S76: Inferring Clinical Workflow Efficiency via Electronic Medical Record Utilization

You Chen
Department of Biomedical Informatics
School of Medicine
Vanderbilt University
Disclosure

We have no competing interests to declare.
Workflow in Diabetes Mellitus Clinics

Activity Diagram for Primary Care Office

Delayed activities in the workflow

- Verify insurance details from insurance company
- Collate patient chart by nurse
- Document progress notes, billing encounters, orders by physician


www.amia.org
Traditional Workflow Modeling

• Methods
  – Questionnaire, interview, & observation in clinics

• Their Goals
  – Develop an in-depth understanding of workflow in disease care
  – Facilitate development of informatics tools (e.g., EHR system) to manage workflows

• Limitations
  – High cost of human effort
  – Limited to a small number of patient population
Automated Learning of Workflow

• Learn workflows from EHR systems

• “Reverse Engineering” - learn clinical workflow via EHR systems to refine process
  – Knowledge generated by healthcare workers
  – Study workflow in a wide range of patient populations
What Can We Learn From EHR Data?

User access data (e.g., a user invoked an action at a patient’s record at 9:am, Nov, 15, 2015)

Diagnosis data (e.g., ICD-9 codes, medications, lab tests, and notes)

Phenotypes

Association?

www.amia.org
Example of a Learned Phenotype

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Child Birth</strong></td>
<td></td>
</tr>
<tr>
<td>Short gestation; low birth weight; and fetal growth retardation</td>
<td>0.25</td>
</tr>
<tr>
<td>Other perinatal conditions</td>
<td>0.18</td>
</tr>
<tr>
<td>Perinatal jaundice; isoimmunization</td>
<td>0.16</td>
</tr>
<tr>
<td>Endocrine and metabolic disturbances of fetus and newborn</td>
<td>0.10</td>
</tr>
<tr>
<td>Cardiac shunt; heart septal defect</td>
<td>0.06</td>
</tr>
</tbody>
</table>

Example of a Learned Workflow

The physician approves the quality of radiological report or peer review process / The primary physician responsible for an inpatient’s care

The primary physician responsible for an inpatient’s care / Patient care associated with nursing roles
Inferring Workflow Through Utilization of an EHR
How Can We Learn Workflow From EHR?

A physician requested a lab test
A lab user uploaded a lab test result
Physician office received the lab test result
A nurse provided counseling service

Nov, 9, 2015, 9:00am
Nov, 9, 2015, 4:00pm
Nov, 9, 2015, 4:20pm
Nov, 10, 2015, 10:20am

Using stable strong relation to construct workflow
Learning the Ordered Relations of Events

Window size matters

e_1 has an order relation with e_2 and e_3, but not with e_4 or e_5

Distance matters

e_1 has a stronger relation with e_2 than e_3
Learning the Ordered Relation of Events

**Window size set as 1**

- **position**($e_1$) = 1
- **position**($e_2$) = 2

$$r_1(e_1, e_2) = \frac{1}{(2-1)^2}$$

- **position**($e_1$) = 3
- **position**($e_2$) = 4

$$r_2(e_1, e_2) = \frac{1}{(4-3)^2}$$

$$R(e_1, e_2) = r_1(e_1, e_2) + r_2(e_1, e_2) + r_3(e_1, e_2) + r_4(e_1, e_2) = 4$$
Keep Strong Relations

Sequences

\( S_1 \)
\[ e_1 \rightarrow e_2 \rightarrow e_2 \rightarrow e_3 \rightarrow e_4 \]

\( S_2 \)
\[ e_2 \rightarrow e_1 \rightarrow e_1 \rightarrow e_2 \rightarrow e_1 \]

\( S_3 \)
\[ e_1 \rightarrow e_2 \rightarrow e_1 \rightarrow e_3 \rightarrow e_4 \]

\( S_4 \)
\[ e_3 \rightarrow e_4 \rightarrow e_1 \rightarrow e_2 \]

\( S_5 \)
\[ e_5 \rightarrow e_6 \rightarrow e_6 \rightarrow e_7 \]

\( S_6 \)
\[ e_7 \rightarrow e_6 \rightarrow e_5 \rightarrow e_6 \]

\( S_7 \)
\[ e_7 \rightarrow e_6 \rightarrow e_3 \]

Event Relation \( \geq 2 \)

\[ e_1 \rightarrow e_2 \quad (4) \]

\[ e_2 \rightarrow e_1 \quad (3) \]

\[ e_3 \rightarrow e_4 \quad (3) \]

\[ e_5 \rightarrow e_6 \quad (2) \]

\[ e_7 \rightarrow e_6 \quad (2) \]
Using Blocks to Represent Sequences

**Sequences**

- $s_1$: $e_1 \rightarrow e_2 \rightarrow e_3 \rightarrow e_4$
- $s_2$: $e_2 \rightarrow e_1 \rightarrow e_1 \rightarrow e_2 \rightarrow e_1$
- $s_3$: $e_1 \rightarrow e_2 \rightarrow e_1 \rightarrow e_3 \rightarrow e_4$
- $s_4$: $e_3 \rightarrow e_4 \rightarrow e_1 \rightarrow e_2$
- $s_5$: $e_5 \rightarrow e_6$
- $s_6$: $e_7 \rightarrow e_6 \rightarrow e_5 \rightarrow e_6$
- $s_7$: $e_7 \rightarrow e_6$

**Blocks**

- $e_1 \rightarrow e_2$
- $e_3 \rightarrow e_4$
- $e_2 \rightarrow e_1$
- $e_1 \rightarrow e_2 \rightarrow e_1$
- $e_5 \rightarrow e_6$
- $e_7 \rightarrow e_6$
Grouping Co-Common Blocks

Sequences

\[
\begin{align*}
S_1 & : e_1 \rightarrow e_2 \rightarrow e_3 \rightarrow e_4 \\
S_2 & : e_2 \rightarrow e_1 \rightarrow e_1 \rightarrow e_2 \rightarrow e_1 \\
S_3 & : e_1 \rightarrow e_2 \rightarrow e_1 \rightarrow e_3 \rightarrow e_4 \\
S_4 & : e_3 \rightarrow e_4 \rightarrow e_1 \rightarrow e_2 \\
S_5 & : e_5 \rightarrow e_6 \\
S_6 & : e_7 \rightarrow e_6 \rightarrow e_5 \rightarrow e_6 \\
S_7 & : e_7 \rightarrow e_6
\end{align*}
\]

LDA (Latent Dirichlet Allocation)

Topics

\[
\begin{align*}
& e_1 \rightarrow e_2 \\
& e_3 \rightarrow e_4 \\
& e_2 \rightarrow e_1 \\
& e_1 \rightarrow e_2 \rightarrow e_1 \\
& e_5 \rightarrow e_6 \\
& e_7 \rightarrow e_6
\end{align*}
\]
Transform Topic into Workflow

Block

- Attending Phys/Prov -> Physician-CPOE 0.04076
- Physician-CPOE -> Patient Care Staff Nurse - Lactation 0.01873
- RAD - Technologist -> Physician Hospitalist-CPOE 0.01765
- Physician Hospitalist-CPOE -> RAD - Technologist 0.01726
- Patient Care Staff Nurse - Lactation -> Physician-CPOE 0.01711

ProM Tool
Measuring the Efficiency of Inferred Workflows
A Block can Exist in **Different Sequences** for Different **Reasons** with Different **Durations**

**Sequences**

\[ S_1 \rightarrow e_1 \rightarrow e_2 \rightarrow e_3 \rightarrow e_4 \]

**Radiology Manager and Resource Coordinator**
*(includes scheduling and patient experience issues)*

\[ S_2 \rightarrow e_2 \rightarrow e_1 \rightarrow e_2 \rightarrow e_1 \]

**Radiology Mgr/RC → Resident- Inpatient Consulting Service**
*(Half hour)*

\[ S_3 \rightarrow e_1 \rightarrow e_2 \rightarrow e_1 \rightarrow e_3 \rightarrow e_4 \]

**Radiology Mgr/RC → Approved Quality or Peer Review Process**
*(Half hour)*

\[ S_4 \rightarrow e_3 \rightarrow e_4 \rightarrow e_1 \rightarrow e_2 \]

**Radiology Mgr/RC → Patient Care (associated with nursing roles)**
*(5 Hours)*

\[ S_5 \rightarrow e_5 \rightarrow e_6 \]

\[ S_6 \rightarrow e_7 \rightarrow e_6 \rightarrow e_5 \rightarrow e_6 \]

\[ S_7 \rightarrow e_7 \rightarrow e_6 \]
Can We Manage Effectiveness of Blocks through Their Duration (and Variances)?

Most of time, they are fast, but sometimes are slow

Difficult to capture its characteristics, sometimes are fast, whereas sometimes are slow

They are always fast

They are always slow

Average Duration

Physician CPOE

Advanced Practice Nurse Provider
Effectiveness of Topic Workflow Can Be Utilized to Manage Complex Patients

Several blocks with long durations, whereas others with short durations, which indicates a patient condition is associated with a combination of long processes and short processes.
An Example of Complex Patients Associated with Multiple Workflow Topics

**Oncology and Diabetes**: multiple myeloma, diabetes mellitus, esophageal reflux, urinary tract infection, and personal history of malignant neoplasm of breast

![Bar chart showing the number of patients associated with different numbers of topics characterizing a patient. The chart highlights the number of patients associated with 5 topics.]
Summary & Next Steps

• A pilot study of workflow modeling through EHR data

• Future steps
  – Inferred workflows need further investigations
  – Gap measurement between inferred workflow and workflow utilized in clinical practice
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Questions?

Thank you!

you.chen@Vanderbilt.edu
http://hiplab.org/~ychen