr>
<tr>
<td>obtain vital signs</td>
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</table>
MENTORS: WHY DO WE NEED THEM AND HOW DO WE FIND THEM?

CRA-W Virtual Undergraduate Town Hall
A MENTOR?

Homer: “wise and trusted counselor”

A Mentor = someone who takes a special interest in helping another person develop into a successful professional.

Mentoring = professional + personal relationship
Research on Mentoring

Research shows that those who are mentored achieve greater career advancement and higher work satisfaction than those who are not mentored.
Why do I need mentors?
Benefits of being Mentored

+ Knowledge of your discipline’s expectations
+ Solid foundation of skills and knowledge in your discipline
+ Self confidence
+ Independent problem solving skills
+ A good start on a professional reputation
+ Access to a professional network
A Good mentor provides:

- advice on courses, career, personal challenges
- Contacts/connections for networking,
- information
- letters of reference,
- Encouragement
- Opportunities (advocates)
- Coaching
- Help: how to use your strengths;
  - overcome your weaknesses
- A role model
- A listening ear
- Powerful/probing questions
- ALL possibilities, w/o judgment
How to Find Mentors
Look Everywhere

- In your department at your institution
- Outside your department at your institution
- In your field outside your institution (e.g., at an internship)
- Outside your field outside your institution
You, the Mentee, have responsibilities too

Attention: SHOW UP with an open mind and respect

Advice: LISTEN + FOLLOW as appropriate

Information: LISTEN, LEARN, and USE

Encouragement: LISTEN + SAVOR

Opportunities: EXPLOIT
You too can be a Mentor...

Benefits of being a Mentor

+ Facilitate another’s accomplishments: parenthood

+ Increase confidence

+ Strengthen your own network

+ Give back