A Practice of UML for Web Development

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Abstract – *This paper proposes a method that uses UML diagrams as a software development process for analysis and design of web applications. The method uses the most needed diagrams only to analyze system requirements and perform software design in a very short term. The method starts with a use case diagram to define functional requirements of the system. Workflow diagrams follow to specify flows of activities of those identified requirements in the use case diagram. Class, sequence, and activity diagrams are then used to determine necessary classes, functions, and algorithms that need to be implemented. The method have been applied to two projects and proved its usefulness in web development.*

Keywords: web application, web development, UML.

1 Introduction

Today almost all commercial companies, educational institutions, governmental organizations, and the other businesses put their information online to extend their markets and/or broadcast their information. Web engineering for developing such web applications and its extended web-based mobile applications, has become an important subject.

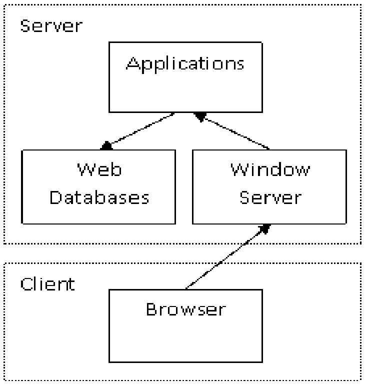


Figure 1. Basic System Architecture for Web Applications

Figure 1 shows a possible system architecture of web applications. Users at the Client side use browsers to communicate with the Window Server at the Server side. Requests are sent to the Window Server, where applications perform computing calculation and send the results back to the users. Web Databases are set for data storage and access. Other components can be added to the architecture [4, 5, 6]. Figure 1 just shows the very basic architecture that a web application can have.

UML, a design and communication tool for analyzing and designing object-oriented systems has been applied to software construction in many domains and projects. Web development is one of these new domains where people try to take its advantages. Although it is not necessary to use UML or OO in web development, in many textbooks and research papers [2, 9], authors emphasize the importance of using OO for web development. Almost all of them agree that agile process models are more appropriate for web development, because they have shorter development time and accommodate to changes. With such process models, techniques such as UML can be used to help specify system requirements and design quickly.

It causes our attentions that a link between basic system architecture such as shown in Figure 1 and agile process models needs to be expressed specifically. This link should meld the implementation of the architecture with a short term process model. With UML, the link is constructed with its different diagrams for specify system requirements and software design issues.

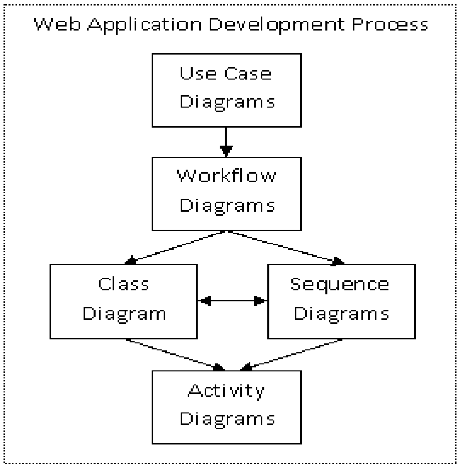


Figure 2. Web Application Development Process

This paper illustrates a practice of UML for web development. It proposes a method that uses UML diagrams as a software development process for analysis and design of web applications. Figure 2 shows the proposed development process for web development. The method uses the most needed diagrams only to analyze system requirements and perform software design in a very short term. The method starts with a use case diagram to define functional requirements of the system. Workflow diagrams follow to specify flows of activities of those identified requirements in the use case diagram. Class, sequence, and activity diagrams are then used to determine necessary classes, functions, and algorithms that need to be implemented. The method have been applied to two projects and proved its usefulness in web development.

The rest of the paper is organized as follows. Section 2 introduces the proposed method for web development. Section 3 discusses the uses of UML diagrams and other techniques in the method in details, including consistency checks of the UML diagrams. Section 4 shows two projects that use the method and complete two web applications, and section 5 concludes the paper.

2 Web Application Development Process

This section introduces the proposed method, which melds the simplified UML process model with the basic web system architecture, described in the previous section, together for web development. Figure 3 shows the idea of the method. The web development process at the right hand side of the figure supports the development of all the system components in the web architecture at the left hand side.

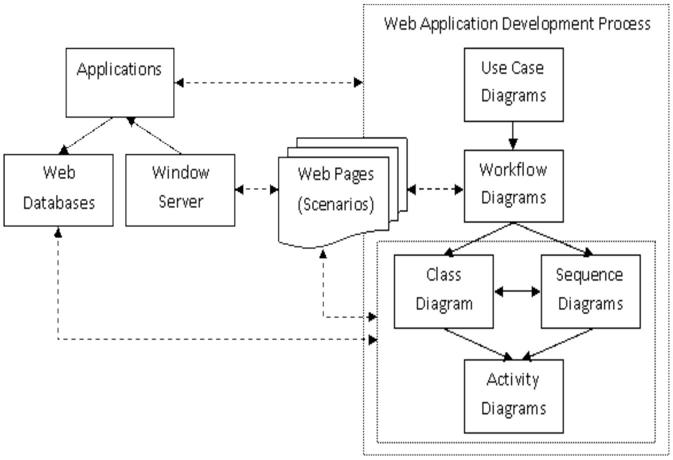


Figure 3. Web Application Construction

In the process, first a use case diagram is used to specify the needs and requirements of a web application with various use cases. Each use case represents a complete business activity. An activity can be defined as a scenario, which is a synthetic description of an event or series of actions and events. To catch these scenarios, we use workflow diagrams to illustrate the events, actions, and their branches of the scenarios. For example, considering a simple logon scenario, both successful logon and unsuccessful logon cases should be expressed in a workflow diagram. Although Fowler [3] indicates that using activity diagrams to specify use cases may not be easy to follow them, there are two major advantages of using workflow diagrams to specify the scenarios of use cases: abstraction and soundness checking. When using activity diagrams to describe the activities, they can focus on their flows of events without specifying classes involved in the events. This feature allows us to specify the behaviors of a system from a more abstract viewpoint, especially for web applications in which events and activities are often specified before classes/objects identification. The other advantage is able to check the soundness of specified activities whether they are sufficient enough to achieve the tasks specified in the use cases. Soundness checking such as dead tasks, and the tasks that causes deadlocks and livelocks, should be identified and prevented in the diagrams [8].

After creating workflow diagrams for the system, the next step can be divided to two branches: one is to design web pages and use them to do scenarios analysis, and the other is to create a class diagram and a set of sequence diagrams. Web page design plays two important roles in the process. First the web pages are used to construct the interfaces of the window server in the system architecture. With the web pages, customers are able to have an early vision of the final product as well as how users will interact with the system. Second the web pages can be used to verify the actions/events in the workflow diagrams. They can help in scenario analysis and check the soundness of the diagrams with a series of graphic user interface displays. We have found that web page design is very important in web development, and it is the first bridge that connects web system architecture and web development process.

The bottom part of the development process concerns the implement issue of the system, which include a class diagram, different sequence diagrams, and activity diagrams. They are related to the components (classes) and their functions that support the services provided in web pages. Web databases provide storage media in which data accesses are implemented in the functions of components.

With workflow diagrams, we can specify classes that are needed and how they interact with each other to accomplish the tasks in the scenarios. A class diagram and a set of sequence diagrams are created next, to show the static system architecture and the dynamic behaviors of the system respectively. These diagrams are constructed simultaneously for saving some development time and for referring to each other.

With identified classes in the class diagram and messages (functions) in the sequence diagrams, the next step is to create various activity diagrams to put details of the messages and classes. Objects in the sequence diagrams are used to create swimlanes, and the sequences of messages are expressed with flows of actions/events, which will be mapped to relevant coding statements later. Some activities in the activity diagrams need to access web databases. Together with the class diagram and the sequence diagrams, they can help to design the schema and queries of the web database system.

The five UML diagrams used in the proposed web application development process support the development of the applications that are needed in the web system. Web page design and web database system design can be done with the constructions of these diagrams.

3 Consistency Checking of UML Diagrams

Consistency checking serves two purposes of software development with UML: it keeps the consistency between the diagrams of UML, and it improves the correct uses of symbols and the completeness of the diagrams [3, 8]. Only when these diagrams are consistent and complete, they are able to express effectively different aspects of a software system [3, 9].

3.1 From Use Cases to Work Flow Diagrams

G1: Make sure that each use case has a corresponding workflow diagram to express the scenarios covered in the use case.

A use case is just a definition of a system service, or a business activity, requested by customers. A specification of such a defined service is descried with a workflow diagram. Guideline G1 is to make sure that each complete service has a definition part (use case) and a specification part (workflow diagram). For example, a possible use case, Make Payment, is a requested service for an online purchase. A workflow diagram should be used to specify the flows of activities necessary to complete the service. These two diagrams together complete the description of a functional requirement of a system.

G2: Make sure that each workflow diagram completely covers all of the scenarios that a use case intends to have.

This guideline suggests that every scenario and its branches of a use case should be covered in a workflow diagram. With the previous Make Payment use case, it may allow customers to make a payment with credit cards, store cards, or checks. All of the three methods may or may not pass the validation of the cards or checks. A workflow should cover all the three scenarios and their two possible branches. If the system allows customers to use the combination of the three payment methods, the workflow diagram also needs to specify such combination of scenarios.

3.2 From Workflow Diagrams to Class Diagram and Sequence Diagrams

G3: Make sure that each workflow diagram has at least one sequence diagram to express its activities with sequences of messages (function calls).

In our method, a sequence diagram is used to express a flow of activities in a workflow diagram with a sequence of messages (functions) that are needed to complete a scenario. For example, when using a credit card to make the payment in the example, a sequence diagram may contain the following sequence of messages: readCard(), validateCard(), and displayConfirmation() (if the card passed through the validation) or diaplayError() (if the card didn't pass through the validation). Guideline G3 requests that each work flow diagram should have at least one sequence diagram to specify necessary functions to cover a scenario in the diagram.

G4: Make sure that all the classes have been used in one or more sequence diagrams. If any class is not used, make sure that it is for reusability or other purpose.

G5: Make sure that all the classes in the class diagram have correct relationships to interact with each other in the sequence diagram.

Guidelines G4 and G5 are from our previous work [1]. The purpose of these two guidelines is to make sure that each class is necessary and used in the system, and their relationships are consistently expressed in both the class diagram and the sequence diagrams.

3.3 From Class Diagrams and Sequence Diagrams to Activity Diagrams

G6: Make sure that each sequence diagram has a corresponding activity diagram to illustrate each message passing (function call) with flows of actions/events.

G6 indicates that a sequence diagram is used to construct a corresponding activity diagram. Each message in the sequence diagram is expressed in detail with flows of actions/events that are needed to fulfill the requirements of the message. Take the readCard() message in G3 as example. Actions that may take to complete this function include *displaying a form*, *asking customers to enter card information*, and *reading and saving the card information temporary in the system*. If the customers missed some fields of the form, another set of actions should be performed to ask the customers to modify the missing fields. The flow of these actions is like an algorithm design for the function readCard(). They will be implemented in the later coding phase.

G7: Make sure that all the classes have been used in one or more activity diagrams. If any class is not used, make sure that it is for reusability or other purpose.

This guideline is a reflection of G5. It makes sure that all of the classes in the class diagram have their uses in the system.

4 Project Examples

There were two web applications completed by using the proposed method in 2009. Although they were term projects requested in a Web Engineering course, they were originally requested by two offices at Eastern Kentucky University: Kentucky Educational Collaborative for State Agency Children (KECSAC) and the department of Computer Science. Students were divided into two groups to do the projects. They followed the proposed web development process and completed the projects, in good quality, within two months.

4.1 KECSAC Project

This project was to develop a web application for the KECSAC office of EKU to replace and enhance functionality of its original system. The main task of the system was to keep, access, and search various data of Kentucky State schools in a database. The original system was implemented in Microsoft Access. It was installed in a computer, which allowed only one user to access the system at a time. Data were duplicated and kept in the database for different years. The system was not reliable because of many minor errors. It also was not user friendly because users needed to memorize different complex operations to execute different functions.

The office requested a new system that satisfies multi-users, remote access, and efficiency and effectiveness requirements. A team of four students were assigned to do the project. They spent four weeks in learning the proposed method and applying it to the project. They spent another four weeks to implement the system and relevant documents. Currently the system has been used and tested by the office. So far they haven't found any fatal errors and are very satisfied with the new system. The following figures are some screenshots of the system.

With the new system, users from the office can now use the system with any browsers from different sites. Multiple users can login to the system and access the data simultaneously. Figure 4 shows a login page to verify valid users of the system. Figures 5 and 6 show how various data are displayed in a more organized way. Data can also be modified with the same pages. Figure 7 shows the print function of the system, which allow users to generate different report for printing.

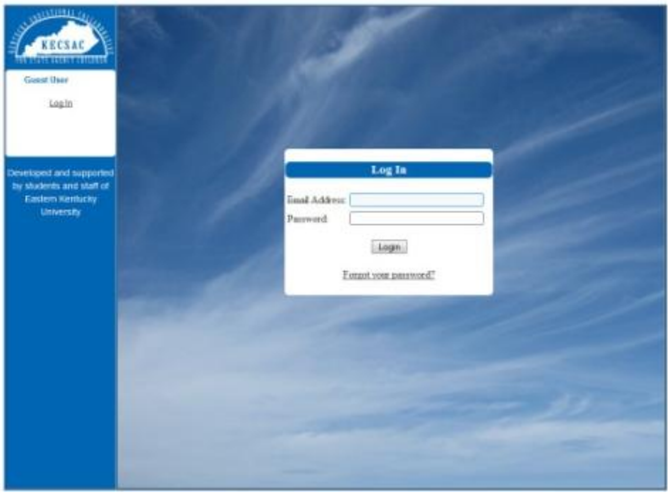
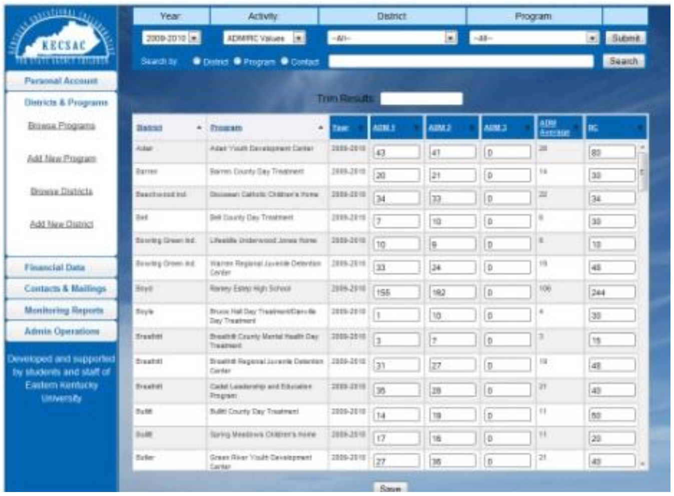


Figure 4. KECSAC Login Page



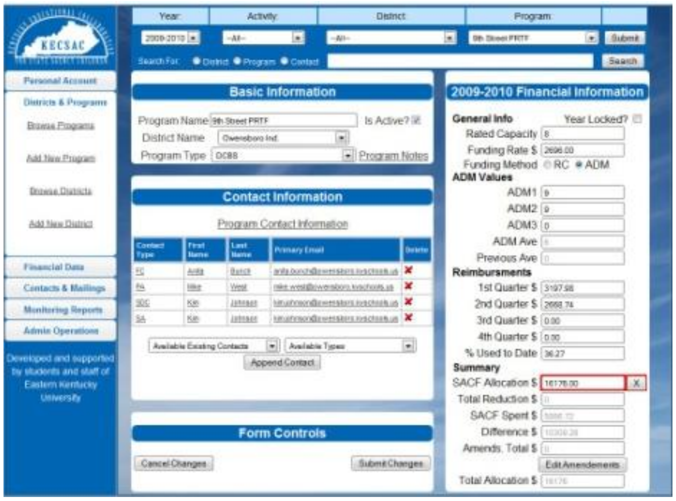
Year: 2009-2010 Activity: ADM/RC Values District: --All-- Program: --All--

Search by: ● District ● Program ● Contact

Trim Results:

District	Program	Year	ADM 1	ADM 2	ADM 3	ADM Average	RC
Adair	Adair Youth Development Center	2009-2010	43	41	0	28	80
Barren	Barren County Day Treatment	2009-2010	20	21	0	14	30
Beechwood Ind.	Diocesan Catholic Children's Home	2009-2010	34	33	0	22	34
Bell	Bell County Day Treatment	2009-2010	7	10	0	6	30
Bowling Green Ind.	Lifeskills Underwood Jones Home	2009-2010	10	9	0	6	10
Bowling Green Ind.	Warren Regional Juvenile Detention Center	2009-2010	33	24	0	19	48
Boyd	Ramey Estep High School	2009-2010	155	182	0	106	244
Boyle	Bruce Hall Day Treatment/Danville Day Treatment	2009-2010	1	10	0	4	30
Breathitt	Breathitt County Mental Health Day Treatment	2009-2010	3	7	0	3	15
Breathitt	Breathitt Regional Juvenile Detention Center	2009-2010	31	27	0	19	48
Breathitt	Cadet Leadership and Education Program	2009-2010	35	28	0	21	40
Bullitt	Bullitt County Day Treatment	2009-2010	14	19	0	11	50
Bullitt	Spring Meadows Children's Home	2009-2010	17	16	0	11	20
Butler	Green River Youth Development Center	2009-2010	27	36	0	21	40

Figure 5. School Activities Display Page



Year: 2009-2010 Activity: --All-- District: --All-- Program: 9th Street PRTF

Search For: ● District ● Program ● Contact

Basic Information

Program Name: 9th Street PRTF Is Active? ☑
District Name: Owensboro Ind.
Program Type: DC88

Contact Information

Program Contact Information

Contact Type	First Name	Last Name	Primary Email	Delete
FC	Anita	Burch	anita.burch@owensboro.kyschools.us	✗
FA	Mike	West	mike.west@owensboro.kyschools.us	✗
SDC	Kim	Johnson	kim.johnson@owensboro.kyschools.us	✗
SA	Kim	Johnson	kim.johnson@owensboro.kyschools.us	✗

Available Existing Contacts / Available Types

2009-2010 Financial Information

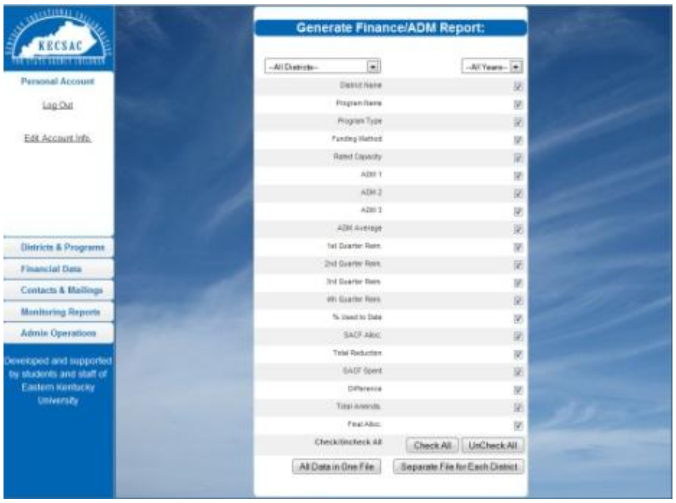
General Info — Year Locked? □
Rated Capacity: 8
Funding Rate $: 2696.00
Funding Method: ○ RC ● ADM

ADM Values
ADM1: 9
ADM2: 9
ADM3: 0
ADM Ave: 6
Previous Ave: 0

Reimbursments
1st Quarter $: 3197.58
2nd Quarter $: 2698.74
3rd Quarter $: 0.00
4th Quarter $: 0.00
% Used to Date: 36.27

Summary
SACF Allocation $: 16176.00
Total Reduction $: 0
SACF Spent $: 5896.72
Difference $: 10309.28
Amends. Total $: 0
Total Allocation $: 16176

Figure 6. Contact Information Editing Page



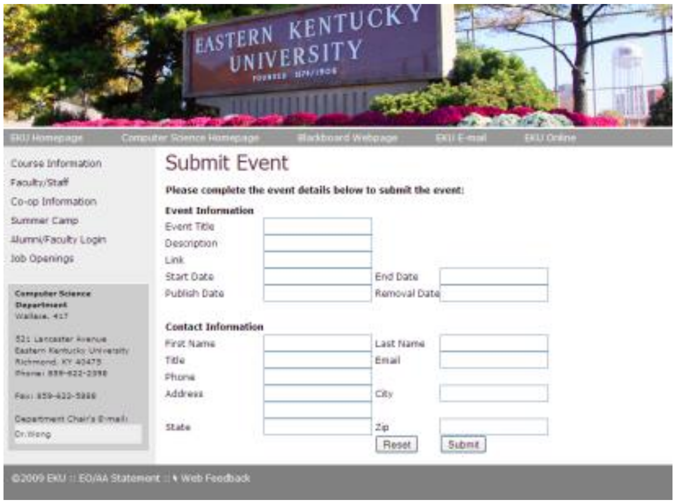
Generate Finance/ADM Report:

--All Districts-- ▾ --All Years-- ▾

District Name ☑
Program Name ☑
Program Type ☑
Funding Method ☑
Rated Capacity ☑
ADM 1 ☑
ADM 2 ☑
ADM 3 ☑
ADM Average ☑
1st Quarter Rem. ☑
2nd Quarter Rem. ☑
3rd Quarter Rem. ☑
4th Quarter Rem. ☑
% Used to Date ☑
SACF Alloc. ☑
Total Reduction ☑
SACF Spent ☑
Difference ☑
Total Amends. ☑
Final Alloc. ☑
Check/Uncheck All [Check All] [UnCheck All]

[All Data in One File] [Separate File for Each District]

Figure 7. Various Reports Generation Page



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Richmond, KY 40475
Phone: 859-622-2398

Fax: 859-622-5888

Department Chair's E-mail:
Dr.Wang

Submit Event

Please complete the event details below to submit the event:

Event Information
Event Title
Description
Link
Start Date End Date
Publish Date Removal Date

Contact Information
First Name Last Name
Title Email
Phone
Address City
State Zip
[Reset] [Submit]

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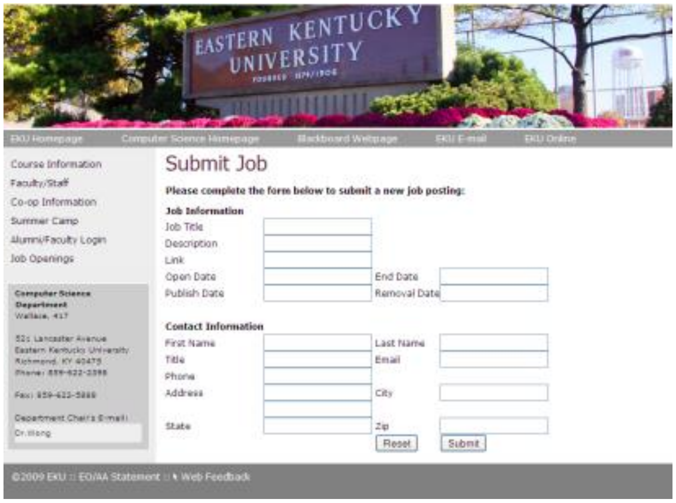
Figure 8. Announcement Editing Web Page

4.2 Computer Science Department Wet Site Project

The main task of this project was to design and implement new web pages for the department of Computer Science of EKU. The department was asked to update its web site so that all the departments and offices would have a uniform look. Other than displaying static departmental information, the department wished to set up an on-line survey for its alumni, create accounts for its alumni for job hunting and resume submission, and create accounts for its faculty members to maintain their own displaying data.

A team of five students were assigned to this project. They spent two months to create a good quality software system for the project. Although the department wasn't able to use the system at the end due to the security policy and server criteria of the university, many faculty members though that the students' system had better performance and quality than the one later used by the department. The following screenshots show some web pages of the system.

Figure 8 shows the web page which allows the department to edit and add new announcements to the web site. Figure 9 shows the page for editing job opportunities. The system also helps companies to find good candidates from the graduates who will be fit for their new positions. Figure 10 shows the page for searching such candidates. Finally, Figure 11 shows the page which allows the graduate to put their resume at the web site.



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Submit Job

Please complete the form below to submit a new job posting:

Job Information
Job Title
Description
Link
Open Date End Date
Publish Date Removal Date

Contact Information
First Name Last Name
Title Email
Phone
Address City
State Zip
[Reset] [Submit]

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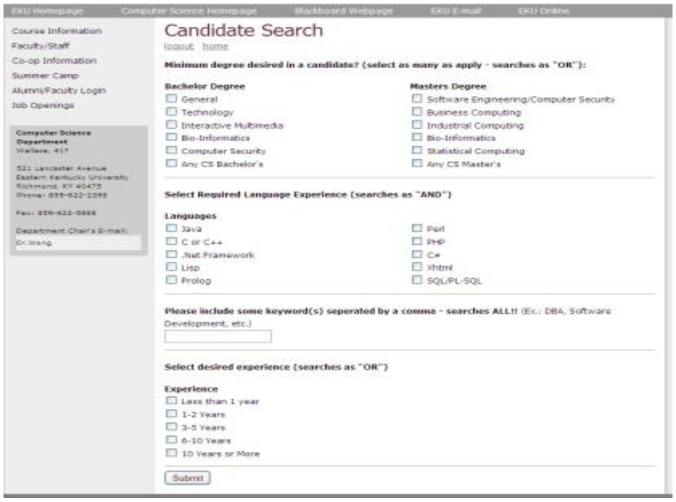
Figure 9. Job Editing Web Page



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Candidate Search
logout home

Minimum degree desired in a candidate? (select as many as apply - searches as "OR"):

Bachelor Degree
□ General
□ Technology
□ Interactive Multimedia
□ Bio-Informatics
□ Computer Security
□ Any CS Bachelor's

Masters Degree
□ Software Engineering/Computer Security
□ Business Computing
□ Industrial Computing
□ Bio-Informatics
□ Statistical Computing
□ Any CS Master's

Select Required Language Experience (searches as "AND")

Languages
□ Java
□ C or C++
□ .Net Framework
□ Lisp
□ Prolog
□ Perl
□ PHP
□ C#
□ Xhtml
□ SQL/PL-SQL

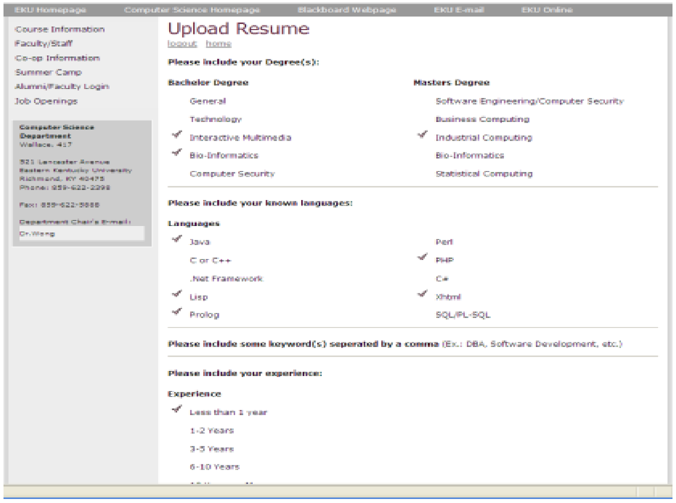
Please include some keyword(s) seperated by a comma - searches ALL!! (Ex.: DBA, Software Development, etc.)

Select desired experience (searches as "OR")

Experience
□ Less than 1 year
□ 1-2 Years
□ 3-5 Years
□ 6-10 Years
□ 10 Years or More

[Submit]

Figure 10. Job Matching Web Page



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Department Chair's E-mail:
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Upload Resume

Please include your Degree(s):

Bachelor Degree	**Masters Degree**
General	Software Engineering/Computer Security
Technology	Business Computing
✓ Interactive Multimedia	✓ Industrial Computing
✓ Bio-Informatics	Bio-Informatics
Computer Security	Statistical Computing

Please include your known languages:

Languages	
✓ Java	Perl
C or C++	✓ PHP
.Net Framework	C#
✓ Lisp	✓ Xhtml
✓ Prolog	SQL/PL-SQL

Please include some keyword(s) seperated by a comma (Ex.: DBA, Software Development, etc.)

Please include your experience:

Experience

✓ Less than 1 year
1-2 Years
3-5 Years
6-10 Years

Figure 11. Resume Submission Web Page

4.3 Discussion

Both the KECSAC and CS Department projects have been implemented with the proposed method. They were team projects of a Web Engineering course. At the beginning of the semester, the instructor didn't expect too much from the students, because the proposed method had never been applied to any project, and the students were just about to learn the disciples and techniques of web engineering. There were other factors that might affect the result of the projects:

1. Time limitation
   The course was a two-month session. The students needed to learn various topics of web development beside the projects, and complete a solid web-based software system for the customers in eight weeks.

2. Students' background
   The students were either undergraduate or graduate. Only a few of them had taken software engineering courses before. Three of them had a full time job. None of them knew web engineering well.

3. Customer's needs
   As in most cases, the customers of both projects didn't have a complete list of requirements at the beginning. The students needed to help them to figure the requirements during the progress of the projects, especially for the KECSAC project.

The outcome was satisfactory. The students followed the process well and worked closely. At the end of the semester, they came out with good quality products and documents. Both the KECSAC office and the CS department were impressed with their work. The only missing part of the projects was testing. However, it seemed that there were only a few minor errors left after delivering the products to the customers, and they had been removed quickly.

5 Conclusion

A practice of UML for web development has been displayed in this paper. A process composed of several UML diagrams —use case, workflow, class, sequence, and activity—provides a short development term for constructing a web application. The process supports the very basic web system architecture, which consists of a server, applications, and web databases. Several guidelines have been provided in the paper for checking consistency among the diagrams. These guidelines help determine what UML diagrams to create next, how many to build, and what need to check in the new diagrams.

Because of its short development term, the process is easy to follow, and easy to move forward and backward for accommodating to requirement changes. At the end of the paper, two projects that use the proposed process to complete two web applications are introduced to show the usefulness of the method.

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