Adaptive Clinical Pathway Using Semantic Web

by

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Acknowledgment

This report has been written by me and has not received any previous academic credit at this or any other institution.

I would like to express my sincere appreciation to my colleagues in Agfa Inc., Helen, Stan, Jos and Peter. Thanks for their strong support, expert advice and great encourage during my internship.

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Abstract

It is commonly believed that the quality of healthcare can be improved by taking advantage of the latest medical knowledge and best practices. This is especially true when designing clinical pathway. A clinical pathway is a multidisciplinary plan of best clinical practice for specified groups of patient with a particular diagnosis. One of the difficulties is how to apply the best practice, for example clinical guideline when drawing the pathway. Another difficulty is clinical pathway should be flexible and in response to the change in the real world. In this report, a method using semantic web technology is proposed by Agfa research group. The medical knowledge will be captured in a semantic model and a rule-based inference engine is used to infer the clinical pathway.

I worked on this ACW project in Agfa Inc. during my internship. In this report, I describe the works done in this period, including practice with BPEL process, review of clinical pathway and first demonstration of the ACW project. At the end of the report, another thought of adaptive clinical pathway and some recommendations for the future work are introduced.

Table of Content

1. Introduction

It is commonly believed that the quality of healthcare can be improved by taking advantage of the latest medical knowledge and best practices. Also the increasing change of technology and medical knowledge make the treatment plan more flexible. This flexibility happens not only from patient to patient, but also from different states of a patient.
In response to this requirement, research group in Agfa proposed the idea of adaptable clinical pathway and workflow using semantic web.[1]

Semantic web is regarded as the next generation of World Wide Web. It allows computers to interpret and process data based on well-defined “ontology,” or relationships between disparate pieces of information. Internet is the biggest knowledge base in the world. If we can make the tacit knowledge in the web explicit, then we can improve the quality of health care by applying them in the medical practices. In this project, agfa research group use N3, one alternative of RDF language, to express the clinical ontology, used rule based reasoning engine to generate the clinical pathway and use service oriented architecture as the platform to orchestrate the medical tasks in the clinical pathway. I am proud to be part of the group during my internship and gain lots of experience in the work.

2. The Agfa Group

The Agfa Group, headquartered in Morsel, Belgium, ranks among the world's leading imaging companies. It is famous for its image-related products and systems. On January 9, 2002, Agfa acquired Mitra Inc, from Waterloo, Ontario, one of the world's leading providers of imaging and information management system for Radiology. Healthcare is one of the two focuses of Agfa in the future.

The group where I do my internship is part of the Architecture and Design Group. That is the group conducting research and innovation in the healthcare. At this time, the two main topics are advanced workflow and semantic web. The objectives include: [2]

- Understand workflow and its abstraction in Healthcare domain
- Research and evaluation workflow representation methodology/framework in healthcare domain, specially semantic of workflow
- Assess proof-of-concept workflow enabling technologies and business process management standards and technologies
- Implement rule-based proof technology using RDF, Web Ontology and N3.

3. Works in Agfa

As an internship student in Agfa research group, my main responsibilities are:

- Joining in the discussions on methodologies to achieve the objective, system design and implementation technology
- Assisting with research on issues related workflow engine
- Developing prototype for demonstration

I would like to divide the internship into four phases to describe the work done in this period.

3.1 Learning and Preparation

Before I join in the research group, they already conduct some research on adaptive clinical pathway. [3] In the whitepaper, they show the idea of using semantic web as knowledge base, Euler [4] and Cwm [5] as prove engine and using BPEL [6] to orchestrate the web service. As I am totally new to this field, I must catch up as soon as possible. Tons of readings have been done in this phase. The main topics include:

- RDF:[7] a language for representing information about resources in the World Wide Web
- N3: [8] a compact and readable alternative to RDF for semantic web
- Euler: an inference engine supporting logic based proofs.
- Cwm: a general-purpose data processor for the semantic web
- OWL:[9] a web ontology language

- Web Service technology: a solution for application-to-application communication, an alterative for RPC. There are three main component: SOPA, WSDL and UDDI.
- BPEL: a language for the formal specification of business processes and business interaction protocols.
- XML technology: includes XSLT, XPATH, DOM, SAX

In additional to the reading, I do some experiments on web service implementation. Experience includes create web service for different web service engines, for example, GLUE[10], Apache Axis[11] and Microsoft .NET. Some web services are used in the later demonstration.

For the future work, some preparations were performed in this phase. The main work is to install all required tools in the machine and make them work well. The software installed in this phase include:

- Cygwin:[12] a Linux-like environment for Windows
- Apache and Tomcat: web server and Servlet engine for web application
- Oracle BPEL Process Manager:[13] a infrastructure for creating, deploying and managing BPEL business processes.
- Web service engine: Apache Axis, GLUE,
- JAVA IDE: NetBeans, Eclipse
- Utility tools: CVS, ANT,

All tools above are frequently used in the later development. Some tools were installed, but just for experience or a simple work, including JBuilder, Oracle Developer, UMLET [14] (free tool for UML diagram), Inkscape [15] (open source tool for SVG file).

3.2 Web Service Orchestration using BPEL

With the changing nature of healthcare workflow in hospital environment, people need a technology that can develop business application with less effort and also can be adapted to the changing environment. Service Oriented Architecture (SOA) is the most recent answer. Many tasks in healthcare, such as checking insurance policies, billing, scheduling, can be implemented as a web service. Those functions can be published and applied by other applications. But only developing the web services and exposing the functionalities are not sufficient. Healthcare workflow always includes much functionality and involves lots of services. Se we need a way to compose these functionalities in the right order, at the right time. Here is the role of BPEL.

Oracle BPEL Process Manager is used as BPEL engine for my experiment. Other choices include ActiveBPEL engine (the best open source BPEL engine), IBM BPWS4J, Microsoft Biztalk. Oracle BPEL PM is chosen for the following reason:

- Implement all activities in BPEL 1.1 specification
- GUI designer for creating BPEL process
- A console to monitor the BPEL process
- Provide API to integrate with existing application
- Good documents, lot of examples and a useful forum.

3.2.1 Experiment One

The first experiment is to create a BPEL process according to the workflow diagram in our case. In this case, a patient with Hip injury enters the hospital for treatment. The procedure includes retrieve patient information, Physical exam, CR exam, Pre-surgery Exam, Insert Bolt Surgery

and post-surgery exam. In this process, some exams may not be performed in a special case according to the medical rule, for example, a woman in pregnancy can not take CR exam. So this BPEL process will include “SWICH” activity to decide the path at run time. Every exam in this process will be implemented as web service that may locate in a remote machine. During the execution, the BPEL process will invoke the web service, get the result and make the decision. The most difficult part for this experiment is that the web service may be an asynchronous service. This is normal in health care environment because some tasks cannot return the result right way, for example, result for CR exam. So, this BPEL process should be able to handle asynchronous web service. This goal is achieved by implementing the service as a user task. Once the task data is set up, the BPEL process initiates the task service and then waiting for the task to complete. Once the task begin, the user can open web page to see the current tasks in the process then complete the task by click the button when the exam finish. A message will be sent to BPEL process manager and continue the process.

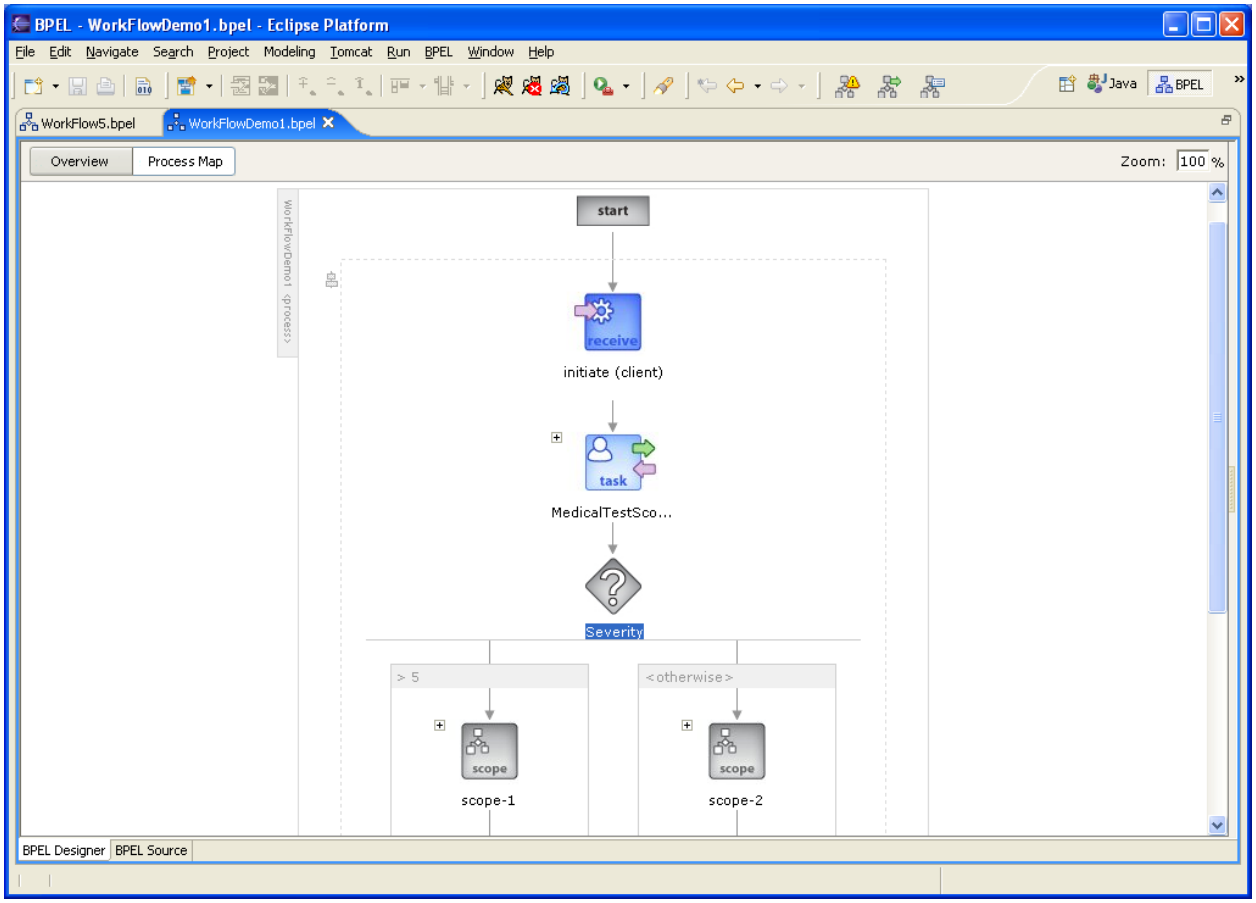

Figure 1 BPEL process in Oracle BPEL Designer

3.2.2 Experiment Two

In the first experiment, a BPEL process is created and executed. This will be enough for a stable workflow. The drawback is the web service is defined when creating BPEL process. But in the adaptive clinical pathway, the web service may change at run time, either another new exam available or the WSDL location of web service is changed. So in the second experiment, I try to implement dynamic binding in the BPEL process.

In BPEL process, web services that will be invoked in the process are defined as *parterlink*. Each partner is characterized by a WSDL *serviceLinkType*, for example in this project, the

serviceLinkType is Physical Exam service, CR Exam service etc. At the time the BPEL process is created, the *parterlink* is defined and cannot be changed. The idea of dynamic partner link is just like create an interface for all services, for example *HospitalService*. The interface will be assigned to the *parterlink*. Later at the run time, the actually service will be executed by changing the *EndpointReference.* In the practice, new service name or new WSDL location will be assigned to *parterlink.*

```
<assign name="assign-1">
  <copy>
    <from><EndpointReference
           xmlns="http://schemas.xmlsoap.org/ws/2003/03/addressing">
             <ServiceName
             xmlns:ns1="http://agfa.com/mchen">ns1:PhysicalExam</ServiceName>
          </EndpointReference></from>
    <to variable="partnerReference"/>
  </copy>
</assign>
```

3.2.3 Experiment Three

In this experiment, a simple web application is built for demonstration. From the use login, create clinical pathway and execute the pathway. User can also see the status of each task in the clinical pathway. Moreover, when the user login again, user can retrieve the clinical pathway created for him/her by giving the Study ID. This is useful because one process may take days or weeks and user may check the status later. The most difficult part in this experiment is

implementing monitor function. Although Oracle BPEL PM provides an API for developers to implement functions themselves, there is no user guide for the API and no samples for using API. Fortunately, Oracle BPEL include source code in its package and give me some ideas.

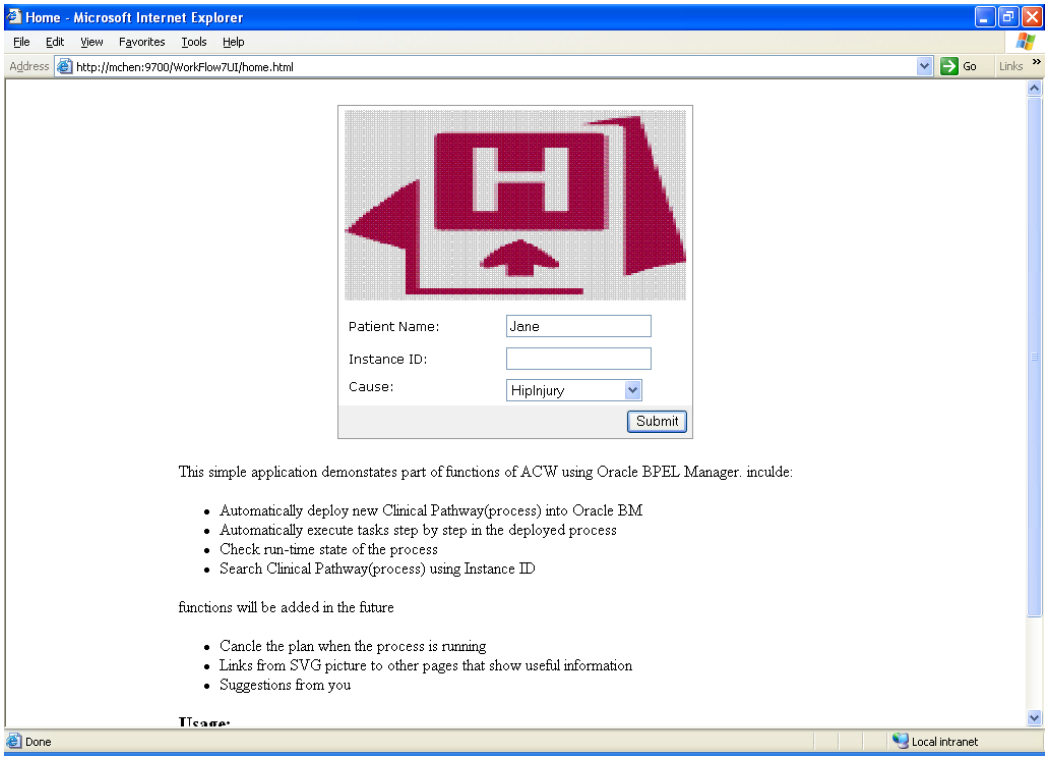

Figure 2 User Login Page

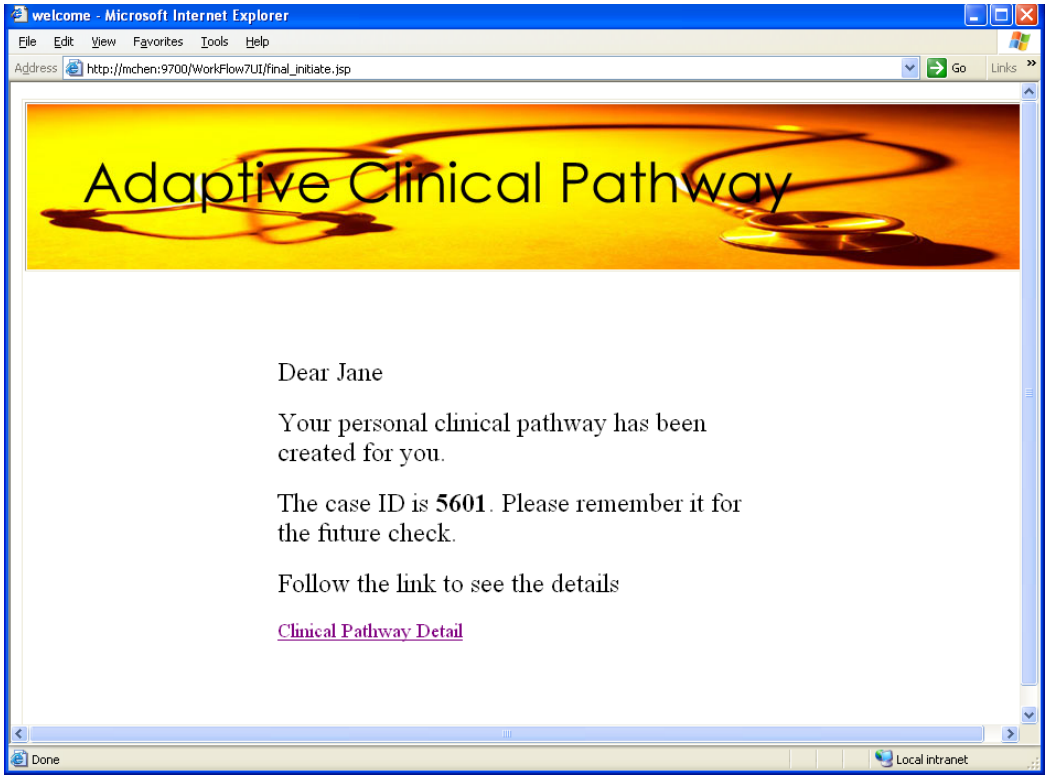

Figure 3 Information Page

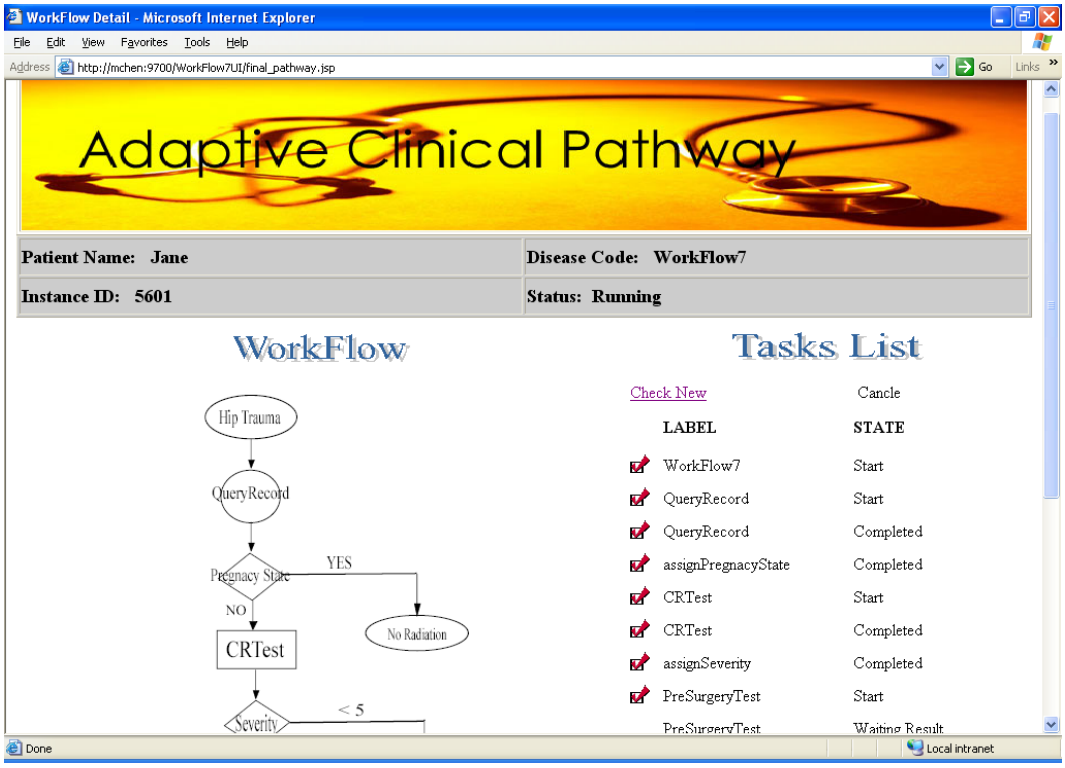

Figure 4 Clinical Pathways Page

3.3 Literature Review of Adaptive Workflow

One of the most difficult problem was confronted in ACW application is how to deploy and execute the changing workflow process. For example, when a new clinical pathway is generated for the patient, the old process should be stopped and aborted, the new process should be deployed and begin to execute. Some workflow engine may support stop, resume and abort, but few commercial workflow engine support deployment at run time.

I-Flow 6.0 [16] from Fujitsu is one of the few commercial products that announce the function of dynamic change. Another choice is InConcert [17] from TIBCO. In the academic research field, the project [18] from Univeristy of Leipzig demonstrates an event-original workflow system using ADEPT workflow engine from University of Ulm, Germany. There are many other workflow projects in healthcare, for example, PATMAN [19], Hygeianet [20], ACL PROforma [21].

3.4 Design and Implement ACW Demo

3.4.1 Demo Design

After long time of research and discussion, we decide the architecture of the Adaptive Clinical Workflow application. In the last phase, I involved in the implementation of our first ACW demo. Although the architecture is defined, the implement detail could be different. We can use J2EE platform or .NET. We can use RMI or SOAP as remote procedure call method. We can build a Java application or a web application.

The design is the heart of the development and needs to consider all kind of requirements in the implementation, from User Interface to data storage. It is not the abstract description in the architecture design, but the detailed elucidation for every part in the system. During this phase, I draft my first application design. Although at last the design had not been applied, but the experience and knowledge learned are valuable. The following diagrams are part of my design.

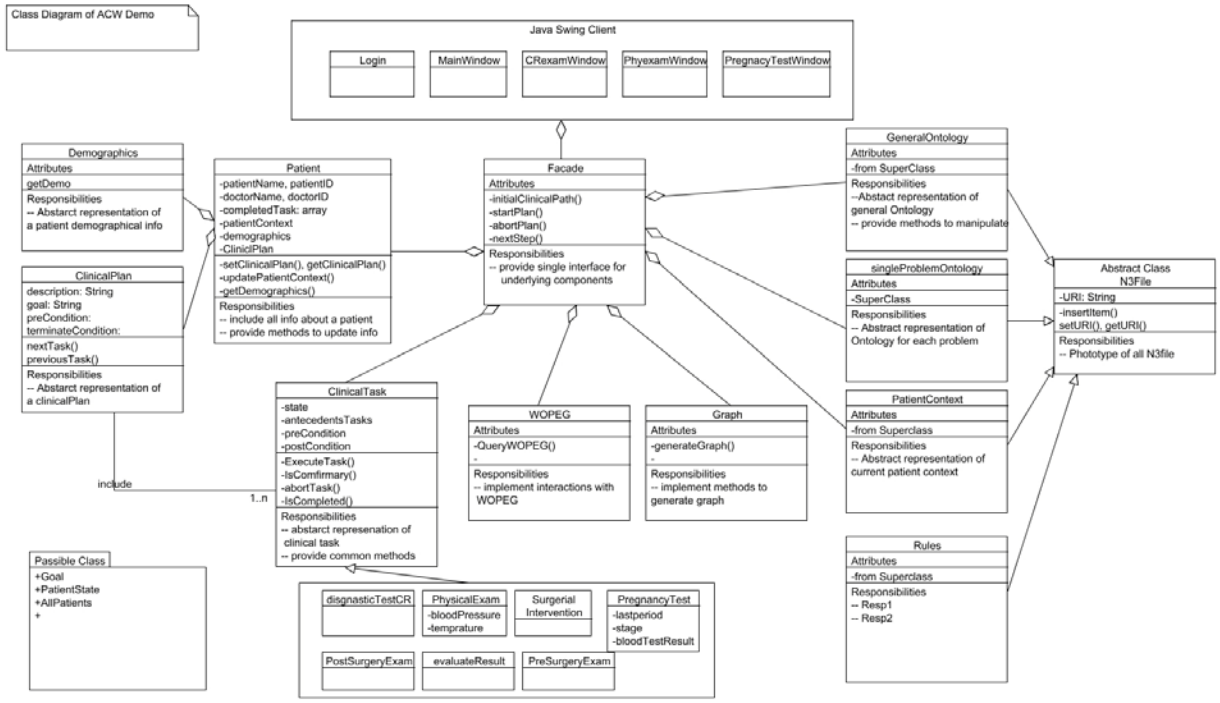

Figure 5 Class Diagram for ACW Demo

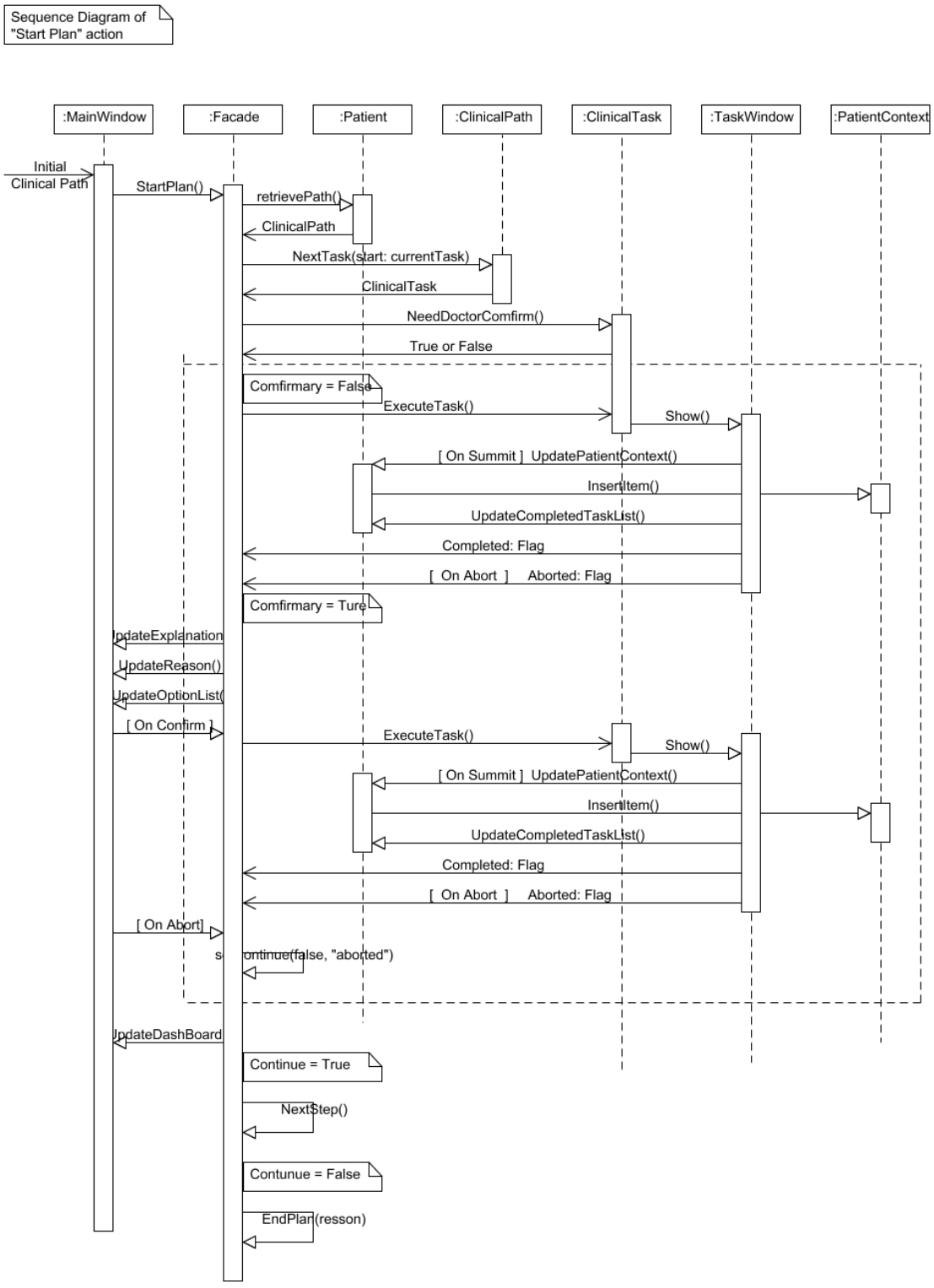

Figure 6 Sequence Diagram for "Start Plan"

3.4.2 Demo Implementation

My responsibilities are to implement java client for the demo. The functions in client include:

- User login and check password
- Initial the main window for the user, include get doctor name, get doctor ID, display patient list, display clinical problems
- Response to the user action, for example initial clinical pathway
- Dynamic generate the contents in the task window according to the parameters in the task instance
- Dynamic generate the day-to-day schedule according to the clinical pathway from web proof engine
- Doctor can confirm or abort the plan or task.
- Execute the clinical pathway by pop up task window one by one.

The client is implemented using java swing. Façade design pattern is applied to provide a unify interface to the client. All method calls to the server are from the pathway façade. By applying this design pattern, we can easy to change the business logic in the server and don't need to rewrite the client UI. In the demo, all instances from the server will be created in a single class. So later it is easy to transform this local call to a remove method call, for example using Java RMI. Once the plan starts, the application will wait for the doctor's decision on current task, confirm or abort. This function is implement using Java Thread. Clicking "Start Plan" Button will start a new thread. There is a loop in its run method and for each iteration, the thread will wait for doctor's decision.

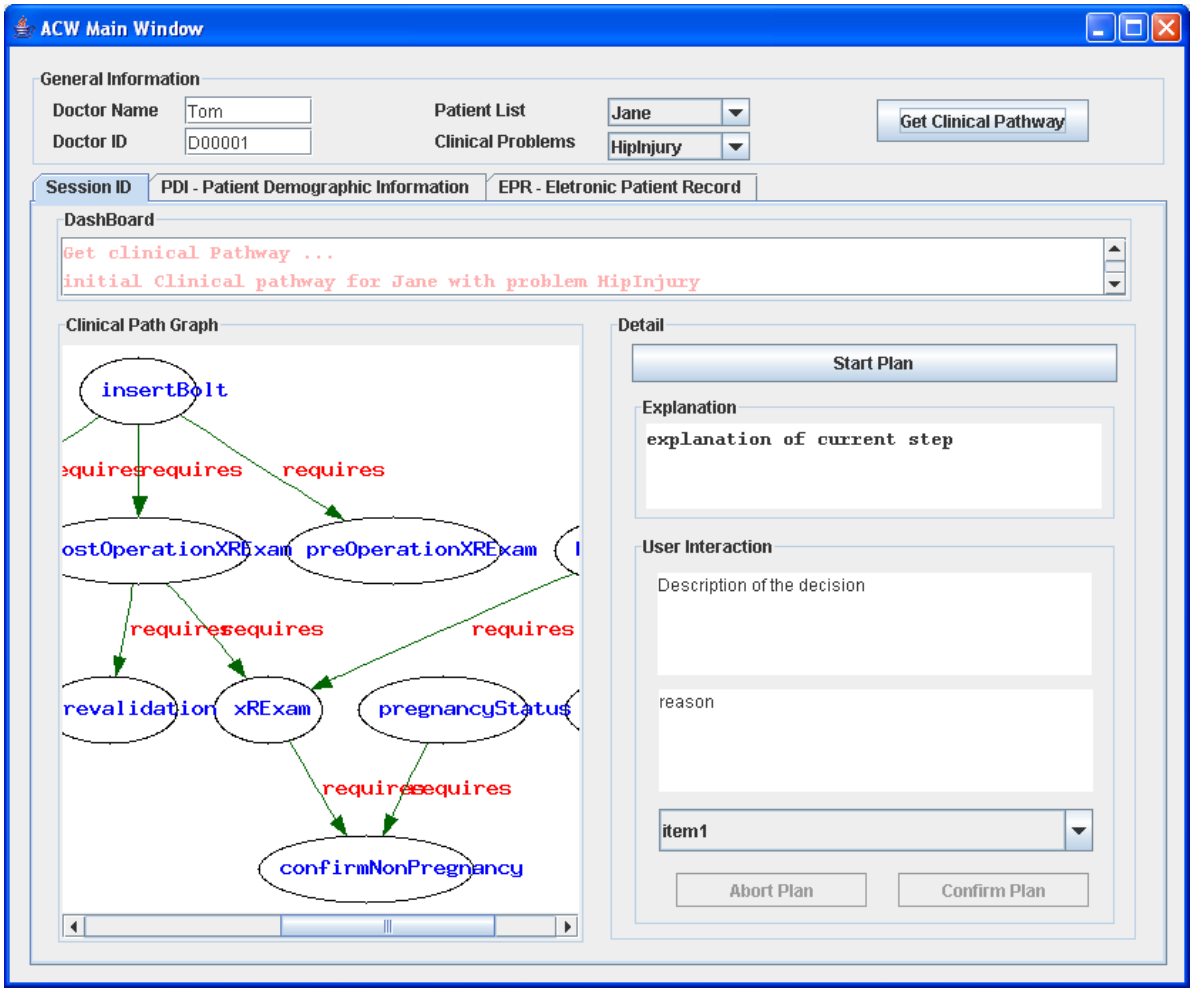

Figure 7 Main window for ACW client

4. Academic Learning and Practice

4.1 Hospital Procedures and Information Flow

One of the fundamental requirements of building a hospital workflow system is the good understanding of the current hospital procedures and the flow of information in the hospital system. Finally, the system will service for doctor, nurse or other health staff and will make their dairy easy and efficient and to prevent error. Things may become more difficult because workflow may be various from department to department. For example, workflow in cardiology is different from workflow in radiology department. I learn a lot from the course in the healthcare informatics program and that help me a lot. For example, in the HI flow and use class, every student will investigate on one department or organization in the Canadian health system and give a presentation on its information flow and use. Fox example, I still remember one group of student give a vivid 3D representation of workflow in ER department in QEII hospital. Although I never go there, but after the presentation, I know the every detail of the procedures in ER department, for instance patient registration, first checking, waiting and take examination. All presentations are valuable and help me when in practice.

4.2 Knowledge Management

In order to get adaptive clinical pathway for the patient, we need to apply the current clinical guideline and other medical knowledge. Before we can use the knowledge, we need to capture and model the knowledge. In the Knowledge Management for Health Informatics class, we learn the application of knowledge management tools and techniques to manage healthcare knowledge,

for example, use GLIP, PROforma to model the clinical guideline. In the ACW project, we create our clinical pathway ontology based on PROforma modeling. This semantic model [22] is implemented using RDF, OWL and N3 noation. It consists of axioms of the clinical pathway, semantic relationships and rules among concepts and properties. For example, “Component” is the most generic concept in expressing clinical pathway and “Task” is a subclass of Component and in turn Action, Enquiry, Decision are subclass of Task. In additional to define the concepts, the semantic model also includes rules that define the dependency and conditional relationship of task.

4.3 IT Project Management

From the IT project Management class, I learned the importance of project management. Good planning in the beginning is always critical for the success of the project, no matter its scale. This is especially important for ACW project because part of the group works in Waterloo, Ontario and another part works in Belgium. People need not only to share the ideas, but also to cooperate. We set up TCON every week. During the TCON, people will describe the works done in the last week, share the new ideas and decide the works in the following week. During the time of demo implementation, we scheduled the works for every one, the actions, the time and the outcome. This makes it easy to integrate later.

5. Thinking of Adaptive Clinical Pathway

Agfa research group did a great job in designing adaptive clinical pathway, using semantic web as the knowledge base, using rule-based reasoning engine to infer the clinical pathway. As an internship student, I learn a lot from a group of knowledgeable people.

This is always difficult to design one, best clinical pathway for the patient. Some reasons are

- The situation of patient is complicated. Some patients may have more than one clinical problems and the state of the patient may change in the middle of the pathway.
- Some tacit knowledge may not result in a guaranteed rule, like if A equal to B, B equal to C, then A equals to C.

So how to design a system that gives patient more informed choices instead of returning one answer. My thought is to implement the system to return the clinical pathways with a confidence score. Just like a Global Map System, the original node is the clinical problem and the destination is the goal. In order to get to the destination, we may go through many nodes in the map. The arc in the graph is one treatment or one method from the knowledge base. The score of the arc is how confidence the treatment or method is effective. The score can be calculated using data mining technology. This system is suit for data mining technology because we know many rules generated from data mining analysis are useful but not guaranteed.

6. Conclusions

In this report, the works performed during internship are described. Also some knowledge learned in class is related to the practice in the ACW project. Finally, I give another thought of adaptive clinical pathway. Although the thought is primary, I hope it can raise more discussions about clinical pathway.

7. Recommendations

The ACW project don’t finish yet and more ideas may be added to the project. There are still lots of work that can be done to improve the current work. For example,

- Improve the web proof engine to make it more stable and handle complicated reasoning
- Automate the transformation from clinical pathway result to executable workflow process, for example from N3 file to BPEL process.
- Improve the methodology to write clinical rules. The rule is critical when calculating clinical pathway and the rules should be easily to design and added to the system.

Reference:

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