



Bilkent University

Department of Computer Engineering

Software Architecture Design

Smart Board System for Bilkent University

Final Report

Group 1

Naime Fulya Kayaalp

Senem Sancar

Aykut Bulca

Anıl Armağan

Instructor

Dr. Bedir Tekinerdoğan

December 27, 2011

Table of Contents

1.	INTRODUCTION.....	4
2.	PROBLEM STATEMENT	5
3.	THE SOFTWARE ARCHITECTURE DESIGN PROCESS.....	6
4.	REQUIREMENTS ANALYSIS.....	7
4.1.	STAKEHOLDERS IDENTIFICATION.....	7
4.2.	FUNCTIONAL REQUIREMENTS.....	13
4.3.	NON-FUNCTIONAL REQUIREMENTS	14
4.4.	USE CASE MODELS	15
4.5.	ARCHITECTURAL SCENARIOS.....	29
4.6.	USER INTERFACE PROTOTYPES.....	32
5.	TECHNICAL PROBLEM ANALYSIS.....	38
5.1.	COMPUTER SCIENCE PROBLEMS	38
5.2.	MATHEMATICS DOMAIN PROBLEMS.....	39
5.3.	APPLICATION DOMAIN PROBLEMS	39
5.4.	QUALITY PROBLEMS	40
6.	DOMAIN ANALYSIS.....	41
6.1.	DATABASE MANAGEMENT SYSTEMS.....	41
6.2.	DISTRIBUTED SYSTEMS	45
6.3.	FILE MANAGEMENT SYSTEMS	47
6.4.	TRANSACTION MANAGEMENT SYSTEMS.....	50
6.5.	COMPUTER NETWORKS	53
6.6.	NETWORK SECURITY	58
6.7.	USER INTERFACE DOMAIN	62
7.	SOFTWARE ARCHITECTURE DESIGN.....	65
7.1.	LOGICAL/CONCEPTUAL SOFTWARE ARCHITECTURE	65
7.2.	DATA DIAGRAMS.....	70

8.	TOP LEVEL CONTEXT DIAGRAMS	73
9.	MODULE VIEWS	74
9.1.	USES VIEW	74
9.2.	DECOMPOSITION VIEW.....	75
9.3.	GENERALIZATION VIEW	78
9.4.	LAYERS VIEW	80
9.5.	ASPECTS VIEW	83
9.6.	DATA MODEL VIEW.....	84
10.	COMPONENT AND CONNECTOR VIEWS.....	86
10.1.	Client-Server Style.....	86
10.2.	Publish-Subscribe Style	88
10.3.	Repository Style	89
11.	ALLOCATION VIEWS	91
11.1.	Deployment View	91
11.2.	Install View	93
11.3.	Work Allocation View.....	96
12.	EVALUATION OF THE SOFTWARE ARCHITECTURE	99
12.1.	Scenario Based Architectural Analysis (SAAM).....	99
12.2.	UTILITY TREE (ATAM)	104
13.	CONCLUSION.....	107
14.	REFERENCES.....	109

1. INTRODUCTION

Education has always played a crucial role in human life and is considered as the most significant factor in the development of a society. It increases life standards of society and brings social consciousness while it contributes to the art, science and technology. To increase the quality of education some ways and innovative solutions are being offered, one of which is provided by technological advancements. However, these advancements provided by technology are very limited and in order to be effective they should be improved.

“Smart Boards in Bilkent” is such a project which aims to increase the quality of education in Bilkent University by providing an interactive education environment. The project purposes to increase student-lecturer interaction and student participation during the lectures. “Smart Boards in Bilkent” offers a reliable teaching environment for instructors while it provides an enjoyable learning environment for students. The project will provide instructors to display the course related documents on the board and allow them to take notes (with an infrared pen) on these documents. Students will be able to see those changes on their tablets and make changes on those documents if instructor gives permission. Students and instructors will also be able to work on same documents simultaneously from their own machines. In order to construct a qualified and beneficial system, the system should be functional and provide ease of use for both students and instructors. It must be adaptable, persistent, highly qualified and must have a low cost to be used extensively. Thus, our aim is to design software architecture for “Smart Boards in Bilkent” which highly satisfies the above mentioned concerns.

This report aims to document the architecture of the Smart Boards in Bilkent project. Section 2, includes the problem statement which encourages us to work on such a smart board system. Section 3 contains software architecture design process which explains the steps done in the requirements analysis, technical problem analysis and domain analysis processes. Section 4 is the requirements analysis section which stakeholder, functional and non-functional requirements, use case models, user interface prototypes and some use cases are identified. Section 5 is technical problem analysis section which covers computer science problems, mathematics domain problems, application domain problems, and quality problems. In section 6 domain analysis which the related solution domains and knowledge sources are explained and glossary is constructed for those identified domains. Section 7

contains software architecture design which presents the conceptual software architecture, designed by UML notations. In Section 8 top level context diagrams which show the boundaries between the Smart Board system and the external entities, is defined. Report continues with the modeling of software architecture, Views and Beyond approach is chosen for description of software architecture model. Next three sections continues with the categories of viewpoints of Views and Beyond Approach. Section 9, Module Views which contains uses, decomposition, generalization, layer, aspect and data flow views in order to documents the system's principal units of implementations. Section 10, Component and Connector Views which contains Client-Server, Publish-Subscribe and Repository views to show that system is structured as a set of elements that have run-time behavior. Section 11, Allocation Views of Smart Boards in Bilkent project which contains deployment, install and work allocation views to mapping software elements of the system to the non-software environment. Section 12 is the final section of this report in which conclusion is included. Lastly, references are given in section 13.

2. PROBLEM STATEMENT

As one of the most prestigious universities, Bilkent University has the vision of qualified education. Students are encouraged to participate in classrooms; they are required to ask or answer questions, reflect their thoughts etc. Furthermore, students supposed to have qualified communication and social skills to participate in projects. However, there are some times that the education quality is damaged. Some of the students are beware of asking or answering questions during the lecture hours which cause them to catch the classes. When such a situation occurs, instructors complain about non cooperative course environments where students do not pay attention to the lecture. Additionally, students complain about copying lecture notes from the board. They are unable to write and listen synchronously which cause their loss of attention.

The goal of the project, "Smart Boards in Bilkent", is to provide an interactive education environment for both Bilkent University students and instructors in order to reduce above mentioned problems. Students will be able to participate to the lectures by writing and displaying their thoughts on the board which provides a cooperative environment. At the same time, they will not be supposed to take notes during the lectures; they can reach the notes

wrote on board at anytime they want. Additionally, “Smart Boards in Bilkent” will be different from the existing similar systems in terms of its ease of usage, adaptability, performance, quality and cost. It is aimed to create a qualified and simple system with simple user interface gadgets.

3. THE SOFTWARE ARCHITECTURE DESIGN PROCESS

Requirements analysis, technical problem analysis, domain analysis and software architecture design are the steps to be followed in the design process of software architecture of Smart Board System. These steps are essentially based on the synthesis-based software architecture design approach.

Requirements Analysis:

This phase is done in order to determine the needs or conditions to meet for a new system that will be developed. It is a critical process for the success of the project. Requirements analysis phase starts with the identification of stakeholders. Then, the related functional and non functional requirements are specified for each stakeholder by considering their primary concerns, needs and expectations. After the specification of stakeholders with their concerns, the requirements of the project are defined with textual requirements, use cases, architectural scenarios and UI prototypes to visualize the system for better understanding.

Technical Problem Analysis:

Technical problem analysis defines the basic technical problems considering the mathematics domain problems, application domain problems, computer science problems and quality problems and the related concerns that need to be solved are specified. This process starts with the identification of the problems. Then the current systems are evaluated according to these problems and their states are found. After this, the desired state by the project “Smart boards in Bilkent” is explained.

Domain Analysis

Domain Analysis process is the process of analyzing related software systems in a domain to find their common and variable parts. In this part, firstly solution domains are identified using the technical problems described in the “Technical Problem Analysis” section. Then

knowledge sources are described and they are evaluated. Lastly, the derived concepts and the structure and description of concepts are specified.

Software Architecture Design

Final step of the design process is the actual architecture design. The logical/conceptual software architecture design is presented by using UML. To achieve this, specific information for each domain is collected. After specifying domain knowledge, a high level architecture using stereotyped classes is designed.

4. REQUIREMENTS ANALYSIS

In order to satisfy the customer's needs, essentials of the system have to be identified. Therefore, requirement analysis process has to be followed. In this part, stakeholders, textual requirements, use cases, architectural scenarios and prototypes will take place.

4.1. STAKEHOLDERS IDENTIFICATION

Stakeholders are a person, group, organization, or system that can affect or be affected by the actions of the system as a whole. In this part, the stakeholders of the system are identified.

4.1.1. Instructors

Instructors are the main users of the smart board system so; their concerns, needs and expectations about the system are important.

Concerns of the Instructors

→ Usability of smart boards

Instructors expect the smart board system to be used easily. They want to share their course related documents without dealing with complex user interface gadgets. They want smart board to be a tool that simplifies their jobs.

→ Functionality of smart boards

Instructors expect smart boards to provide all the functionalities that they are able to do without smart boards. Since most of the instructors use both slide shows and black boards during their lectures, smart boards should at least offer these functionalities.

→ *Security of smart boards*

Instructors expect smart boards to be secure enough to protect their own documents that are shared with the students during the lecture. Students should not be able to reach instructor's documents without having permission.

4.1.2. Managing Committee of the University

Directory of the university will be the owner of the smart board project. Since they want the project to be unique for the university, their concerns will shape the features of the smart board system.

Concerns of the Managing Committee

→ *Low Cost*

Since the boards will be included in all the classes of Bilkent University, Managing Committee wants the project to be affordable.

→ *Reliability of the Project*

Another concern of the Managing Committee is the reliability of the system. Since the project will be used in all classrooms of the university and will be used by almost all the instructors and the students of the university, the system must be persistent and work without any restrictions or errors.

→ *Adaptability of the Project*

Managing Committee want the project to be adaptable for the current classrooms of the university.

→ *Sustainability*

Managing Committee wants the smart board system to serve for years after the project is realized.

4.1.3. Students

Since the project aims to increase the participation of students during the lectures and provide more effective and enjoyable education for them, student's expectations from the system are significant.

Concerns of Students

→ *Usability of Smart Boards*

Students want “Smart Boards in Bilkent” project to have a user interface which is easy to understand and use. Additionally, the pens which will be used to draw on smart boards and which will be given to students should be usable.

→ *Accessibility of the Lecture Notes*

Another concern of the students is the accessibility of the data (including lecture notes, related documents, drawings, projects etc.) stored by the agency of smart board system. The system should offer a data management system that stores all the course related documents put by the instructor and modified in the lectures. These documents should be accessible by the students easily.

4.1.4. Administrator of the System

Administrator of the system will be the maintainer of the project. She/he is responsible for collecting and organizing all the data saved by the smart boards in the university. Any encountered problems will be solved by the administrator of the system so his/her expectations from the system are important.

Concerns of the Administrator

→ *Security of the System*

The main concern of the system administrator is the security of the system. Since the admin is responsible for authentication of students and instructors, and protection of any saved data the system should be secure enough to guarantee that the admin is the only person organizing this structure.

→ *Adaptability of the System*

The system should be easily adaptable by the administrator of the system. The admin wants to make any required changes easily.

→ *Persistency of the System*

The administrator of the system expects the system to be used for years without encountering any problems that are not easy to solve.

4.1.5. Software Engineers

Software engineers are the programmers of the system who are responsible for the software part of the system. Therefore, they have also expectations from the system to produce codes to satisfy the requirements decided by the other stakeholders.

Concerns of the Software Engineers

→ Performance of the System

The main concern of software engineers is the performance of the system they will develop. The system should work with optimal performance and they should achieve implementing such software that works with this desired optimum performance.

→ Qualified Design

Another concern of the software engineers is the design of the project. They need the design to be easily understood and clear. Minor modifications in the design should not allow any problems. Similarly, additions to the design should be done easily.

→ Compatibility with Hardware Part

Another concern of the software engineers is the compatibility of the software components with the hardware components that is designed by the hardware engineers.

4.1.6. Hardware Engineers

Hardware engineers are responsible from the hardware part of the system. They will produce smart boards, smart pens and a control panel to satisfy the requirements decided by the stakeholders of the project. They also have some expectation from the system.

Concerns of the Hardware Engineers

→ Usability of the Hardware Components

The main concern of the hardware engineers is the usability of the components that will be designed. Smart pens, smart boards and the tablet computer for the students should be easily used and they should respond the orders of users in the desired way.

→ *Compatibility with Software Part*

Another concern of hardware engineers is the compatibility of the hardware components with the software components that is designed by the software engineers. The system should work properly with both components.

4.1.7. Software Architect

Software architect is the designer of the smart board system, who shapes the system.

Concerns of the Software Architect

→ *Flawless Design*

The architect wants to produce a good architecture that satisfies the expectations of the stakeholders. The system should work properly after the realization of the design of the software architecture.

4.1.8. Tester

Tester tests all the functionalities of the system before it is delivered to the university board. She/he will also be responsible of designing test scenarios and testing them on the developed system.

Concerns of the Tester

→ *Suitability for testing*

The only concern of the tester is the suitability of the system for testing. The system should be designed and implemented in a good way which makes the testing of the system easier.

4.1.9. Project Manager

Project manager is the person who manages the project. She/he makes the schedule for the delivery of each design step and makes sure that other stakeholders keep up with this schedule. Project manager also provides the communication between the directory of the university who are the customers and other stakeholders of the project.

Concerns of Project Manager

→ *Time to market*

One of the main concerns of the project manager is the time of the delivery of the project. She/he will try to ensure that all other stakeholders keep up with the schedule so that project will be finished on the time.

→ *Quality of the system*

Another concern of the project manager is the quality of the system developed. She/he expects the project to satisfy all the requirements coming from stakeholders.

→ *Cost of the system*

Another concern of the project manager is the cost of the system developed. She/he expects the project is developed with the most optimized cost.

4.1.10. User Interface Designer

User interface designer is responsible for designing the user interface gadgets of the smart boards system.

Concerns of the User Interface Designer

→ *Simplicity of the user interface*

The main concern of the user interface designer is the simplicity of the user interface that will be designed. The interface must be easily understandable by the instructors and the students so that they can get benefit from all of the features of the system.

4.1.11. Industrial Engineer

Industrial engineer is responsible for optimizing the cost of the project. S/he will provide efficient ways for other stakeholders to get a balanced project when the cost and the functionalities of the project are considered.

Concerns of the Industrial Engineer

→ *Optimized Cost*

The main and only concern of the industrial engineer is the cost of the project. The cost must be acceptable by all other stakeholders and should make a difference when other similar projects are considered.

4.1.12. Database Administrator

Database administrator is responsible from the data stores, including database design, data analysis, data modeling and optimization, installation of database software, and monitoring and administration of database security.

Concerns of the Database Administrator

→ *Qualified Data Storage*

The main and only concern of the database administrator is to provide reliable data storage to the system. The necessary precautions should be taken by the database administrator when any errors occur in the data storage system.

4.1.13. Network Administrator

Network administrator is responsible from the maintenance and oversight of the computer hardware and software in a computer network. This may include the deployment, configuration, maintenance, and monitoring of network components.

Concerns of the Network Administrator

→ *Qualified Network Environment*

The main and only concern of the network administrator is to provide a reliable network environment to the system. The necessary precautions should be taken by the network administrator when any errors occur in the network environment which connects the hardware and software components of the system.

4.2. FUNCTIONAL REQUIREMENTS

- The system shall be able to allow instructors to upload the course content for students to reach.
- The system shall be able to allow instructors to communicate with students through the system during the class.
- The system shall be able to allow instructors to see the previous courses lecture notes.
- The system shall be able to allow instructors to display presentations, web pages and videos on the smart board.
- The system shall be able to allow instructors to change/modify lecture notes at any time want.
- The system shall be able to allow instructors to take notes on any content such as; presentations, videos, web pages etc.
- The system shall be able to allow instructors to use the smart board as an ordinary board and allows them to write on plain board.

- The system shall be able to allow instructors to make the lecture notes visible for students.
- The system shall be able to allow instructors to write, read, add comments and make changes on the course related documents simultaneously.
- The system shall be able to allow students to communicate with instructors through the system during the class.
- The system shall be able to allow students to see the previous courses lecture notes.
- The system shall be able to allow students to reach the course related documents such as lecture notes, homework, previous years exams etc.
- The system shall be able to allow students to write, read, add comments and make changes on the course related documents simultaneously.
- The system shall be able to allow students to change anything in the smart board by using their infrared pens.
- The system shall be able to allow administrator of the system to qualify authentication.

4.3. NON-FUNCTIONAL REQUIREMENTS

- The interface of the Smart Board system should be user friendly. The system will have a basic user interface in order to provide user an easy usage of the application. The interface will be simple and clear.
- The smart board will be open to update. The database, the algorithms and the interface design of the application can be updated in time.
- Tablets of the students will be open to update.
- The databases of the system should be enough large to hold all the contents of the lectures.
- The system should connect to the internet via 1 Mbit connection speed.
- The system should be portable to be used in any classroom.
- Both the tablets and the smart board should have access to same local network.
- The tablets of the students should be able to connect the smart board through local network connection.
- The response time of the system while user is sketching or changing slides should be less than 1 second.

- The smart board should be available for instructors for all the time, it has to be ready to use.
- The system should be reliable, in other words, it has to show the exact same sketching with what instructor has drawn.
- The instructors' computers should have Windows Xp/Vista/7 to run the software for the Smart Board system.
- The tablets of the students should be Android tablets.
- Administrative should have a desktop computer running on Windows Xp/Vista/7.
- The system should keep the accounts and the contents for the courses in separate database servers.
- Database servers of the system should be Linux based.
- The system should not lose any data in case of damage to the database servers. The system should have a back-up server.
- The system should be secure to prevent other people to access the system and reach the contents of the courses.
- Each of the instructors and the students should have different log on information like user id and password.
- Students should not be able to log in to the smart board as an instructor. System should authenticate it.

4.4. USE CASE MODELS

In this part, the use case diagrams of the system and related scenarios explaining the diagrams are explained.

4.4.1. USE CASE FOR INSTRUCTORS

Figure 1 explains the interaction of instructors with the system. Instructor logs into the system. He/she can display the course content (lecture notes, videos and web pages) on the board and can share this content with the students. Instructor can change the course content or upload additional materials at any time. He/she can take notes on the board (which he/she also takes notes on the content at the same time) and can ask questions to the students.

Additionally, instructor can change the options of the smart board system. Finally, instructor logs out from the system.

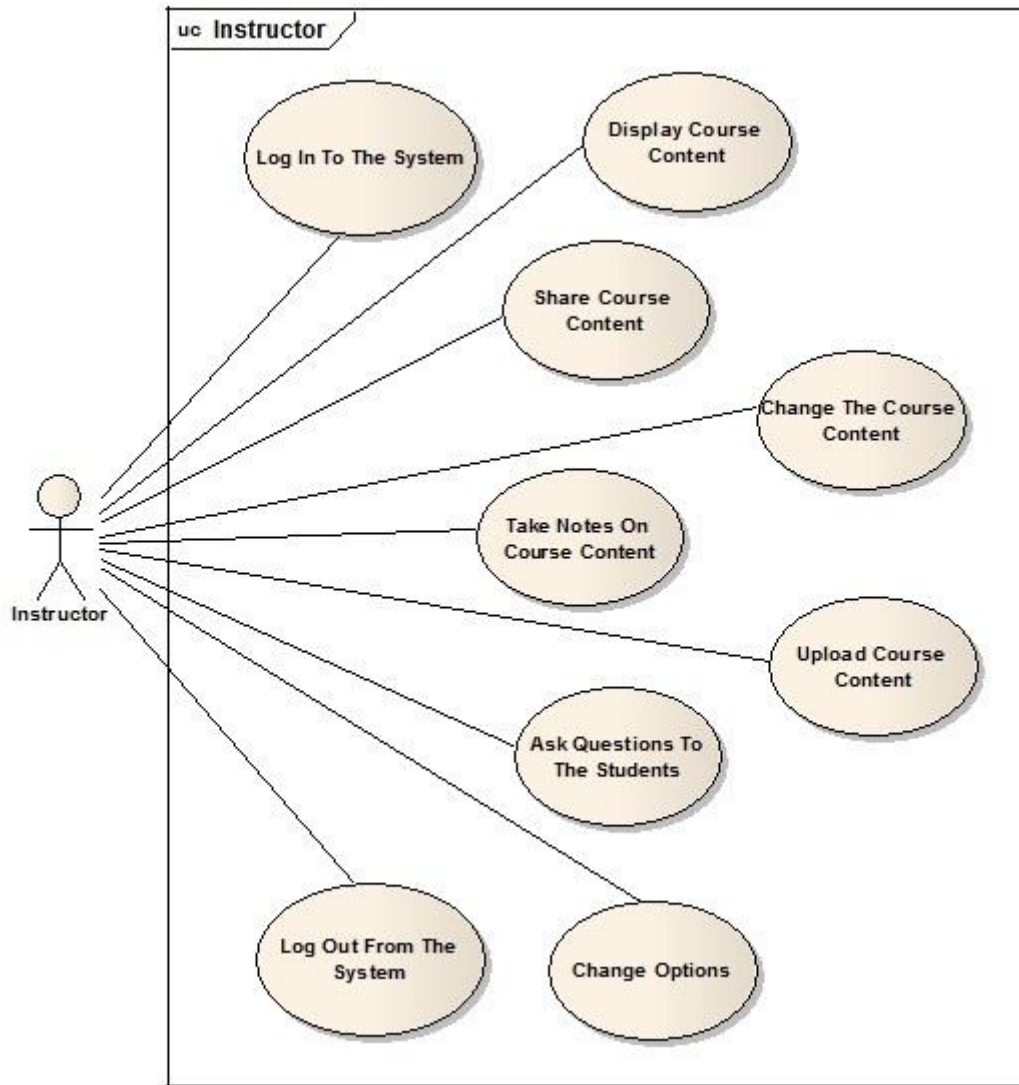


Figure 1 Use Case Diagram for Instructors

Use Case 1: Instructor displays a presentation

ID	UC1
Name	Instructor displays presentation
Primary Actor	Instructor
Preconditions	Instructor is registered to the system by the admin
Post conditions	Related course content displayed on the smart board.
Main Scenario	<ol style="list-style-type: none">1. Instructor logs in to the system using his/her password and the computer.2. Instructor touches the “Presentations” tab using his/her pen on the smart board.3. The list of courses of the instructor is shown to the instructor.4. Instructor chooses the related course using his/her pen.5. The uploaded presentations are shown to the Instructor.6. Instructor touches the name of the presentation s/he wants to display using his/her pen.7. The selected presentation is shown on the smart board.
Extensions	<p>*. The instructor can quit system any time.</p> <p>1a. Instructor enters his/her username or password incorrect.</p> <ol style="list-style-type: none">1. A warning is displayed to the Instructor explaining the reason of the failure.

Use Case 1 Instructor displays a presentation

Use Case 2: Instructor displays a web page

ID	UC2
Name	Instructor displays a web page
Primary Actor	Instructor
Preconditions	Instructor is registered to the system by the admin.
Post conditions	Related course content displayed on the smart board.
Main Scenario	<ol style="list-style-type: none">1. Instructor logs in to the system using his/her password using the computer.2. Instructor touches the “Web” tab using his/her pen.3. A web browser is executed for the usage of the instructor.4. Instructor enters the url of the web page using the ‘computer’.5. The selected web page is shown on the smart board.
Extensions	<p>*. The instructor can quit system any time.</p> <p>1a. Instructor enters his/her username or password incorrect.</p> <ol style="list-style-type: none">1. A warning is displayed to the Instructor explaining the reason of the failure.

Use Case 2 Instructor displays a web page

Use Case 3: Instructor displays a video

ID	UC3
Name	Instructor displays a video
Primary Actor	Instructor
Preconditions	Instructor is registered to the system by the admin.
Post conditions	Related course content displayed on the smart board.
Main Scenario	<ol style="list-style-type: none">1. Instructor logs in to the system using his/her password using the computer.2. Instructor touches the “Multimedia” tab using his/her pen.3. The uploaded materials are shown to the instructor.4. Instructor chooses one of them to display to the class.5. The selected video is played on the smart board.
Extensions	<p>*. The instructor can quit system any time.</p> <p>1a. Instructor enters his/her username or password incorrect.</p> <ol style="list-style-type: none">1. A warning is displayed to the Instructor explaining the reason of the failure.

Use Case 3 Instructor displays a video

Use Case 4: Instructor takes notes on a presentation

ID	UC4
Name	Instructor takes notes on a presentation
Primary Actor	Instructor
Preconditions	Instructor is registered to the system by the admin and related course content is already uploaded to the system.
Post conditions	Instructor takes notes on the selected course content.
Main Scenario	<ol style="list-style-type: none"> 1. Instructor logs in to the system using his/her password using the computer. 2. Instructor touches the “Presentation” tab using his/her pen. 3. The list of courses of the instructor is shown to the instructor. 4. Instructor chooses the related course using his/her pen. 5. The uploaded presentations are shown to the Instructor. 6. Instructor touches the name of the presentation s/he wants to display using his/her pen. 7. The selected presentation is shown on the smart board. 8. The Instructor holds the pen on the smart board for 2 seconds. 9. A menu appears on the smart board and displays the features that provide the necessary options for instructor to make the necessary changes. 10. Instructor chooses one of the options displayed and takes the note wherever s/he wants in the presentation. 11. After the change, the appeared menu is closed and instructor continues to the lecture.
Extensions	<p>*. The instructor can quit system any time.</p> <p>1a. Instructor enters his/her username or password incorrect.</p> <ol style="list-style-type: none"> 1. A warning is displayed to the Instructor explaining the reason of the failure.

Use Case 4 Instructor takes notes on a presentation

Use Case 5: Instructor takes notes on a video

ID	UC5
Name	Instructor takes notes on a video
Primary Actor	Instructor
Preconditions	Instructor is registered to the system by the admin and related course content is already uploaded to the system.
Post conditions	Instructor takes notes on the selected course content.
Main Scenario	<ol style="list-style-type: none"> 1. Instructor logs in to the system using his/her password using the computer. 2. Instructor touches the “Multimedia” tab using his/her pen. 3. The uploaded videos are shown to the Instructor. 4. Instructor touches the name of the video s/he wants to display using his/her pen. 5. The selected video is shown on the smart board. 6. The Instructor holds the pen on the smart board for 2 seconds. 7. Video pauses and a menu appears on the smart board and displays the features that provide the necessary options for instructor to make the necessary changes. 8. Instructor chooses one of the options displayed and takes the note wherever s/he wants in the video. 11. After the change, the appeared menu is closed and the video continues.
Extensions	<p>*. The instructor can quit system any time.</p> <p>1a. Instructor enters his/her username or password incorrect.</p> <ol style="list-style-type: none"> 1. A warning is displayed to the Instructor explaining the reason of the failure.

Use Case 5 Instructor takes notes on a video

Use Case 6: Instructor asks a question to the students

ID	UC6
Name	Instructor asks a question to the students
Primary Actor	Instructor
Preconditions	Instructor is registered to the system by the admin.
Post conditions	The questions asked by the instructor is shown on the smart board and on the tablets of the students
Main Scenario	<ol style="list-style-type: none"> 1. Instructor logs in to the system using his/her password using the computer. 2. Instructor touches the “Sketch” tab using his/her pen. 3. A blank page appeared in the smart board. 4. Instructor is able to write anything on the smart board and writes a question for the students. 5. The question is appeared on the smart board and on the tablets of the students.
Extensions	<p>*. The instructor can quit system any time.</p> <p>1a. Instructor enters his/her username or password incorrect.</p> <ol style="list-style-type: none"> 1. A warning is displayed to the Instructor explaining the reason of the failure. <p>5a. Network connection is lost.</p> <ol style="list-style-type: none"> 1. A warning is displayed to the students explaining the reason of the failure.

Use Case 6 Instructor asks a question to the students

Use Case 7: Instructor uploads a presentation to the system

ID	UC7
Name	Instructor uploads presentation to the system
Primary Actor	Instructor
Preconditions	Instructor is registered to the system by the admin.
Post conditions	The course material is uploaded to the related section.
Main Scenario	<ol style="list-style-type: none"> 1. Instructor logs in to the system using his/her password using the computer. 2. A menu screen is appeared on the screen of the ‘computer’. 3. Instructor chooses the “Upload Material” section from this menu using the mouse of the computer. 4. Instructor chooses the “Presentation” from the newly appeared menu. 5. The presentation to be uploaded is chosen from the computer. 6. Instructor chooses the related section to upload the presentation. 7. Instructor clicks the upload button at the bottom of the page. 8. A message appears telling that the upload is successful. 9. System returns to the main menu.
Extensions	<p>*. The instructor can quit system any time.</p> <p>1a. Instructor enters his/her username or password incorrect.</p> <ol style="list-style-type: none"> 1. A warning is displayed to the Instructor explaining the reason of the failure. <p>8a. Internet connection is lost.</p> <ol style="list-style-type: none"> 1. A warning is displayed to the instructor explaining the reason of the failure.

Use Case 7 Instructor uploads a presentation to the system

4.4.2. USE CASE FOR STUDENTS

Figure 2 explains the interaction of students with the system. Students logs in to the system from their tablets. They can take notes on the course content, displayed on the board, from their tablets and ask questions to the instructor. Additionally, students can reach the permitted course content any time they want. Finally, students logs out from the system.

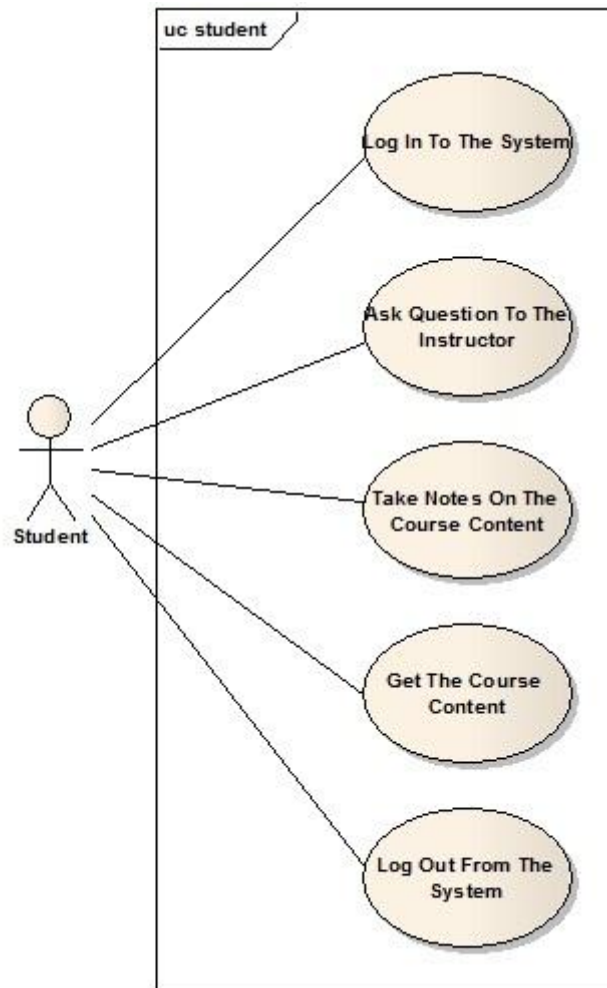


Figure 2 Use Case Diagram for Students

Use Case 8: Student takes notes on a presentation

ID	UC8
Name	Student takes notes on a presentation
Primary Actor	Student
Preconditions	Instructor allows students to take note on a course material.
Post conditions	Student takes notes on the selected course content.
Main Scenario	<ol style="list-style-type: none"> 1. Students logs in to the system using his/her password using the tablet computer. 2. The material on the smart board is now shown on the tablet computers of the students 3. Student holds his/her pen on the tablet computer for 2 second 4. A menu appears on the tablet computer and displays the features that provide the necessary options for student to make the necessary changes. 5. Student chooses one of the options displayed and takes the note wherever s/he wants in the presentation 6. After the change, the appeared menu is closed and the change is saved only for the account of that student. 7. Student continues to follow the lecture from his/her tablet computer.
Extensions	<p>*. The instructor can quit system any time.</p> <p>1a. Student enters his/her username or password incorrect.</p> <ol style="list-style-type: none"> 1. A warning is displayed to the student explaining the reason of the failure. <p>2a. Network connection is lost.</p> <ol style="list-style-type: none"> 1. A warning is displayed to the student explaining the reason of the failure.

Use Case 8 Student takes notes on a presentation

Use Case 9: Student asks a question to the instructor

ID	UC9
Name	Student asks a question to the instructor
Primary Actor	Student
Preconditions	Instructor allows students to ask question during the lecture.
Post conditions	Student asks a question to the instructor.
Main Scenario	<ol style="list-style-type: none"> 1. Students logs in to the system using his/her password using the tablet computer. 2. The material on the smart board is now shown on the tablet computers of the students 3. Student holds his/her pen on the tablet computer for 2 second 4. A menu appears on the tablet computer and displays the features that provide the necessary options for student to make the necessary changes. 5. Student chooses the “ask” option from this menu. 6. A warning appeared on the smart board and instructor accepted the question. 7. Student is now able to any change on the smart board. 8. Student holds his/her pen on the tablet computer for 2 second and a menu appeared. 9. Student chooses related options and asks his/her questions and it is displayed on the smart board. 10. Instructor answers the question and continues to the lecture.
Extensions	<p>*. The instructor can quit system any time.</p> <p>1a. Student enters his/her username or password incorrect.</p> <ol style="list-style-type: none"> 1. A warning is displayed to the student explaining the reason of the failure. <p>2a. Network connection is lost.</p> <ol style="list-style-type: none"> 1. A warning is displayed to the student explaining the reason of the failure. <p>6a. Instructor rejects the question</p> <ol style="list-style-type: none"> 1. A warning is displayed to the student.

Use Case 9 Student asks a question to the instructor

Use Case 10: Student answers a question asked by the instructor

ID	UC10
Name	Student answers a question asked by the instructor
Primary Actor	Student
Preconditions	Instructor has already asked a question
Post conditions	Student answers a question asked by the instructor.
Main Scenario	<ol style="list-style-type: none"> 1. Students logs in to the system using his/her password using the tablet computer. 2. The material on the smart board is now shown on the tablet computers of the students 3. Student is able to write anything to the screen since the question is asked using the “Sketch” feature 4. Student writes the answer of the question using his/her tablet computer and the pen. 5. Instructor sees the answer of the student and confirms the trueness of the answer. 6. The lecture continues.
Extensions	<p>*. The instructor can quit system any time.</p> <p>1a. Student enters his/her username or password incorrect.</p> <ol style="list-style-type: none"> 1. A warning is displayed to the student explaining the reason of the failure. <p>2a. Network connection is lost.</p> <ol style="list-style-type: none"> 1. A warning is displayed to the student explaining the reason of the failure.

Use Case 10 Student answers a question asked by the instructor

4.4.3. USE CASE FOR ADMIN

Figure 3 explains the interaction of the admin with the system. Admin logs into the system from a computer. He/she confirms instructors and students to authorize them to the system. Admin manages the content which is uploaded and modified by instructors. Finally, admin logs out from the system.

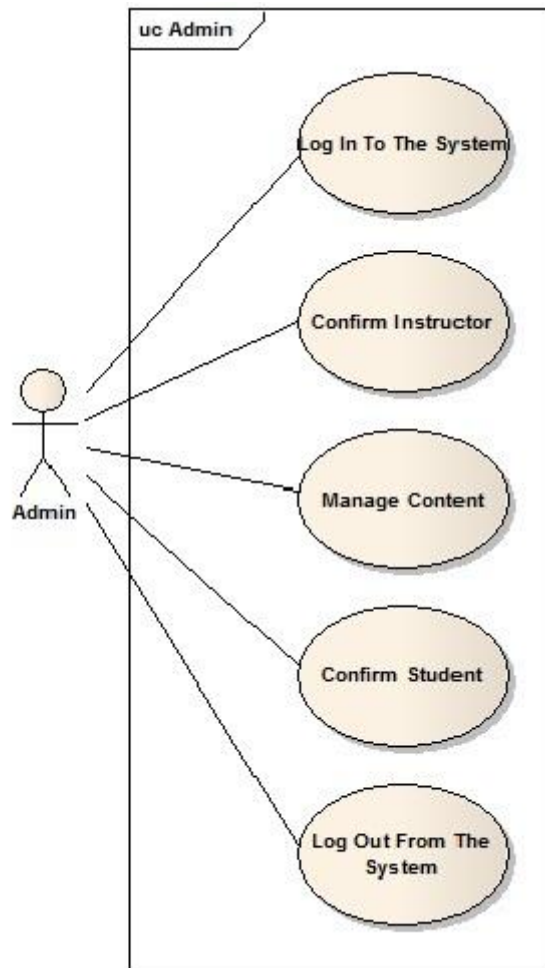


Figure 3 Use Case Diagram for Admin

4.5. ARCHITECTURAL SCENARIOS

Authentication to Smart Board System

Bilkent University has just bought Smart Boards system. Instructor Senem is going to use this Smart Board for one of her courses and she has to login to the system and create her personal profile. In order to do that she goes to admin to be registered to the system. Admin asks her instructor id and sees the courses of instructor Senem. Senem gives the names of the courses in which she wants to use the smart board system. Admin creates a profile for Senem and adds these courses to that profile. After this, admin gives a username and a password to instructor Senem for further usage of the system. With this password and the username, Senem can change the contents of her courses with any computer in Bilkent that is connected to the university network.

Uploading Lecture Contents

After registration to the system, Instructor Senem goes to her office for a cup of coffee. While having her coffee, she wants to add the presentations of her course, product line engineering, to the system. She turns her computer on and opens the webpage of the system. To be able to enter the website, she is asked for her username and password. She logs in to the system using her username and password provided to her by the admin. After logging in to the system, the available courses of her for the smart board system are listed. She chooses “CS 415: Product Line Engineering” course and some options are displayed. Instructor Senem chooses the option “Upload Presentation” option and uploads her presentations to the system from her personal computer. Then, she decides to add a video defining what product line really means. She chooses “Upload Multimedia” option and uploads the video to the system. The presentations and the video are available for her to be used in the classroom.

Displaying Presentation

Senem does not realize the time when she drinks her coffee in her office and remembers she has a lecture ten minutes later. She walks out of her office and goes to the classroom. She turns the computer on in the classroom and logs in to the smart board system using her username and password. After the logging in, the smart board in the classroom is automatically turned on and the menu screen is displayed. Senem walks through the smart board and touches the “Presentation” option with the smart pen which comes with the smart board. A menu page that lists the registered courses of her is displayed. She touches the “CS

415: Product Line Engineering” option and the uploaded slides of the course are displayed. She chooses the presentation called “Lecture_1” and the related slide show starts.

Taking Notes on a Presentation

After the slide show starts, Senem uses the arrows at the bottom of the smart board to browse around the pages. While the lecture continues, she realizes that students started to lose their attention to the content. In order to get the attention of the students, she wants to emphasize the important points of the lecture and decides to underline an important sentence. Senem holds the smart pen on the smart board for 2 seconds and a small menu appears. Since she wants to underline an important sentence, Senem touches the “line” icon from newly appeared menu. After this, the menu disappears and Senem draws the sentence using her smart pen like she writes on a traditional black board. After drawing, she tells that important part again and continues the slide show.

Displaying a web page

After mentioning about the important points of the “Lecture_1” listed at the last page of the presentation, instructor Senem realizes students still have questions about the lecture and they do not fully understand the subjects taught. In order to make the point of the lecture clearer, she decides to display a web page which has important material about the issue. To do that, she touches the “Main Menu” icon with the smart pen and the smart board starts to display the welcome screen. From this menu, she chooses “Web Page” option and touches on it with the smart pen. The web browser of the system starts and waits for the instructor to enter an URL. Senem goes in front of the computer and enters the URL of the web site using the keyboard of the computer. Students see the URL from the smart board and continue to follow the lecture. After Senem presses the enter button, the entered web page is displayed on the smart board. She wants every student to read the content displayed on the smart board and on the tablets of the students. While they read, she notices an imported point on the web site and wants to circle that point in. She touches to the smart board for 2 seconds with the smart pen and a small menu appears. Since she wants to circle an important point in, Senem touches the “circle” icon from newly appeared menu. After this, the menu disappears and Senem circles the sentence using her smart pen like she writes on a traditional black board. After this, students realize which point to focus on. When the reading finishes, Senem touches “Main Menu” icon to return the main menu.

Asking a Question

After instructor Senem is convinced that the students have understood the lecture, she decides to ask a question to them. In order to do this, she touches “Sketch” icon from the main menu and a blank screen appear where she knows that she can write or draw anything she wants. By the help of smart pen, she writes a question to the smart board like she writes on a traditional black board. The question is displayed on the smart board and on the tablet computer of each student. Aykut, a successful student of Senem, reads the question and realizes that he is able to answer. He writes the answer of the question to his tablet using the smart pen of his tablet. Since “Sketch” option allows students to share on the smart board, what he writes to the tablet computer is also displayed on the smart board. Instructor Senem sees the answer and verifies its correctness by drawing a plus sign near to the answer using the smart pen. After this, she realizes the time for the lecture is finished and she tells students that they are free to go. While students are leaving, she touches the “Main Menu” icon with the smart pen to return the welcome page. From this page, she touches “Exit” icon to log out from the system and turns the smart board off. She starts to walk through her office with the pleasure of having a good lecture.

4.6. USER INTERFACE PROTOTYPES

The following figures display the graphical user interfaces of the system.

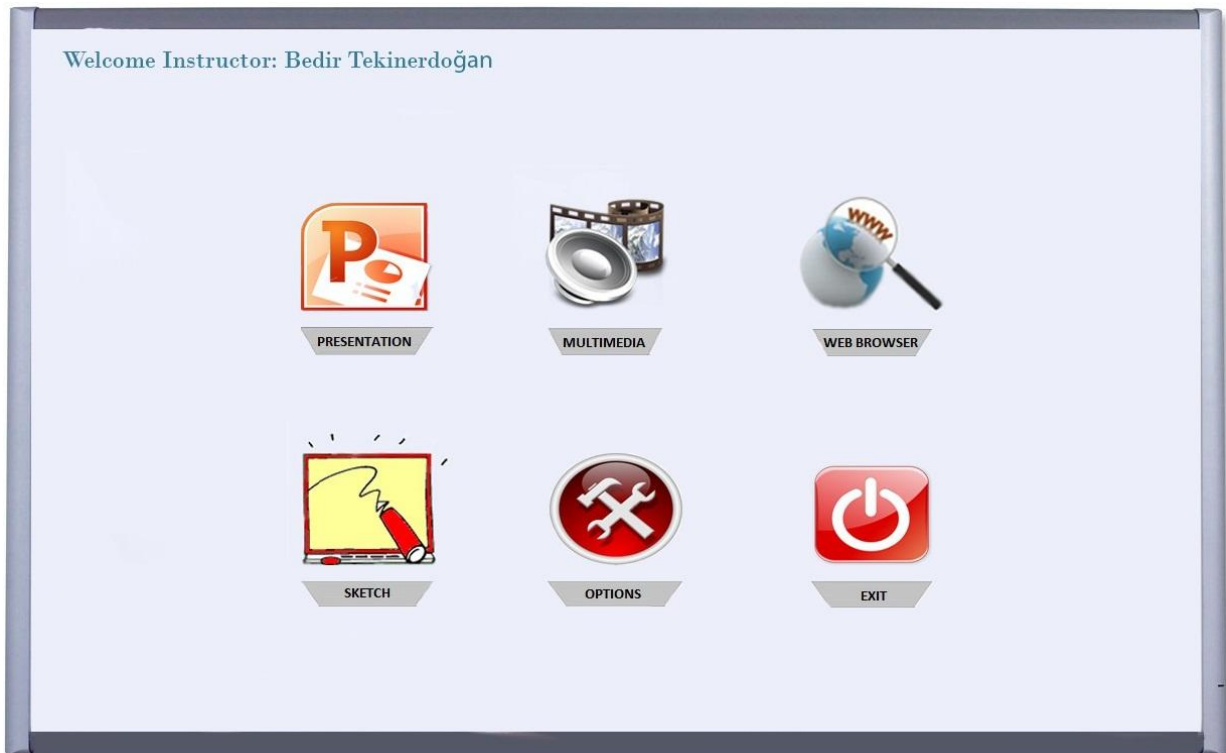


Figure 4 Main Menu

The screen has shown in Figure 4 is the main screen of smart board that appears after logging in to the system from the computer. At the left corner of the main screen the name of the instructor who logged in, is shown. Presentation, Multimedia, Web Browser, Sketch, Options and Exit choices can be found in the main menu.



Figure 5 Courses Screen

If the instructor touches to the Presentation choice from the main screen, Courses Screen shown in Figure 5 will appear. The course names that the instructor teaches are shown in this screen. There are two buttons at left and right bottom corners of the screen to navigate to the main page.



Figure 6 Uploaded Slides Screen

After instructor selects the course, the related lecture notes of that course will be loaded into the Slides Screen as shown in Figure 6. From this screen instructor can select the slide that he/she wants to present.

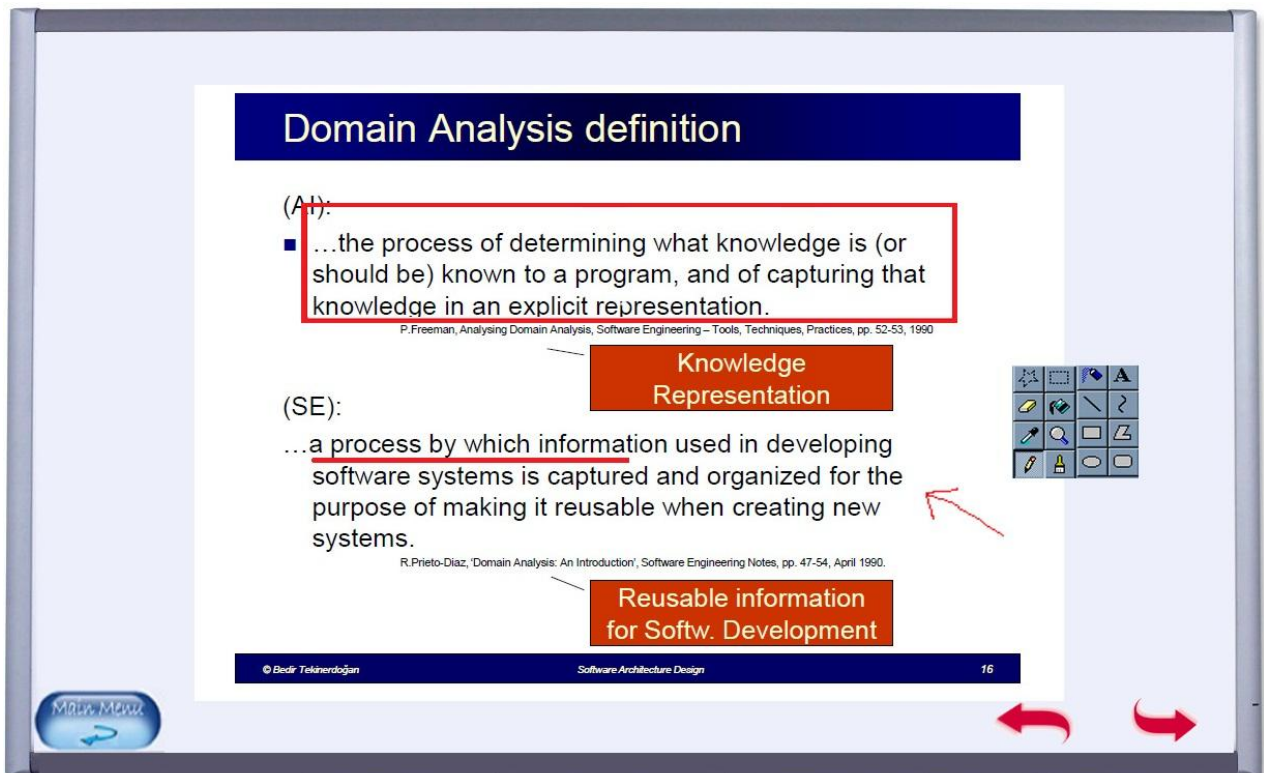


Figure 7 A Presentation Screen with Taken Notes

After selecting the relevant slide for the course, the slides will show up as in Figure 7 above. Instructor can modify the slides. By touching the smart board with the infrared pen for two seconds, instructor can make the tool box appear and by selecting a tool he can modify the slide. Main Menu button at the left bottom corner is to open the main screen. Two arrows at the right bottom are to go to the next slide or the previous one. Instructor can also open the next or previous slide with dragging his hands to left or right.

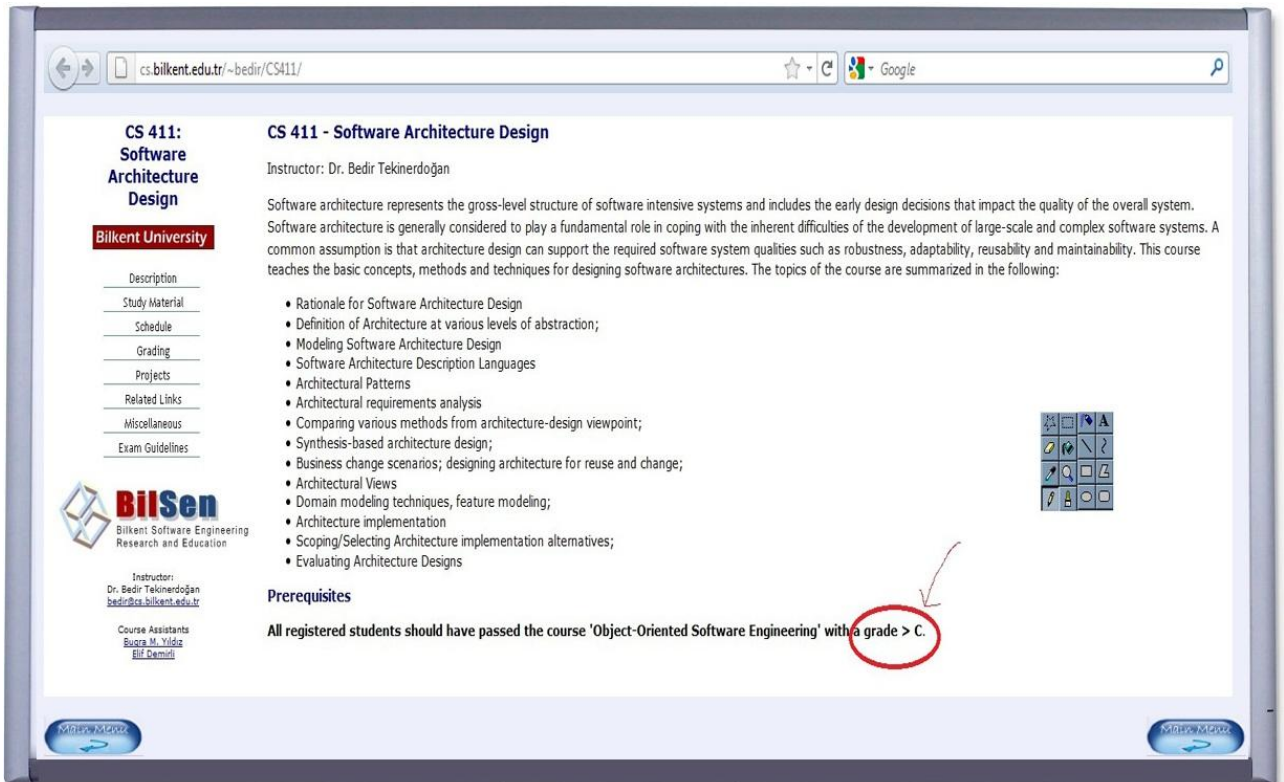


Figure 8 Web Browser Screen

The Web Browser Screen is shown at Figure 8 above. Instructor can choose to browse on the internet. To browse on the internet, instructor has to click Web Browser button on the main screen. After that instructor will write the url, that s/he wants to open, with the keyboard of the computer and the web page will appear. Like in the slides, instructor can also use the tool box which is displayed by touching to the board with the infrared pen for two seconds and use the tools on the page.



Figure 9 Interaction of the Board with the Students' Tablets

If instructor touches on the sketch button from the main screen, a screen that user can draw sketches or write with the infrared pen is shown as in Figure 9 above. Also the tool box is available on this screen. While instructor is drawing or writing some things on the board, students can see these sketches of the board from their tablets. If instructor allows, students can also modify the smart board.

5. TECHNICAL PROBLEM ANALYSIS

5.1. COMPUTER SCIENCE PROBLEMS

Name: How to design a parallel system?

Initial State: In current smart board systems, board and tablets are in connection between each other. The work done on board is visible and usable simultaneously on other machines and vice versa.

Desired State: The system should be able to provide at least such parallelization facility. In other words, changes or drawings made on the board should be visible on tablets at the time they are implemented and also the work done on tablets should be visible on the board at the time they are implemented.

Name: How to design a distributed system?

Initial State: Smart board systems consist of a board, projector, computer and tablets which are connected with each other. Therefore, the work done on the board is visible on the tablets of students, and the work done on student's tablets is visible on boards.

Desired State: The system does not require a projector because the board is digital and it is in connection with computer and tablets. In order to provide such integration, components of the system should be connected to each other by a local area network connection.

Name: How to store the data?

Initial State: Current smart board systems works through a database which stores course related documents put by the instructor.

Desired State: The system should provide a large capacity database to store the course material and allow instructors to reach and upload new material.

Name: How to model/design the database?

Initial State: Current systems are lack of having a precise design for their databases which reduces the quality of their database system.

Desired State: The system should have a layered architecture, in which one of the layers is reserved for database. Therefore, design of the database does not affect other layers of the system and provide an easy implementation. The design of database should be made by considering performance, capacity and cost issues.

Name: How to recover the damaged database?

Initial State: Current systems have one database to keep data, which is almost impossible to recover.

Desired State: The system should have two databases, one of which is reserved for backup applications. In specific time periods, the data in the main database should be backed up. Therefore, when there is a problem about the main database, secondary database will be used for recovery.

5.2. MATHEMATICS DOMAIN PROBLEMS

Name: How to handle the optimization of cost of the project?

Initial State: The cost of existing smart board projects is expensive.

Desired State: The system will require minimum cost while it achieves high quality. For this purpose, optimization techniques (linear programming) should be used.

5.3. APPLICATION DOMAIN PROBLEMS

Name: How to save the work done on the board?

Initial State: Current systems allow users to make changes on the board with the infrared pen. These changes are saved successfully and become visible from the tablets of students.

Desired State: In order to save and display the work done on boards, the system will have a control management system which observes the changes made on the board and saves them at the time they are implemented to the database.

Name: How to make modifications on a document by two or more users simultaneously?

Initial State: Current systems are not properly providing simultaneousness. The changes/modifications appear on the board or tablets of other users after a sufficient amount of time.

Desired State: The system should work simultaneously. Instructors and students should be able to see the changes/modifications at the time they are implemented simultaneously.

Name: How to handle authorization/permission?

Initial State: Current systems have a login mechanism which assigns special permissions for instructors and students.

Desired State: Instructors will be able to upload documents, choose and display the documents, change/modify on documents and assign permissions to students. On the other hand, students will be able to change/modify only the documents displayed on the board by the instructor, ask questions and reach the course related documents outside the lecture. To handle these, the system should have a login mechanism managed by an authorization management system which authorizes instructors and the students according to their qualifications.

Name: How to reach the previously saved lectures/notes?

Initial State: Smart board applications do not allow students to reach previously saved files. Outside the lectures, students do not have a permission to reach the course related documents while the instructors do.

Desired State: Bilkent smart board system should allow students to reach the course related documents for which instructor permits. Students should also be able to reach the database content outside the school.

5.4. QUALITY PROBLEMS

Name: How to create a high performance system?

Initial State: Current systems are not efficient enough to display changes on the board and on the machines of students simultaneously. Response time of the system is high which causes low performance.

Desired State: The system should provide concurrency and it should serve better response time in order to display changes on board and the machines of students as fast as possible.

Name: How to create a secure and reliable system?

Initial State: Existing smart board systems are secure and reliable; they provide authorization protocol for its users. People who are not eligible to login to system cannot reach the content.

Desired State: Bilkent smart board system should be secure and reliable at least the existing systems. The system will provide authorization protocols and will have a precise design to prevent any security leaks.

Name: How to create a user-friendly system?

Initial State: Current systems are difficult to understand due to its complex user interface design. They do not provide usefulness and easiness for its users.

Desired State: Bilkent smart board system may be used by the people who do not know using technological devices very well. Therefore, the system should be easy to use. Its user interface gadgets should be clear, simple and understandable.

Name: How to provide robustness for system?

Initial State: Current systems have some minor errors.

Desired State: The system should be error-free to provide robustness and it should be tested many times before being put on the market.

Name: How to overcome the cost-quality trade off of the system?

Initial State: Although the current smart board systems have some quality problems, they are expensive.

Desired State: The system should be designed considering corresponding optimization principles in order to provide a high qualified product with a price as low as possible.

6. DOMAIN ANALYSIS

6.1. DATABASE MANAGEMENT SYSTEMS

As the complexity of datasets is increasing, users require tools that simplify the task of managing the data and extracting useful information in a timely fashion. Database management systems are one of these tools.

A database is a collection of data, which describes the activities of one or more related organizations. In other words, it is an integrated collection of data records, files, and other database objects [1]. For example, in smart boards system, students, instructors, courses and materials are some of the entities and database describes the relationship between these entities.

A database management system (DBMS) is a software package that is responsible for utilizing and maintaining large collections of data [2]. It allows organizations to conveniently develop databases for various applications by database administrators (DBAs) and other

specialists. While choosing the DBMS it is important to know the capabilities of DBMS to get benefit from it efficiently. DBMS provides data independence, efficient data access, data integrity and security, data administration, concurrent address and crash recovery and reduced application development time.

Knowledge of this domain will help us to solve the technical problems defined as how to store data, how to model/design the database, how to recover the damaged database.

Knowledge Sources

Table 1 shows the knowledge sources for the database management part of the smart boards system in Bilkent.

ID	Knowledge Sources	Form
KS1	<i>Database Management Systems</i> , Ramakrishnan R. and Gehrke J., McGraw-Hill, 3rd Edition, 2007	Textbook
KS2	<i>Relational Database Principles</i> , Colin R., Cengage Learning Business Press, 2 nd Edition, 2002	Textbook
KS3	<i>Distributed Database Management Systems</i> , Saeed K. R., Frank S. H., Wiley-IEEE Computer Society Pr, 1 th Edition, 2010.	Textbook
KS4	<i>Beginning Microsoft SQL Server 2011 Programming</i> , Robert V., Wrox, 1 th Edition, 2011.	Textbook
KS5	Database Administrator	Expert
KS6	Bilkent University Data Repository System	Existing System

Table 1 Knowledge Sources of Database Management System

Evaluation of Sources

Table 2 shows the abstraction quality of the knowledge sources that are analyzed.

ID	Knowledge Sources	Objectivity	Relevance
KS1	<i>Database Management Systems</i> , Ramakrishnan R. and Gehrke J., McGraw-Hill, 3rd Edition, 2007	Medium	High
KS2	<i>Relational Database Principles</i> , Colin R., Cengage Learning Business Press, 2 nd Edition, 2002	Low	High
KS3	<i>Distributed Database Management Systems</i> , Saeed K. R., Frank S. H., Wiley-IEEE Computer Society Pr, 1 th Edition, 2010.	High	High
KS4	<i>Beginning Microsoft SQL Server 2011 Programming</i> , Robert V., Wrox, 1 th Edition, 2011.	High	High
KS5	Database Administrator	Medium	High
KS6	Bilkent University Data Repository System	High	High

Table 2 Evaluation of Resources

Glossary

Table 3 shows some key words with their definitions about database management.

<i>Entity</i>	Organizations that form the database.
<i>Relational Database System</i>	RDBMS is a database in which data is stored using tables and the relationships among the data are also stored in tables.
<i>Data Independence</i>	This means DMBS provides an abstract view of the data that hides details about data representation and storage.
<i>Data Integrity</i>	It is the trustworthiness of system resources over their entire life cycle. I data is always accessed through the DBMS, the DBMS can enforce integrity constraints.
<i>Data Administration</i>	Organization of groups that have access to DBMS or do not have access.
<i>Crash Recovery</i>	Crash recovery means, DBMS protects users from the effects of system failures.
<i>Database Query Language</i>	Query languages are computer languages used to make queries into databases. DBMS query language attempts to give factual answers to factual questions.
<i>Concurrency</i>	It means, DBMS allows many users to access data concurrently.
<i>Robustness</i>	It means, DBMS protects data in the event of system failures.
<i>Efficiency and scalability</i>	It means, DBMS is able to store large datasets and answer questions efficiently.

Table 3 Glossary for Database Management System

6.2. DISTRIBUTED SYSTEMS

A distributed system is a collection of autonomous computers, connected through a network and distribution middleware, which enables computers to coordinate their activities and to share the resources of the system, so that users perceive the system as a single, integrated computing facility [3]. Distributed system connects resources to users (resource sharing) and it provides transparency, openness, concurrency, fault tolerance and scalability [4].

Smart board system is a distributed system, which have three components: computers, tablets and boards. They are all connected to each other with a local area network connection. Their coordination is provided by the feature of distributed systems. Users can access the system concurrently and share the resources of the system.

Knowledge of this domain will help us to solve the technical problems defined as how to design the distributed system.

Knowledge Sources

Table 4 shows the knowledge sources of the distributed system domain part of the smart boards system in Bilkent.

ID	Knowledge Sources	Form
KS1	<i>Pattern-Oriented Software Architecture</i> , Frank B., Kevlin H., Douglas C. S., 4 th Edition, 2007	Textbook
KS2	<i>Distributed systems architecture: a middleware approach</i> , Arno P., Kay R., Frank P., Morgan K., 1 st Edition, 2005	Textbook
KS3	<i>Distributed Database Management Systems</i> , Saeed K. R., Frank S. H., Wiley-IEEE Computer Society Pr, 1 th Edition, 2010.	Textbook
KS4	<i>Distributed System: Definition</i>	Document
KS5	<i>Distributed System Principles</i> , Wolfgang E., 1997	Document

Table 4 Knowledge Sources of Distributed Systems

Evaluation of Sources

Table 5 shows the abstraction quality of the knowledge sources that are analyzed.

ID	Knowledge Sources	Objectivity	Relevance
KS1	<i>Pattern-Oriented Software Architecture</i> , Frank B., Kevlin H., Douglas C. S., 4 th Edition, 2007	Medium	Medium
KS2	<i>Distributed systems architecture: a middleware approach</i> , Arno P., Kay R., Frank P., Morgan K., 1 st Edition, 2005	Low	High
KS3	<i>Distributed Database Management Systems</i> , Saeed K. R., Frank S. H., Wiley-IEEE Computer Society Pr, 1 th Edition, 2010.	High	High
KS4	<i>Distributed System: Definition</i>	High	High
KS5	<i>Distributed System Principles</i> , Wolfgang E., 1997	Low	High

Table 5 Evaluation of Sources

Glossary

Table 6 shows some key words with their definitions about distributed systems domain.

<i>Distribution Transparency</i>	Hides some information from the users of the system. (Access transparency, location transparency, concurrency transparency, failure transparency etc.)
<i>Openness</i>	It means, being able to interact with other systems, independent of the underlying environment.
<i>Scalability</i>	Number of users and/or processes, maximum distance between nodes and number of administrative domains are both means scalability.
<i>Concurrency</i>	In distributed systems, components are executed in concurrent (simultaneous) processes.
<i>Fault Tolerance</i>	Availability at low levels of hardware, software and network reliability.

Table 6 Glossary for Distributed Systems

6.3. FILE MANAGEMENT SYSTEMS

File Management System is a method of storing and organizing files and the data, in order to provide an easy and an efficient access to them. File management systems use data storage devices such as hard disks or CD-ROMs and involve maintaining the physical location of the files. They have an ability to access to data on a file server, in this access they act as clients for a network protocol or they may be virtual and exist only as an access method for virtual data. A file management system is a special-purpose database for the storage, organization, manipulation, and retrieval of data.

In addition to accessing the existing files, file management systems provide ability to create new files or an ability to edit and save existing file. Saved files can be opened, modified, loaded into memory or closed without saving it. Also, files can be grouped in the directories. File managements are accomplished in different ways, on different operating systems and storage medium is used depending on the user interface design..

In the Smart Board project, the system will benefit from the file system. The system will keep the student lists, instructor lists, course-contents, lecture-notes, homework, quizzes, sample exams, projects in different files and will group the related ones in directories. The system may create new student list files for a new class or by adding new students to the existing file can edit it and save existing file.

Knowledge of this domain will help us to solve the technical problems defined as how to store the course content, how to save the modifications done on a file and how to store the previously lecture notes.

Knowledge Sources

The Table 7 below shows the knowledge sources of the file management part of the project.

ID	Knowledge Sources	Form
KS1	<i>File Structures: An Analytical Approach</i> , Salzberg Betty, Prentice-Hall, 1988	Textbook
KS2	<i>File Organization and Processing</i> , Tharp Alan L., Wiley	Textbook
KS3	File Management System	Existing System
KS4	Database and File Manager Consultant (University Professor)	Expert

Table 7 Knowledge Sources of File Management Systems

Evaluation of Sources

The Table 8 below shows the objectivity and relevance of the knowledge sources after they are examined.

ID	Knowledge Sources	Objectivity	Relevance
KS1	<i>File Structures: An Analytical Approach</i> , Salzberg Betty, Prentice-Hall, 1988	High	Medium
KS2	<i>File Organization and Processing</i> , Tharp Alan L., Wiley, 1988	High	Medium
KS3	File Management System	High	High
KS4	Database and File Manager Consultant (University professor)	High	High

Table 8 Evaluation of Sources

Glossary

Table 9 below shows some key words with their definitions about the file management.

<i>Database</i>	Is an integrated collection of data records, files, and other database objects.
<i>Directories</i>	An organizational unit, or container, used to organize folders and files into a hierarchical structure.
<i>Records</i>	Records are the unit of information which the files are composed of. A record may be decomposed into more atomic units called <i>fields</i> .
<i>Fields</i>	Fields are files that contain only specific values for attributes describing the entity.
<i>Sequential File Organization</i>	In sequential organization, the fields of a file are stored contiguous to and

	immediately after the element.
<i>Indexed Sequential File Organization</i>	Index Sequential Field Organization refers that, fields of a file are reached with an index.
<i>File Server</i>	A file server is a computer attached to a network that has the primary purpose of providing a location for shared disk access.
<i>File Administration</i>	Some files which contain secret information such as system files cannot be accessed by users.
<i>Concurrency</i>	File Management System allows multiple users to access the same file concurrently.
<i>Robustness</i>	File Management System protects files in case of system failures.
<i>Efficiency and scalability</i>	File Management System is able to store large files and answer questions efficiently.

Table 9 Glossary for File Management Systems

6.4. TRANSACTION MANAGEMENT SYSTEMS

Transaction Management System deals with the transaction processes of different kinds of systems. Transaction processing is designed to maintain software systems such as databases, modern file systems etc. Multiple individual operations are linked together automatically by the transaction processes and it is important to ensure that these operations carried out on the transaction process are interdependent from each other. The transaction management system ensures that either all operations in a transaction are completed successfully without any errors, or none of them. It is not possible some operations are completed but the others are not completed because of some errors. The transaction management system rolls back to the start of all the operations of the transactions until all operations are completed successfully. By rolling back it is emphasized the erasing all the transactions and restoring the system to the

state that it was before processing of the transaction began. The usage of this mechanism provides system to consistency.

In the Smart Board project the system will use the benefits of Transaction Management System. Since the Smart Board system is a complex system which has to transact all the operations without any errors and has to complete all the transactions successfully in case avoiding of possible future failures, Transaction Management System is used in this project to handle possible errors.

Knowledge of this domain will help us to solve the technical problems defined as how to recover the damaged database elements.

Knowledge Sources

The Table 10 below shows the knowledge sources of the transaction management part of the project.

ID	Knowledge Sources	Form
KS1	<i>Transaction Processing: Concepts and Techniques</i> , Jim Gray, Edwards Brothers Inc.	Textbook
KS2	Transaction Processing	Existing System
KS3	Database and Transaction Processing Consultant (University maintainer)	Expert

Table 10 Knowledge Sources of Transaction Management Systems

Evaluation of Sources

The Table 11 below shows the objectivity and relevance of the knowledge sources after they are examined.

ID	Knowledge Sources	Objectivity	Relevance
KS1	<i>Transaction Processing: Concepts and Techniques</i> , Jim Gray, Edwards Brothers Inc.	High	Medium
KS2	Transaction Processing	High	Medium
KS3	Database and Transaction Processing Consultant (University maintainer)	High	High

Table 11 Evaluation of Sources

Glossary

Table 12 below shows some key words with their definitions about the file management.

<i>Atomicity</i>	Atomicity means series of transaction operations either all occur, or nothing occurs.
<i>Consistency</i>	The data consistency model specifies a contract between programmer and system, system guarantees that if the programmer follows the rules, memory will be consistent and the results of memory operations will be predictable.
<i>Isolation</i>	Isolation is a property that defines how/when the changes made by one operation become visible to other concurrent operations.
<i>Durability</i>	Durability guarantees transactions that have committed will survive permanently. For example, if in the course registration lists that a student registered for a class, student still remain registered even if the system crashes.
<i>Concurrency</i>	Transaction Management System allows many users to access data concurrently.
<i>Robustness</i>	Robustness has the same meaning with durability.
<i>Efficiency and scalability</i>	TMS have a ability to manage large transactions in the system in an efficient way.
<i>Roll Back</i>	Rollback is an operation which returns the database to some previous state. Rollbacks are important for database integrity, because they mean that the database can be restored to a clean copy even after erroneous operations are performed.

Table 12 Glossary for Transaction Management Systems

6.5. COMPUTER NETWORKS

A computer network is an interconnection of various computer systems located at different places. In computer network two or more computers are linked together with a medium and data communication devices, cabling systems, specialized software, and devices that manages data traffic, for the purpose of communicating data and sharing resources such as printers. The computer that provides resources to other computers on a network is known as server.

The connection in networks can be implemented in two main types. First of them is client/server networks which uses one or more dedicated machines (the server) to share the files, printers, and applications. The second way is peer-to-peer network allows any user to share files with any other user and does not require a central, dedicated server.

Computer Networks may also be classified in terms of area:

Local Area Network (LAN): Networks used to interconnect computers in a single room, rooms within a building or buildings on one site are called Local Area Network (LAN). LAN transmits data with a speed of several megabits per second. LAN links computers, i.e., software and hardware, in the same area for the purpose of sharing information. In LAN every computer has the potential to communicate with any other computers of the network. It also provides high degree of interconnection between computers. The disadvantage of LAN is if the communication way implemented fails the entire network system fails.

Wide Area Networks (WAN): WAN is used to describe a computer network spanning a regional, national or global area. The distance between computers connected to WAN is larger than the distance in LAN. Therefore the transmission medium used is normally telephone lines, microwaves and satellite links. WAN provides an easy communication facility, remote data entry and centralized information. An example of WAN is Ethernet which coaxial cables for data transmission.

Metropolitan Area Network (MAN): MAN is a network that can connects two or more local area networks or campus area networks together via switches, hubs and routers using a high-capacity backbone technology, such as fiber-optical links.

Personal Area Network (PAN): PAN is a computer network organized around an individual person. Personal area networks typically involve a mobile computer, a cell phone and/or a handheld computing device such as a PDA.

Virtual private network (VPN): VPN is a network that uses a public telecommunication infrastructure, such as the Internet, to provide remote offices or individual users with secure access to their organization's network. A virtual private network can be contrasted with an expensive system of owned or leased lines that can only be used by one organization. The goal of a VPN is to provide the organization with the same capabilities, but at a much lower cost.

Global Area Network (GAN): GAN is used for supporting mobile communications across an arbitrary number of wireless LANs, satellite coverage areas.

Storage Area Network (SAN): SAN is a high speed special purpose network that interconnects different kinds of data storage devices with associated data servers on behalf of a larger network of users.

Smart board system should have a network to connect to internet or to connect the board and the tablets to each other. The smart board system allows sharing the resources. Without a network end users cannot connect to each other or the internet. Therefore, the system will be connected to a network.

Knowledge of this domain will help us to solve the technical problems defined as how to make modifications on a document by two or more users simultaneously, how to handle authorization/permission and how to reach the previously saved lecture notes.

Knowledge Sources

Table 13 shows the knowledge sources of the computer networks domain of the smart boards system in Bilkent.

ID	Knowledge Sources	Form
KS1	J.F. Kurose and K.W. Ross, Computer Networking, 5th ed., Addison Wesley, 2010.	Textbook
KS2	Andrew S. Tanenbaum, Computer Networks, 4th Edition, 2010	Textbook
KS3	<i>Computer Networking: A Top Down Approach</i> , Kurose James F., Ross Keith W., Pearson, 5 th Edition	Textbook
KS4	William Stallings, Data and Computer Communications, 9th Edition, Perentice Hall, 2010	Textbook
KS5	Network Administrator	Expert
KS6	Bilkent University Network System	Existing System

Table 13 Knowledge Sources of Computer Networks Domain

Evaluation of Sources

After analyzing the knowledge sources the objectivity and the relevance of the sources are examined which are shown in the Table 14 below.

ID	Knowledge Sources	Objectivity	Relevance
KS1	J.F. Kurose and K.W. Ross, Computer Networking, 5th ed., Addison Wesley, 2010.	High	High
KS2	Andrew S. Tanenbaum, Computer Networks, 4th Edition, 2010	High	High
KS3	Computer Networking: A Top Down Approach, Kurose James F., Ross Keith W., Pearson, 5 th Edition, 2009	Medium	Medium
KS4	William Stallings, Data and Computer Communications, 9th Edition, Perentice Hall, 2010	High	Medium
KS5	Network Administrator	High	High
KS6	Bilkent University Network System	High	High

Table 14 Evaluation of Sources

Glossary

Table 15 shows some key words with their definitions about computer networks.

<i>Central Server</i>	Provides local area networking services. It consists of a set of high-speed computers that stores office applications and data files shared by many different people.
<i>Dedicated Server</i>	A dedicated server is a single computer in a network reserved for serving the needs of the network.

<i>Local Area Network</i>	A network that serves in a small physical area.
<i>Wide Area Network</i>	A network that covers a broad area.
<i>Data</i>	Any information we are using and sharing through the network.
<i>Remote Data Entry</i>	Remote Data Entry means while sitting at any location you can enter data, update data and query other information of any computer attached to the
<i>Coaxial Cable</i>	Coaxial cable is a cable that has an inner conductor surrounded by a flexible, tubular insulating layer, surrounded by a tubular conducting shield.
<i>Switches</i>	Switch is a computer networking device that connects network segments
<i>Hubs</i>	A common connection point for devices in a network.
<i>Routers</i>	Routers are physical devices that join multiple wired or wireless networks together.
<i>Backbone Technology</i>	A backbone is a larger transmission line that carries data gathered from smaller lines that interconnect with it.
<i>Fiber Optic Link</i>	A technology that uses glass threads to transmit data. A fiber optic cable consists of a bundle of glass threads, each of which is capable of transmitting messages modulated onto light waves.
<i>Ethernet</i>	Ethernet is a family of frame-based computer networking technologies for local area networks.
<i>PDA</i>	Short for personal digital assistant, a handheld device that combines computing, telephone/fax, Internet and networking features.
<i>Internet</i>	The Internet is a global system of interconnected computer networks that use the standard Internet protocol suite (TCP/IP) to serve billions of users worldwide.
<i>Data Server</i>	A data server is a computer program that provides database services to other computer programs or computers, as defined by the client–server model.

Table 15 Glossary for Computer Networks Domain

6.6. NETWORK SECURITY

The area of network security consists of the provisions and policies adopted by the network administrator to prevent and monitor unauthorized access, modification, or denial of the computer network and network-accessible resources. The networks are comprised of "nodes", which are "client" terminals (individual user PCs) and one or more "servers" or "host" computers. Network security includes the protection of resources of the application from intruders who may intend to harm the consistency and maintenance of those resources. In order to provide a secure network, each application is created with a set of rules that determine the security policies of the existing system such as the usage of usernames and passwords, cryptographic storage of these user credentials etc. Network security involves all activities that organizations, enterprises, and institutions undertake to protect the value and ongoing usability of assets and the integrity and continuity of operations. An effective network security strategy requires identifying threats and then choosing the most effective set of tools to combat them.

In this project, the instructors and the students will log in to the system via their passwords and user names. Also, the contents of the lectures will be stored using the system. Handling authorization/permission and designing secure/reliable system will be the main problems that will be tried to be solved by the understanding of the network security domain.

Knowledge Sources

The table 16 below illustrates the knowledge sources of the network security domain.

ID	Knowledge Sources	Form
KS1	<i>Cryptography and Network Security, 3rd Edition.</i> W. Stallings. Pearson.	Textbook
KS2	<i>Network Security: Private Communication in a Public World, 2nd Edition.</i> C. Kaufman, R. Perlman, and M. Speciner. Prentice-Hall	Textbook
KS3	Moodle Security System	Existing System
KS4	<i>The Froehlich/Kent Encyclopedia of Telecommunications vol. 15.</i> Marcel Dekker, New York, 1997, pp. 231-255.)	Article
KS5	Webmail Security Manager	Expert

Table 16 Knowledge Sources of Network Security Domain

Evaluation of Sources

The table 17 shows the objectivity and relevance of the knowledge sources.

ID	Knowledge Sources	Objectivity	Relevance
KS10	<i>Cryptography and Network Security, 3rd Edition.</i> W. Stallings. Pearson.	High	High
KS11	<i>Network Security: Private Communication in a Public World, 2nd Edition.</i> C. Kaufman, R. Perlman, and M. Speciner. Prentice-Hall	High	High
KS12	Moodle Security System	High	Medium
KS13	<i>The Froehlich/Kent Encyclopedia of Telecommunications vol. 15.</i> Marcel Dekker, New York, 1997, pp. 231-255.)	High	Medium
KS14	Webmail Security Manager	High	Medium

Table 17 Evaluation of Sources

Glossary

The table 18 shows some keywords and their definitions about the network security domain.

<i>Authenticate</i>	To verify the identity of an Internet user or computer or person
<i>Username</i>	Username is a string that represents the user in the system.
<i>Password</i>	Password is a combination of numbers and letters that is used to approve the user before logging in to the system.
<i>IPSec</i>	Internet Protocol security (IPSec) is a framework of open standards for helping to ensure private, secure communications over Internet Protocol (IP) networks through the use of cryptographic security services.
<i>Firewall</i>	security system for protecting against illegal entry to a local area network which is connected to the Internet
<i>Computer Worms</i>	A computer worm is a self-replicating computer program
<i>Intrusion Prevention System</i>	An Intrusion Prevention System is a network security device that monitors network and/or system activities for malicious or unwanted behavior and can react, in real-time, to block or prevent those activities
<i>Anomaly-Based Intrusion Detection System</i>	An Anomaly-Based Intrusion Detection System, is a system for detecting computer intrusions and misuse by monitoring system activity and classifying it as either <i>normal</i> or <i>anomalous</i>
<i>Denial of Service</i>	A denial-of-service attack (DoS attack) or distributed denial-of-service attack (DDoS attack) is an attempt to make a computer resource unavailable to its intended users

Table 18 Glossary for Network Security Domain

6.7. USER INTERFACE DOMAIN

User Interface Domain (UID) is the domain of the improving way that allows users to perceive and express the information given. UID seeks to improve the communication between users and all computer based devices. In particular, the domain is working on formats and languages that will present information to users with more accuracy and a higher level of control. Users want from developers to build applications that meet their needs and that are easy to use. The goal of this domain is to provide interfaces that are easy to use, understandable and meets the needs of users.

User Interface Design is important in many aspects. Firstly, a good user interface is more easy to use than the others. When it is easy to use it improves the understanding of the contents. A user interface provides an easier way to train people to use it, reduces the training cost. User interface increases the user satisfaction with the work you have done. Therefore, user interface design carries extremely important role in design of a system.

While developing user interface some aspects should be considered:

Consistency: A good user interface design should be consistent. The buttons should be placed in consistent places on the window, the labels and messages should have same wordings and a consistent color scheme should be used throughout the windows. These consistencies in UI allows users to build an accurate mental model of the way that it works.

Setting Standards: The way to provide consistency is to setting some standards and stick to them.

Explain Rules: Users want to know how to work with the related application that we are providing UI. If an application works consistently then that means we only need to explain the rules once.

Support both Novices and Experts: Novice and expert users are both using the system. Therefore, while designing the UI both of their needs should be considered.

Navigation between Screens: If it is difficult to get from one screen to another then user will quickly become frustrated and give up. To accomplish the work user is trying to do, there must be flow between screens.

The smart board system is dealing with students and instructors. It has an important role in education of the students and it has to make easy to teach for instructors. Therefore, smart board system needs to have a good user interface. The knowledge of this domain will help us to solve the technical problem defined as how to design a user-friendly interface for the application.

Knowledge Sources

Table 19 shows the knowledge sources of the user interface domain of the smart boards system in Bilkent.

ID	Knowledge Sources	Form
KS1	<i>Essentials of User Interface Design</i> , Alan Cooper, About Face, 3rd Edition, Hungry Minds, 2010	Textbook
KS2	<i>Designing Interfaces</i> , Jenifer Tidwell, O'Reilly, 2nd Edition, 2010	Textbook
KS3	<i>Designing Interactions</i> , Bill Moggridge, 2nd edition, MIT Press, 2006	Textbook
KS4	User Interface Designer	Expert
KS5	<i>Smart Board 885ix</i>	Existing System

Table 19 Knowledge Sources of User Interface Domain

Evaluation of Sources

After analyzing the knowledge sources the objectivity and the relevance of the sources are examined which are shown in the Table 20 below.

ID	Knowledge Sources	Objectivity	Relevance
KS1	<i>Essentials of User Interface Design</i> , Alan Cooper, About Face, 3rd Edition, Hungry Minds, 2010	Medium	High
KS2	<i>Designing Interfaces</i> , Jenifer Tidwell, O'Reilly, 2nd Edition, 2010	High	High
KS3	<i>Designing Interactions</i> , Bill Moggridge, 2nd edition, MIT Press, 2006	Medium	High
KS4	User Interface Designer	High	High
KS5	Smart Board 885ix	Medium	High

Table 20 Evaluation of Sources

Glossary

Table 21 shows some key words with their definitions about user interfaces.

<i>Understandable Interface</i>	Understandable Interface means making sure that user perceives all the information we want to give.
<i>Training Cost</i>	The cost of the trainings when users trying to learn usage of the system.
<i>Consistency</i>	Consistency means providing a consisted system in terms of language formats, buttons, and colors.
<i>Rules</i>	Rules refer to the rules of the usage of a system that users have to follow.
<i>Navigation</i>	Navigation refers to the transaction between the screens of a system.

Table 21 Glossary of User Interface Domain

7. SOFTWARE ARCHITECTURE DESIGN

Conceptual software architecture model defines the application architecture at a conceptual level that includes some dependencies between concepts and conceptual distribution strategy between them. Conceptual software architecture model consists of diagrams and text documents that describe the application architecture at a high level.

7.1. LOGICAL/CONCEPTUAL SOFTWARE ARCHITECTURE

The conceptual software architecture models of “Smart Boards in Bilkent” project are given below. These conceptual architecture model diagrams represent the working mechanism of the system. Logical/Conceptual software architecture of the system is designed using UML notations and explained textually. Figure 10, 11 and 12 presents the conceptual components of the system and their interaction with each other. Each figure illustrates different mechanisms of the system.

- ✓ "System manager" represents the main management component of Smart Board System, which uses sketch manager, presentation manager, multimedia manager and data manager mechanisms.
- ✓ Each "dynamic content" is managed by a data manager which ensures that the dynamic content is accessed in a consistent way. Data manager uses data saver and recovery manager mechanisms.
- ✓ Each "sketch application" is managed by a sketch manager which ensures that the sketch application is accessed in a consistent way. Sketch manager does not use any mechanism.
- ✓ Each "presentation application" is managed by a presentation manager which ensures that the presentation application is accessed in a consistent way. Presentation manager does not use any mechanism.
- ✓ Each "multimedia application" is managed by a multimedia manager which ensures that the multimedia application is accessed in a consistent way. Multimedia manager does not use any mechanism.

Figure 10 illustrates the interaction and work flow among the components of the system when a sketch application is in process.

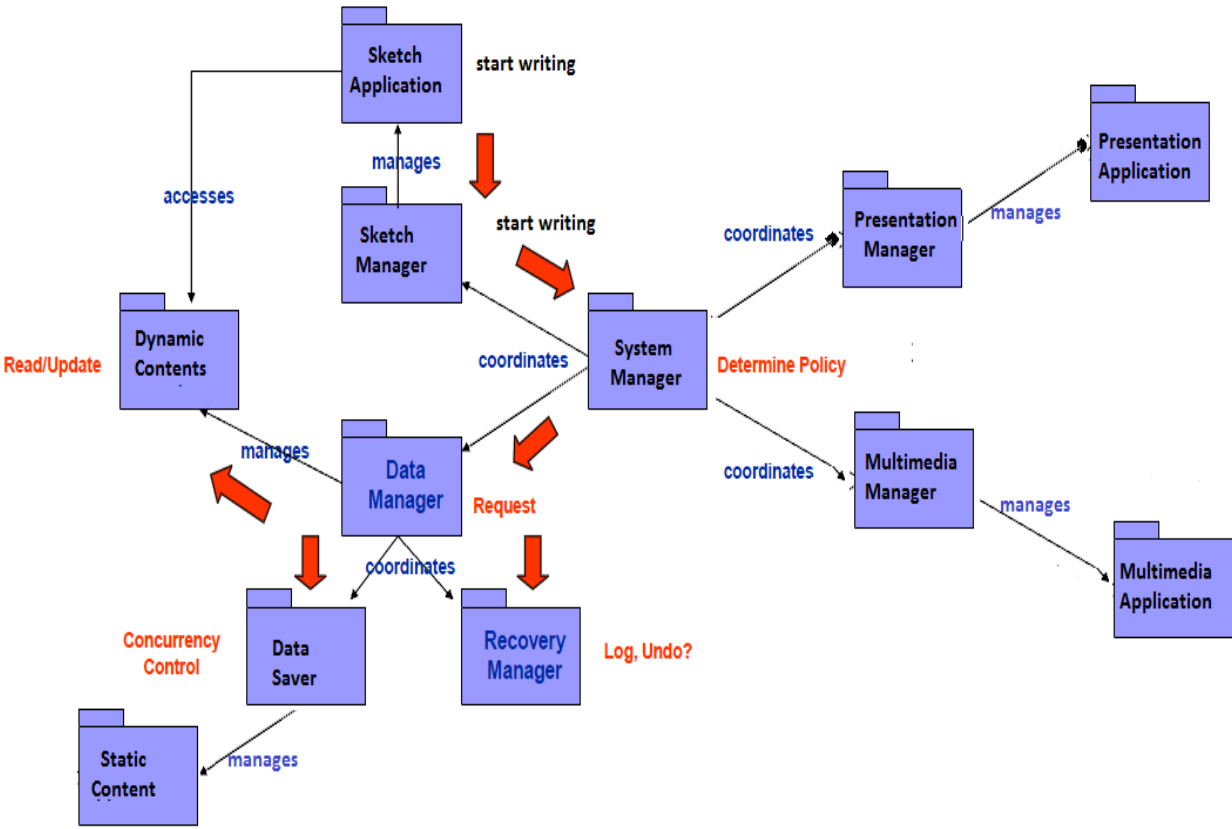


Figure 10 Top Level Conceptual Architecture- Sketch Application

"Sketch application" which is managed by a sketch manager ensures that the sketch application is accessed in a consistent way.

Sketch application sends “start writing” command to the sketch manager. Sketch manager gets the command “start writing” and sends it to the system manager. System manager sends request to Data Manager. Data Manager asks Recovery Manager if the request is valid or not. If it is not valid Data Manager asks Recovery Manager to undo the sketch request and returns form application. If the request is valid Data Manager sends concurrency control command to the Data Saver and saves data as a Static Content and also updates the Dynamic Content then finishes its job. By tracing these steps “Dynamic Content” is prepared for the access of Sketch Application.

Figure 11 illustrates the interaction and work flow among the components of the system when a presentation application is in process.

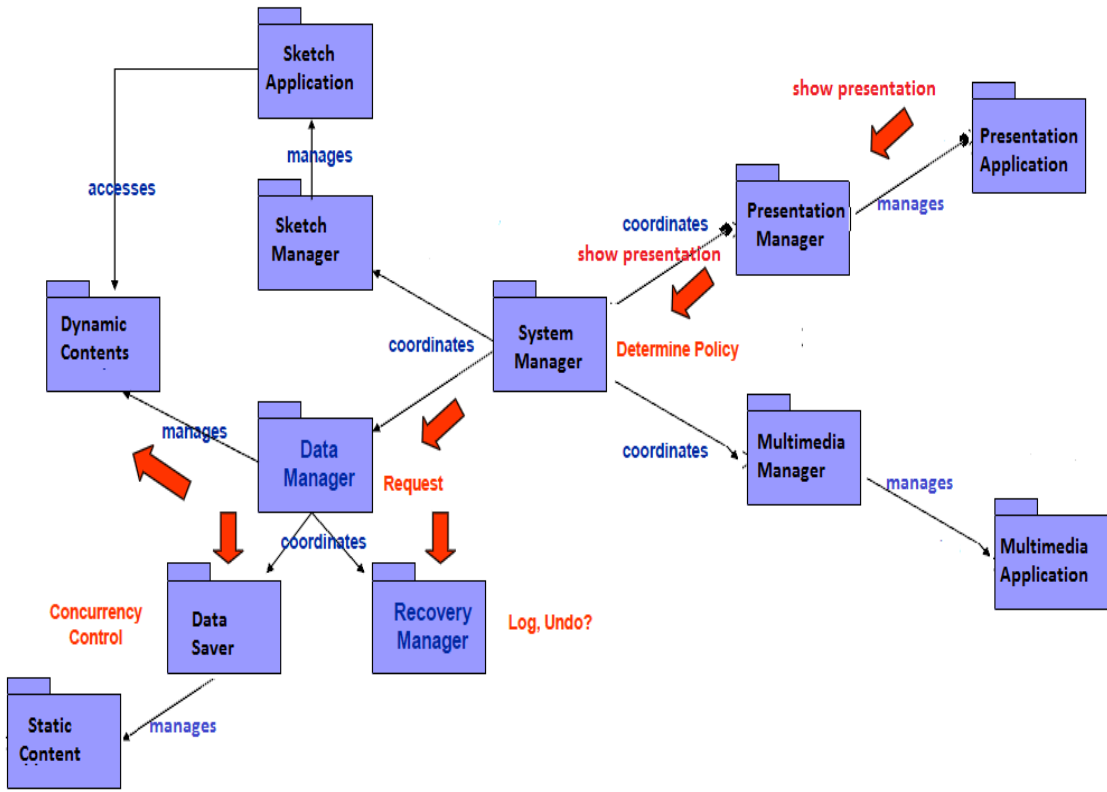


Figure 11 Top Level Conceptual Architecture- Presentation Application

"Presentation Application" ensures that the presentation application is accessed in a consistent way. Presentation application sends "show presentation" command to the Presentation Manager. Presentation Manager gets the command "show presentation" and sends it to the System Manager. System Manager sends request to Data Manager. Data Manager asks Recovery Manager if the request is valid or not. If it is not valid Data Manager asks Recovery Manager to undo the sketch request and returns form application. If the request is valid Data Manager sends concurrency control command to the Data Saver and saves data as a Static Content and also updates the Dynamic Content then finishes its job. By tracing these steps "Dynamic Content" is prepared to display presentation contents.

Figure 12 illustrates the interaction and work flow among the components of the system when a multimedia application is in process.

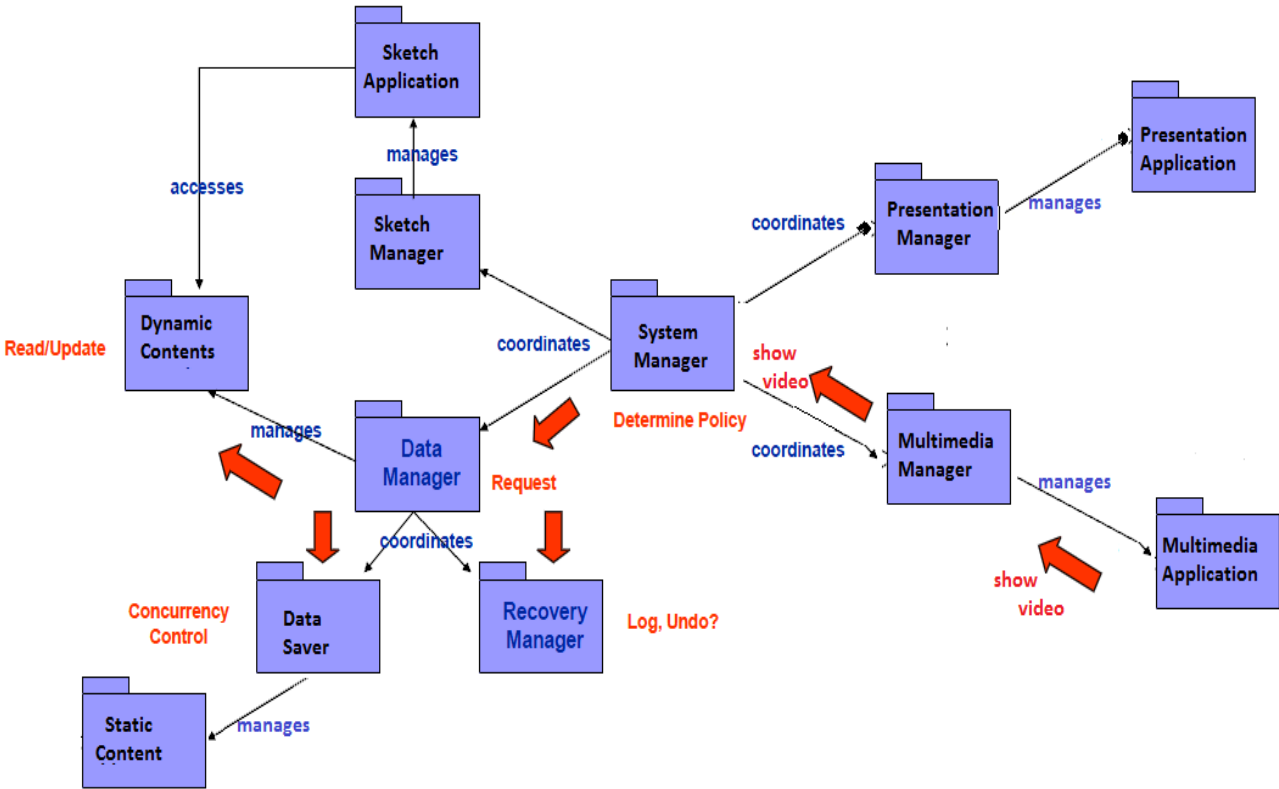


Figure 12 Top Level Conceptual Architecture- Multimedia Application

"Multimedia Application" ensures that the multimedia application is accessed in a consistent way. Multimedia application sends "show video" command to the Multimedia Manager. Multimedia Manager gets the command "show video" and sends it to the System Manager. System Manager determines policy and sends request to Data Manager. Data Manager asks Recovery Manager is the send request is valid or not. If it is not valid Data Manager asks Recovery Manager to undo the "show video" request and returns form application. If the request is valid, then Data Manager sends concurrency control command to the Data Saver and saves data as a Static Content and also updates the Dynamic Content then finishes its job. By tracing these steps "Dynamic Content" is prepared to display video contents.

Figure 13 illustrates the identification of knowledge domains per component which are showed in the conceptual architectural design of the system.

Specific Domains

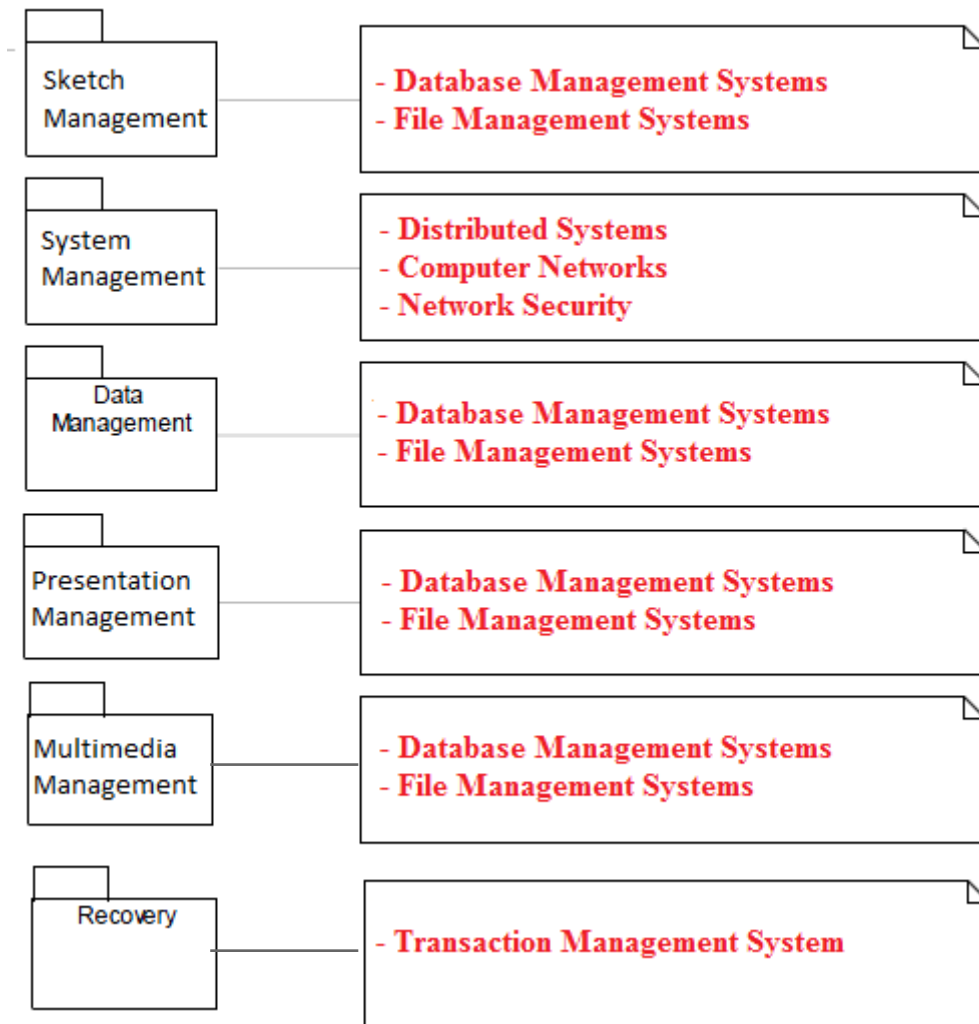


Figure 13 Component-Domain Mapping

For each sub-problem Sketch Management, System Management, Presentation Management, Multimedia Management and Recovery, specific solution domains are identified and prioritized. Then for each solution domain knowledge sources are identified and prioritized. Lastly for “Smart Boards in Bilkent” project solution domain concepts are extracted from solution domain knowledge. Figure 13 represents Component-Domain Mapping of “Smart Boards in Bilkent”.

- Sub-problem Sketch Management is mapped to the domain of Database Management Systems and File Management Systems.

- Sub-problem System Management is mapped to the domain of Distributed Systems and Computer Networks Systems and Network Security Systems.
- Sub-problem Presentation Management is mapped to the domain of Database Management Systems and File Management Systems.
- Sub-problem Data Management is mapped to the domain of Database Management Systems and File Management Systems.
- Sub-problem Multimedia Management is mapped to the domain of Database Management Systems and File Management Systems.
- Sub-problem Recovery is mapped to the domain of Transaction Management Systems.

7.2. DATA DIAGRAMS

Figure 14 shows the users of the “Smart Boards in Bilkent” system and their interactions with the system. First of all Admin should authorize both Instructor and the Student to the system. Sketch Web Browser, Presentation, Multimedia and Exit are the capabilities of the system which can be used by both student and instructor. However, there are differences between the capabilities of students and instructors while using the system. The system provides ability to choose Sketch, Web Browser, Presentation and Multimedia for instructors. However, students are required to take permission from instructor before starting their actions. After Instructor gives permission to students, students can be able to modify sketch and modify presentation but cannot be able to modify anything on web browsers and multimedia, but can see them without doing any modifications. Student and Instructor can exit from the system any time they want.

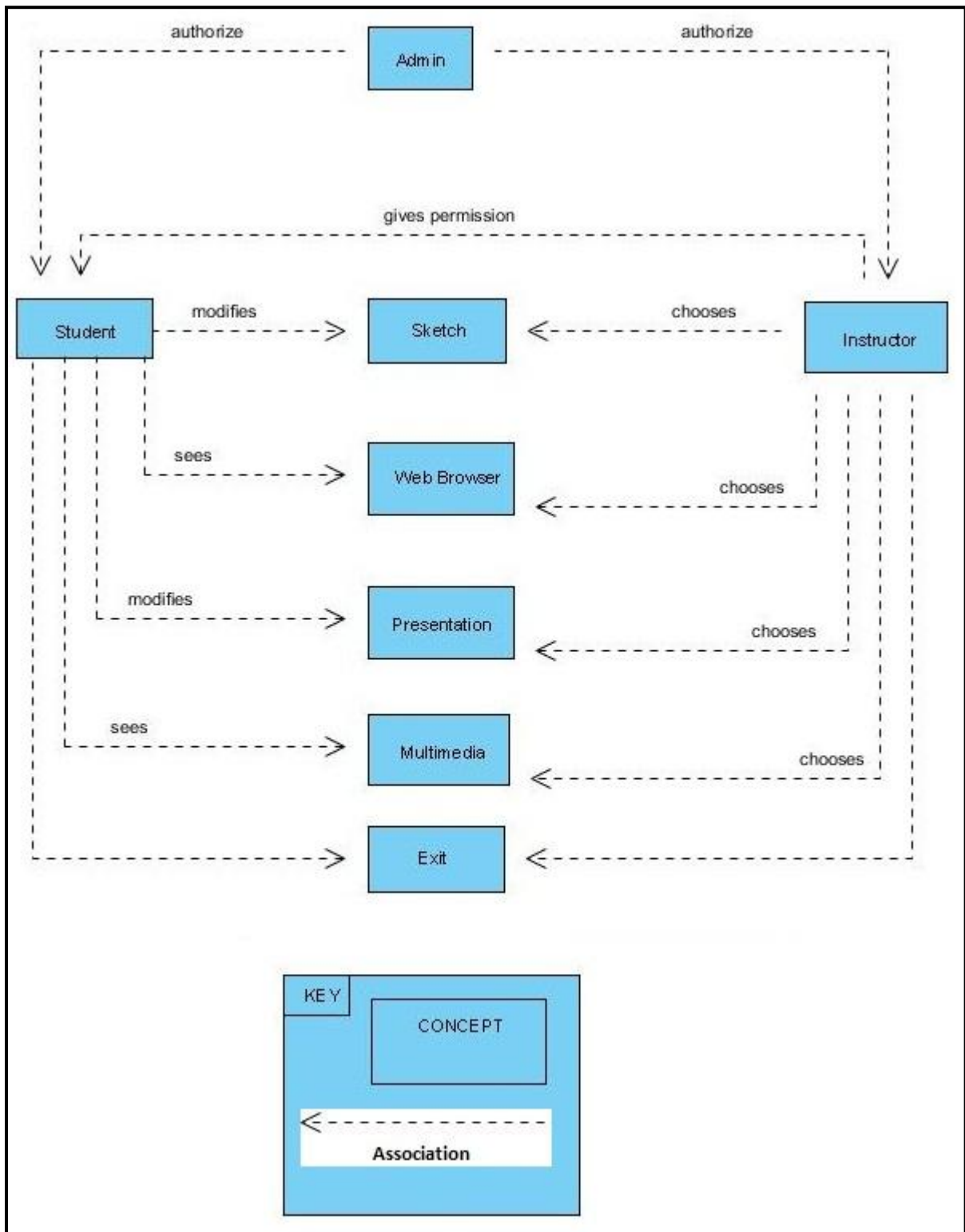


Figure 14 Architectural Conceptual Model for All Users

Figure 15 shows “Smart Boards in Bilkent” system and its interactions with the instructor. Instructor can be able to choose between the options Presentation, Web Browser, Sketch and Multimedia.

- ✓ If instructor chooses the “Web Browser”, he/she will be directed to the “Website” where he/she can open any website and display it on the board.
- ✓ If instructor chooses the “Sketch”, he/she will be directed to the “Sketch Board” where he/she can start to take notes on the sketch board.
- ✓ If instructor chooses the “Multimedia”, he/she will be directed to the “Video” and he/she can open a video which he/she loaded to the system previously and display it on the board.
- ✓ Instructor exits from the system at the end of the lecture.

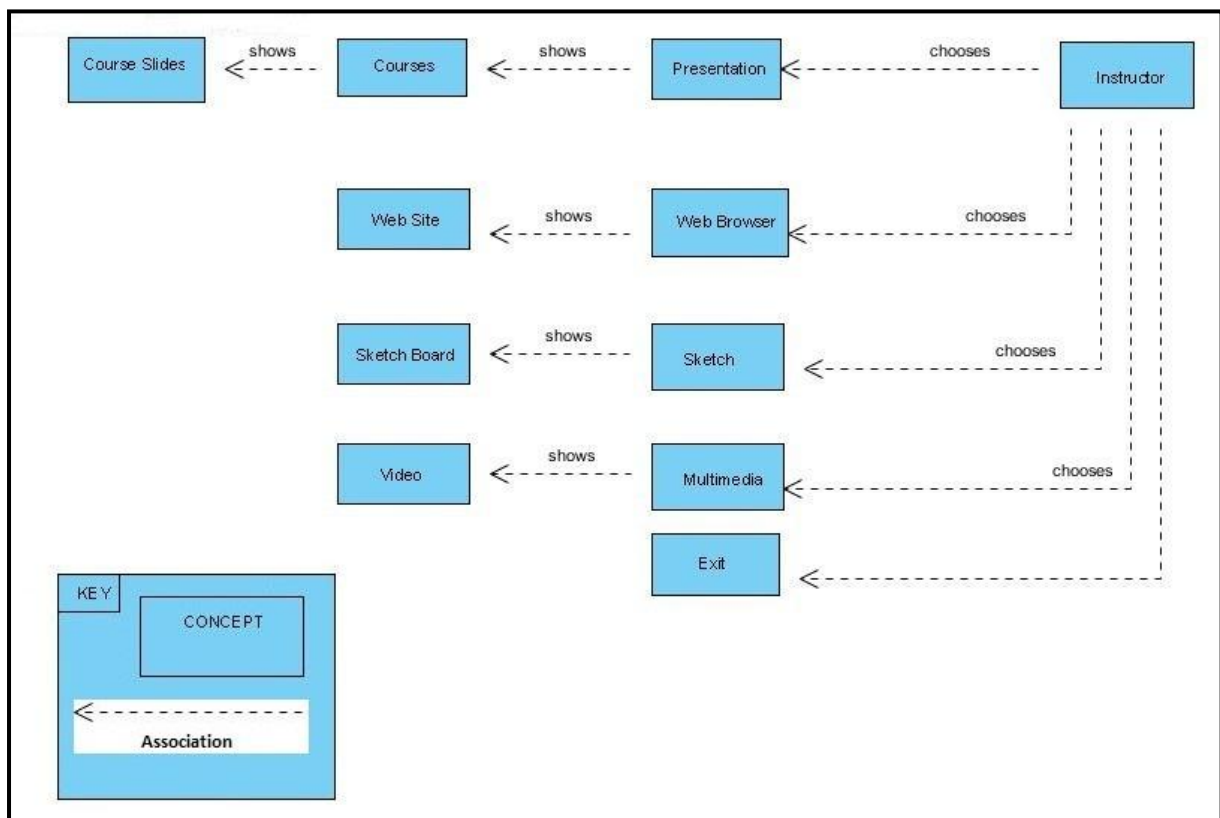


Figure 15 Architectural Conceptual Model for Instructors

8. TOP LEVEL CONTEXT DIAGRAMS

Top level Context Diagram is used in Smart Board system in order to show the boundaries between the Smart Board system and the external entities in its environment. External entities are Students, Instructors, Admin and Internet.

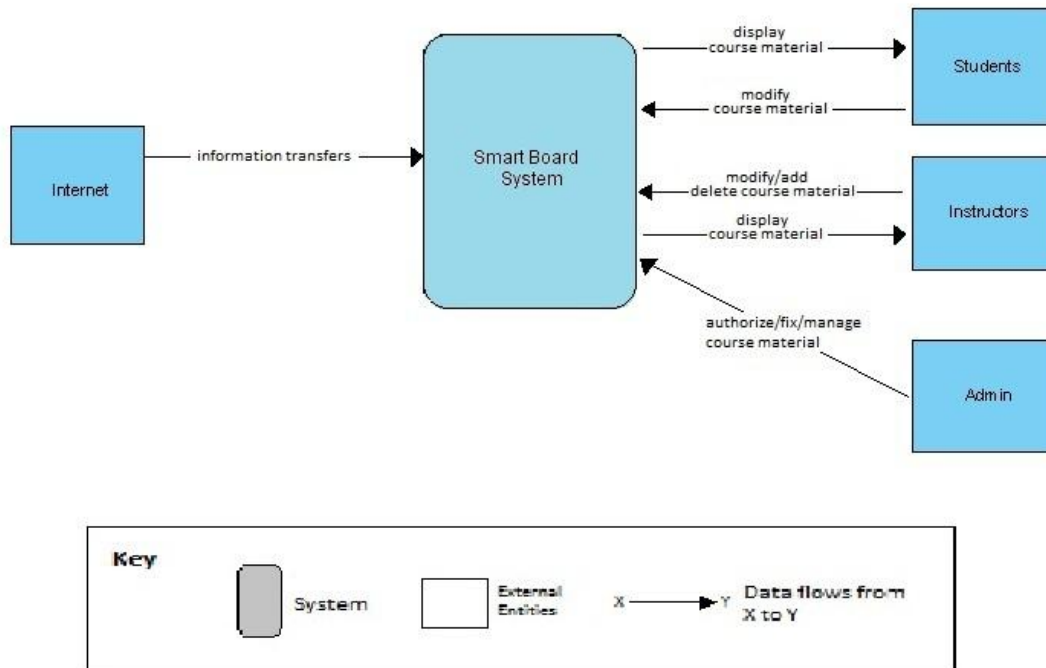


Figure 16 Top Level Context Diagram of the Smart Board System

Figure 16 shows the top level context diagram of the system. Smart Board system has four external entities. Each of the external entities is interacting with the system. The context diagram shows the external entities and their interactions with the Smart Board system. The external entity Internet transforms information to Smart Board system. For example, user can search something on the internet and while doing that Internet transforms information to the system. Student can interact with the system with modifying the course material and smart board system displays the course material to Student. Instructor can modify the contents and add a new course material to the system. Also smart board displays the course materials to the instructors. Admin can interact with the system to authorize the instructors and the students for the course materials and fix, manage the course material by deleting from the system or

adding a new one. During these interactions the data flows between Smart Board system and the external entities.

9. MODULE VIEWS

Module views of the “Smart Board in Bilkent” system are going to be presented in this part. Module views are to documents the system’s principal units of implementations. As the elements of these views modules are going to be used. Modules are the implementation units of software that provides a coherent unit of functionality.

9.1. USES VIEW

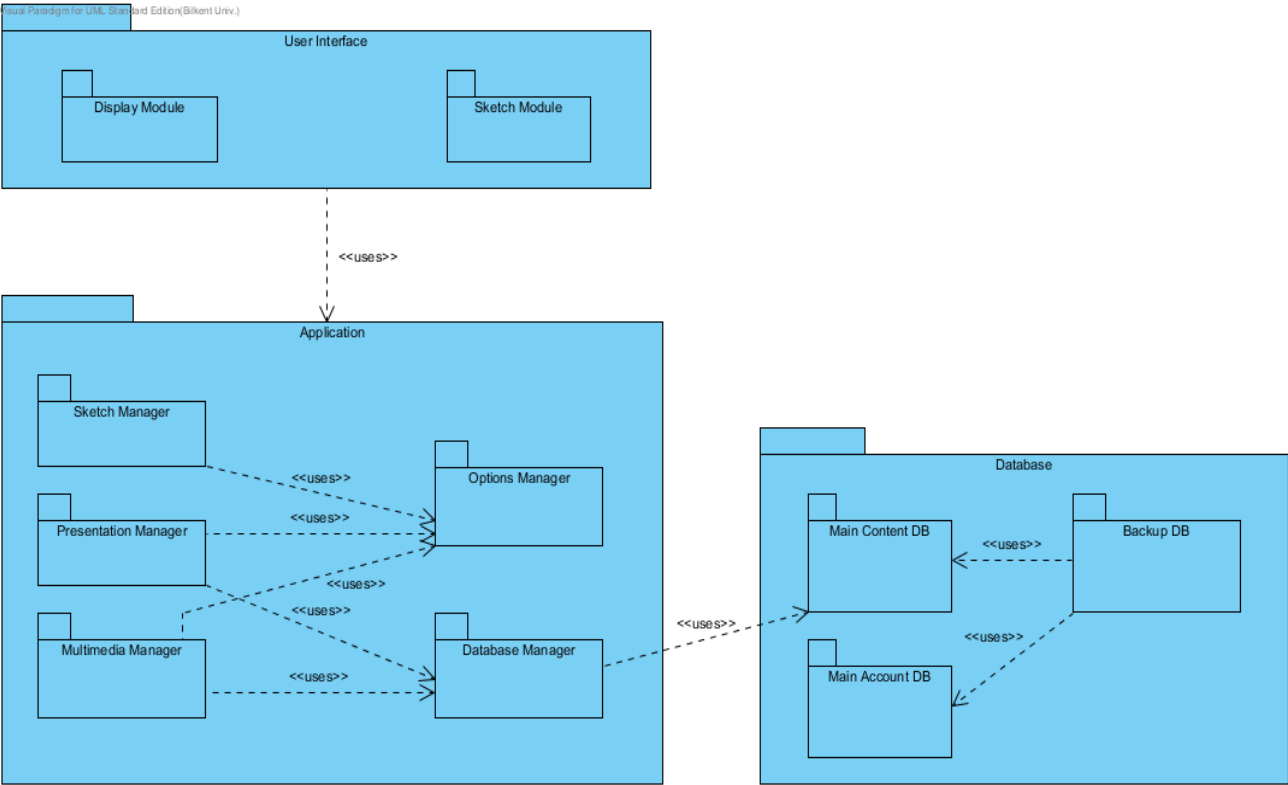


Figure 17 Uses View of Smart Board System

Figure 17 shows the uses view of the Smart Boards System. In general User Interface Module uses Application Module; Application Module uses Database Module. In Application Module, Sketch Manager, Presentation Manager and Multimedia Manager use Options Manager; they act according to the commands of Options Manager. Additionally, Presentation

Manager and Multimedia Manager both uses Database Manager; they need to access the DB to do their jobs. Database Manager in Application Module specifically uses Main Content DB to provide information to Presentation Manager and Multimedia Manager. In Database Module, Main Content DB and Main Account DB are both used by Backup DB to recover the system when it is needed.

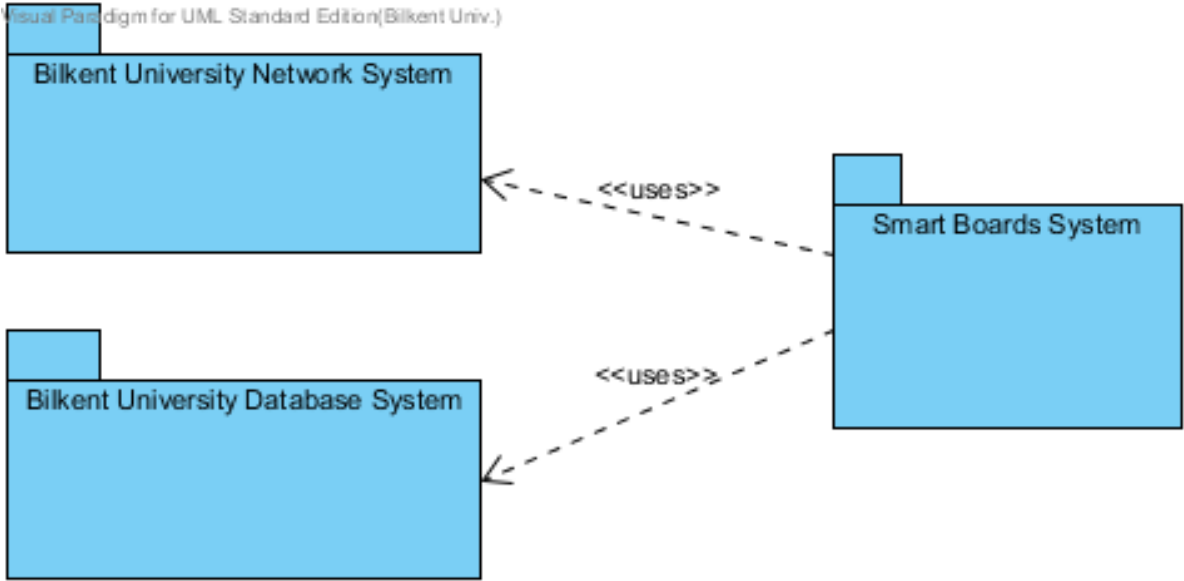


Figure 18 Context Diagram of Uses View

Context diagram for uses view represents what external entities use or are used by the system under development. Smart Boards in Bilkent System consists of external systems which have uses relationship with each other as shown in Figure 18. There are two external systems such as Bilkent University Database and Bilkent University Network System which are used by Smart Board System.

9.2. DECOMPOSITION VIEW

Figure 19 is the top level decomposition view of the Smart Board System. The system consists of three main modules which are User Interface Module, Application Module and Database Module. In User Interface Module, GUI related modules exists which provides

visual features of the system. In Application Module, the main business of the system is handled. Finally, Database Module acts as the repository of the system.

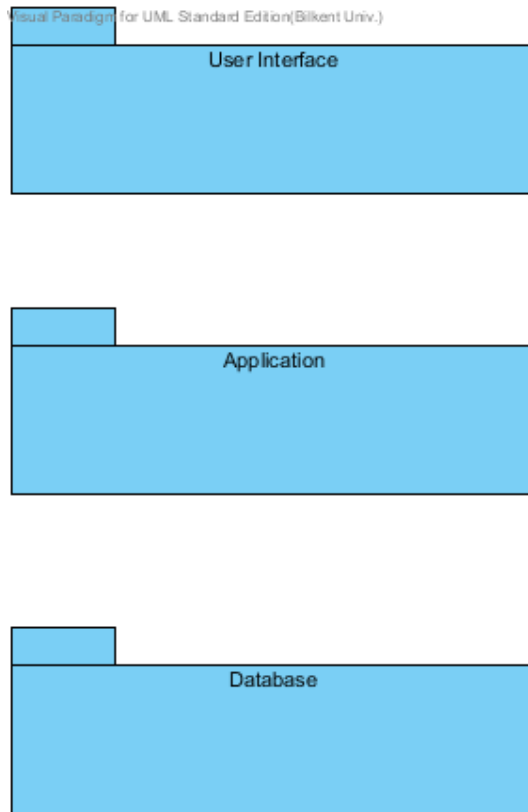


Figure 19 Top Level Decomposition View of Smart Board System

Figure 20 is the decomposition view of the Smart Boards System which consists of three main modules named User Interface, Application and Database, and the modules in each of them. User Interface Module consists of Display Module, where slides and multimedia related course content are provided to be visualized and Sketch Module, where sketches made on the board and tablets are provided to be visualized. In Application Module, there are Sketch Manager, Presentation Manager and Multimedia Manager which control sketch applications, presentation applications and multimedia applications respectively. Furthermore, there is Options Manager in Application module which controls or changes the options of the system such as volume, contrast, pen color etc. Finally, there is a Database Manager which is responsible for retrieving or sending information to database. In the Database Module, there

are two main databases which are Main Content DB and Main Account DB, in addition to these there is a Backup DB to recover the two databases if it is required.

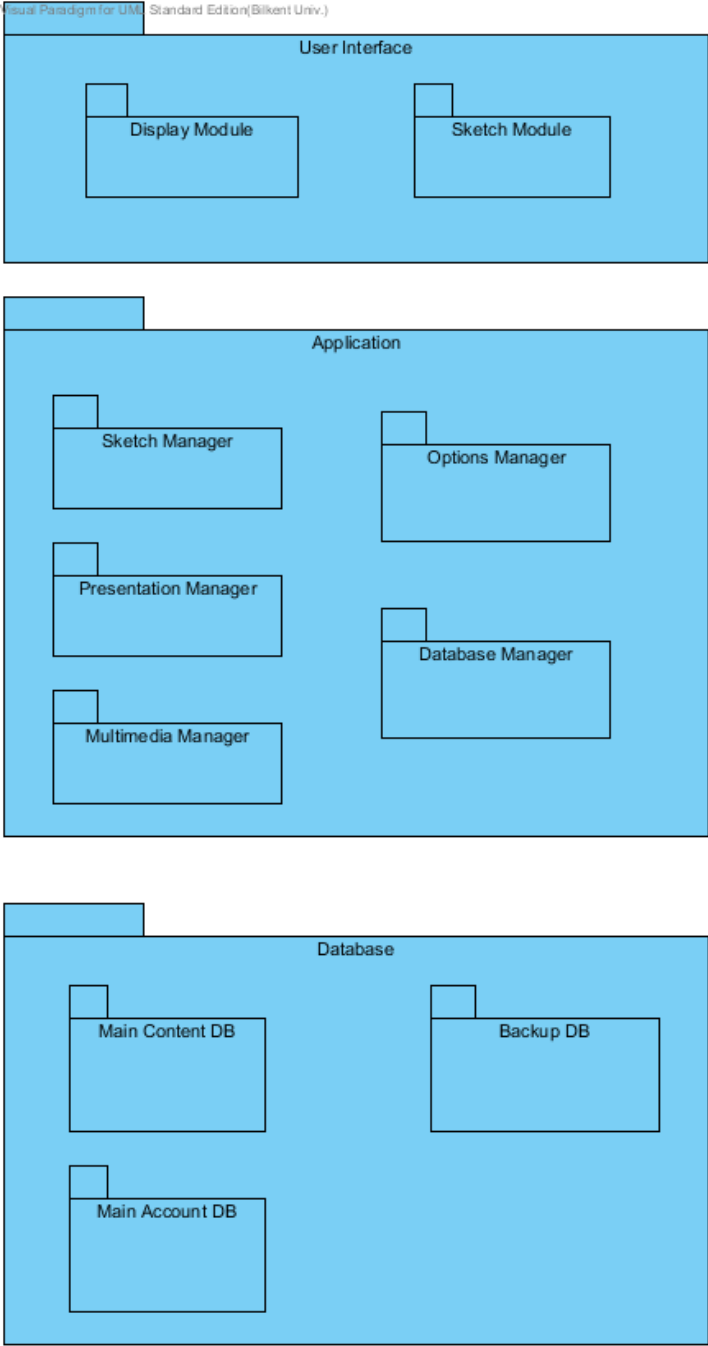


Figure 20 Decomposition View of the Smart Board System

Context diagram for decomposition view represents “is a part of” relation between a larger system and its subsystems. Smart Boards in Bilkent System is a part of Bilkent University Information System which can be represented by context diagram as shown in Figure 21. In that system, there are Bilkent University Network System and Bilkent University Database System in addition to Smart Board System.

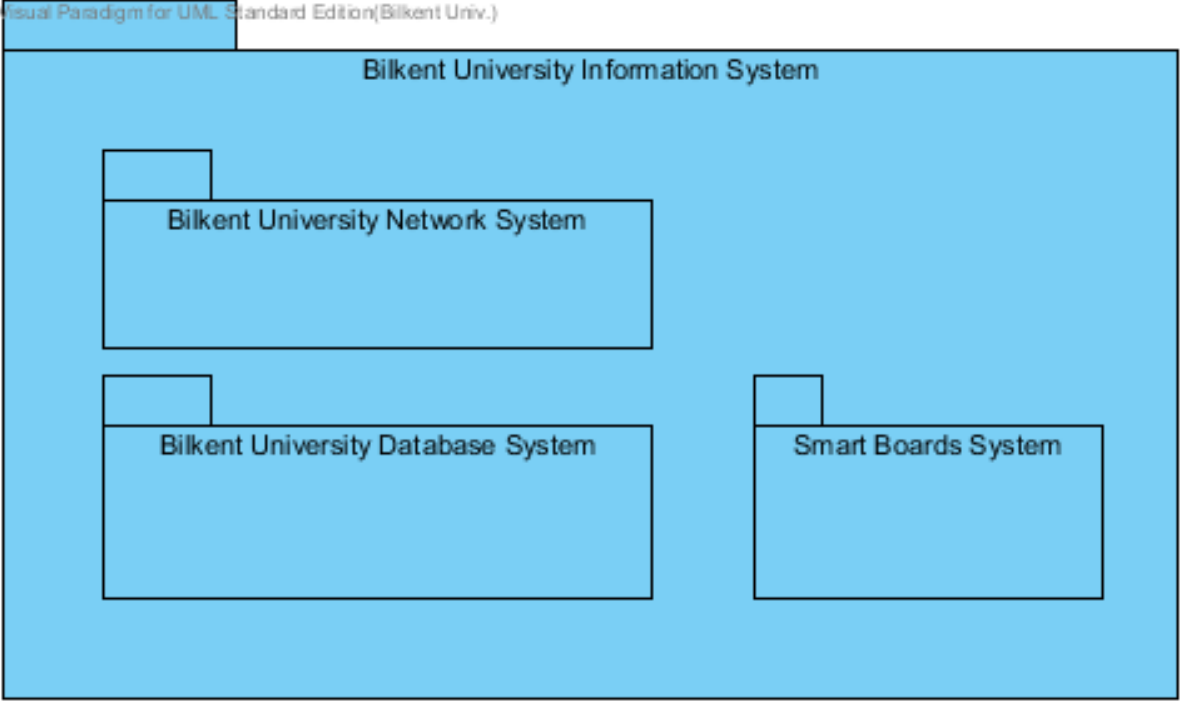


Figure 21 Context Diagram of the Decomposition View

9.3. GENERALIZATION VIEW

Figure 22 illustrates the generalization view of Smart Board System. The system has Sketch Manager, Presentation Manager, Multimedia Manager and Options Manager which are the extension of Application Manager. In other words, Application Manager is the parent of those managers. Additionally, User Interface Manager, Application Manager and Database Manager are the subsystems which control related parts of the system; these are the extensions of System Manager.

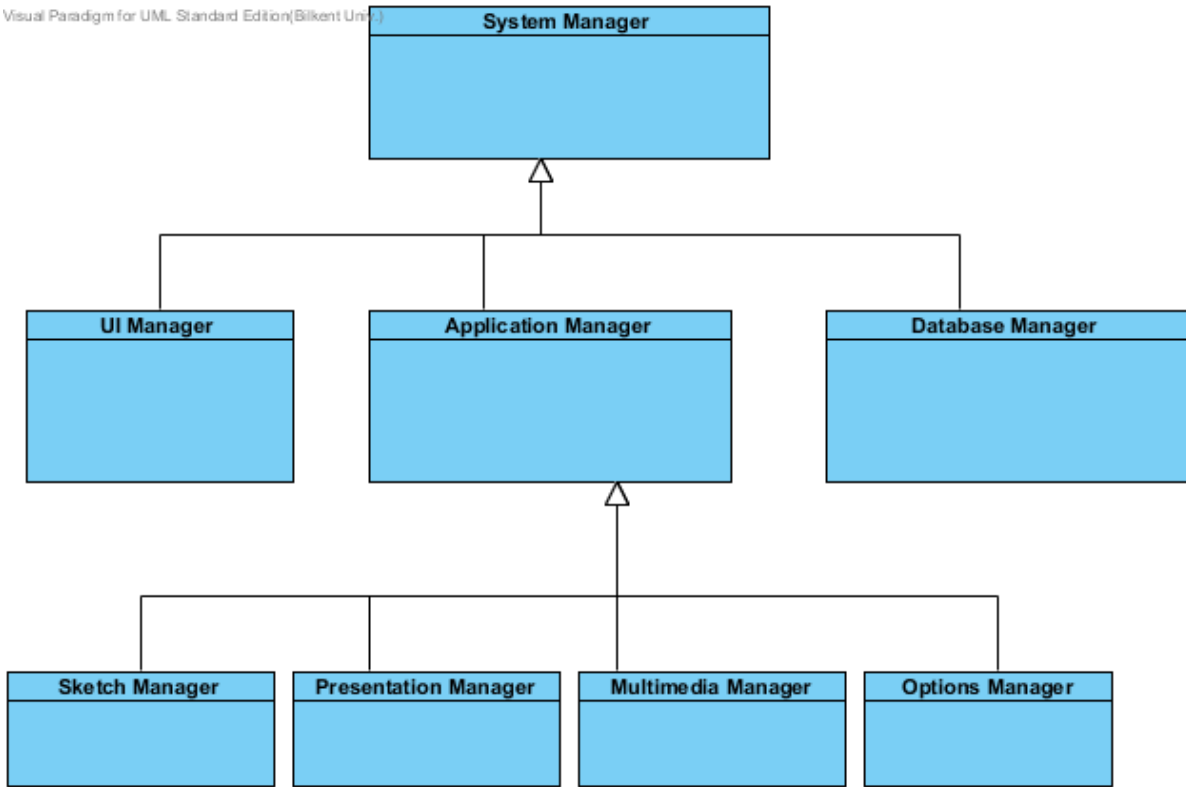


Figure 22 Generalization View of Smart Board System

9.4. LAYERS VIEW

Layered view is used to separate the modules of the Smart Board system and define their allowed to use relationships to each other. In other words, it will show how the modules of the Smart Board system are allowed to use another module of the system. Layered view is necessary for separation of concerns and modularity of the system. The elements of Layered view are the layers and their relationships are allowed to use relations.

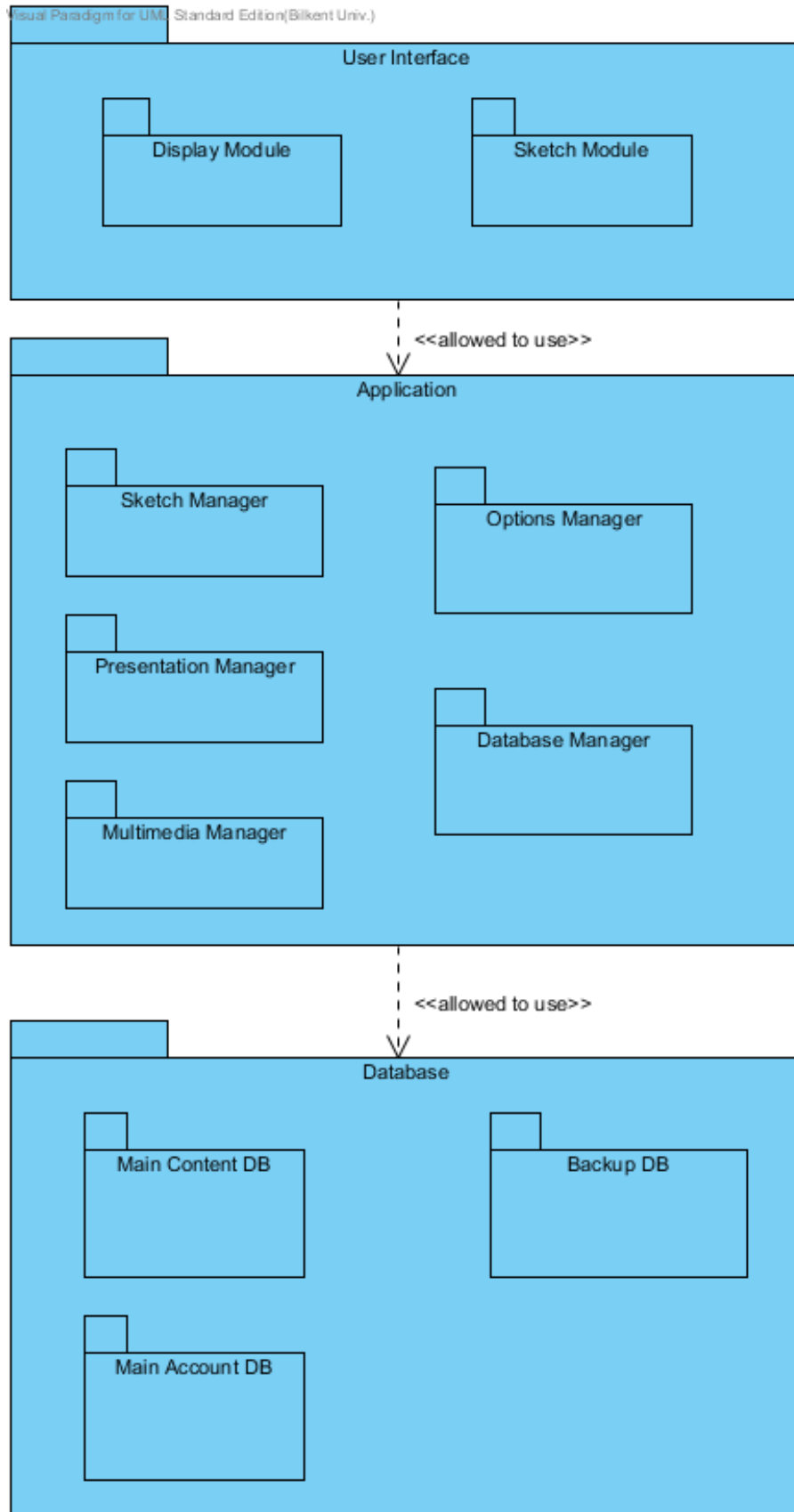


Figure 23 Layers View of Smart Board System

Smart Board system has three layers and these layers have shown in Figure 23. The layers in the system are User Interface, Application, and Database. User Interface layer (which contains Display Module, Sketch Module) is the layer at the top and User Interface layer is allowed to use Application and Database layer. Application layer (which contains Sketch Manager, Presentation Manager, Multimedia Manager, Options Manager, Database Manger) is the middle layer that is not allowed to use User Interface layer but is allowed to use Database layer. Database layer (which contains Main Content DB, Main Account DB, Backup DB) cannot use any of the layers because it is the layer at the bottom. User Interface, Application and Database layers provides cohesive a set of services that are semantically related. Each of these layers provides public interface facilities that maybe invoked or accessed by other software.

Context diagram for layer view represents “is allowed to use” relation between the layers. Figure 24 shows Smart Boards System being developed on the top of the Network System Layer, Database Layer and Operating System Layer. Smart Board System is allowed to use services of Network System Layer and Database Layer; while Network System Layer and Database Layer are allowed to use services of Operating System Layer.

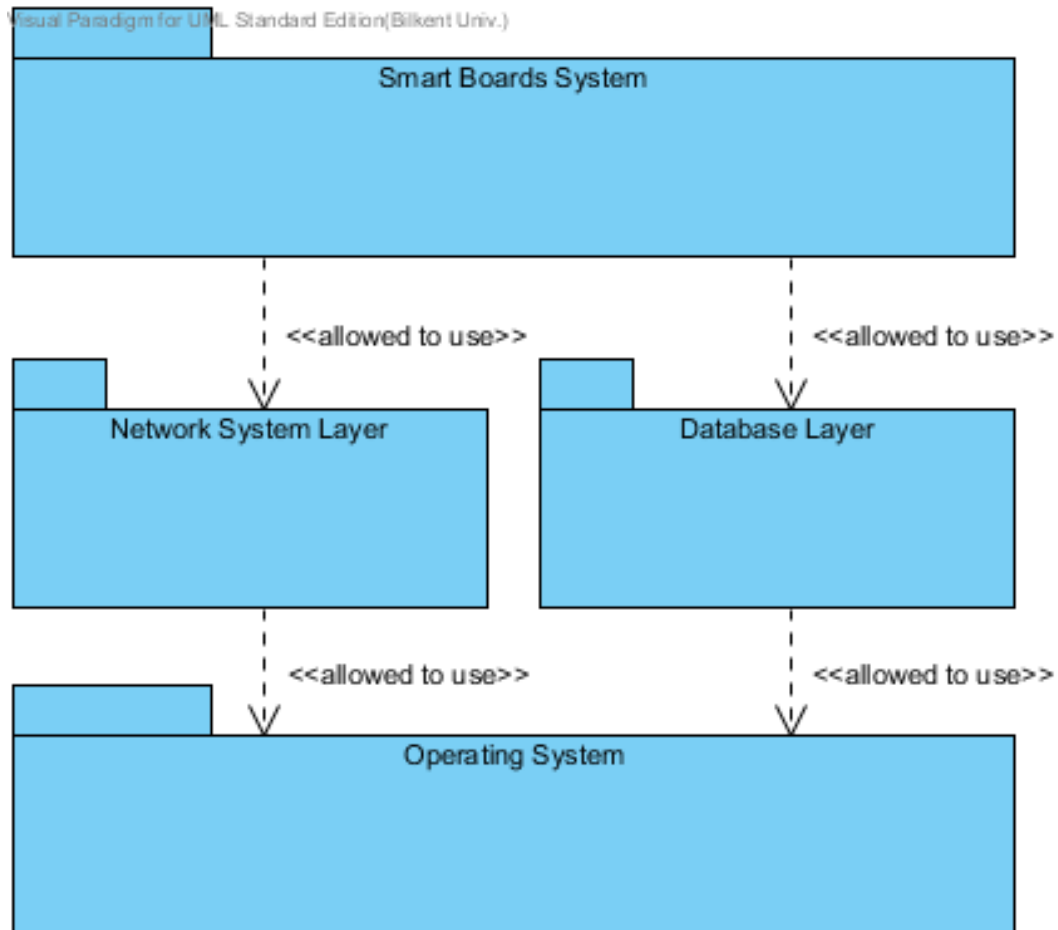


Figure 24 Context Diagram of the Layers View

9.5. ASPECTS VIEW

In Smart Board System, aspects style is used in order to model the implementation of crosscutting concerns. Aspect Style is chosen for our project in order to promote the modifiability by increasing modularity by avoiding the tangling of crosscutting functionality and business domain functionality.

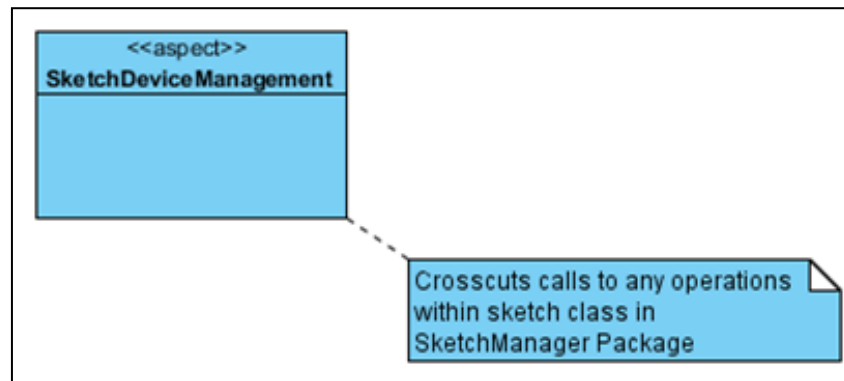


Figure 25 Aspects View of Smart Board System

Figure 25 shows the Aspect Style of Smart Boards in Bilkent. SketchDeviceManagement has an aspect type which is a specialized module that contains the implementation of crosscutting concerns in Smart Board System. SketchDeviceManagement aspect crosscuts calls to any operations within the SketchManager package.

9.6. DATA MODEL VIEW

The Data Model Style is chosen to describe the static information structure of Smart Boards in Bilkent project in terms of data entities and their relationships. The data model is represented graphically in entity relationship diagrams.

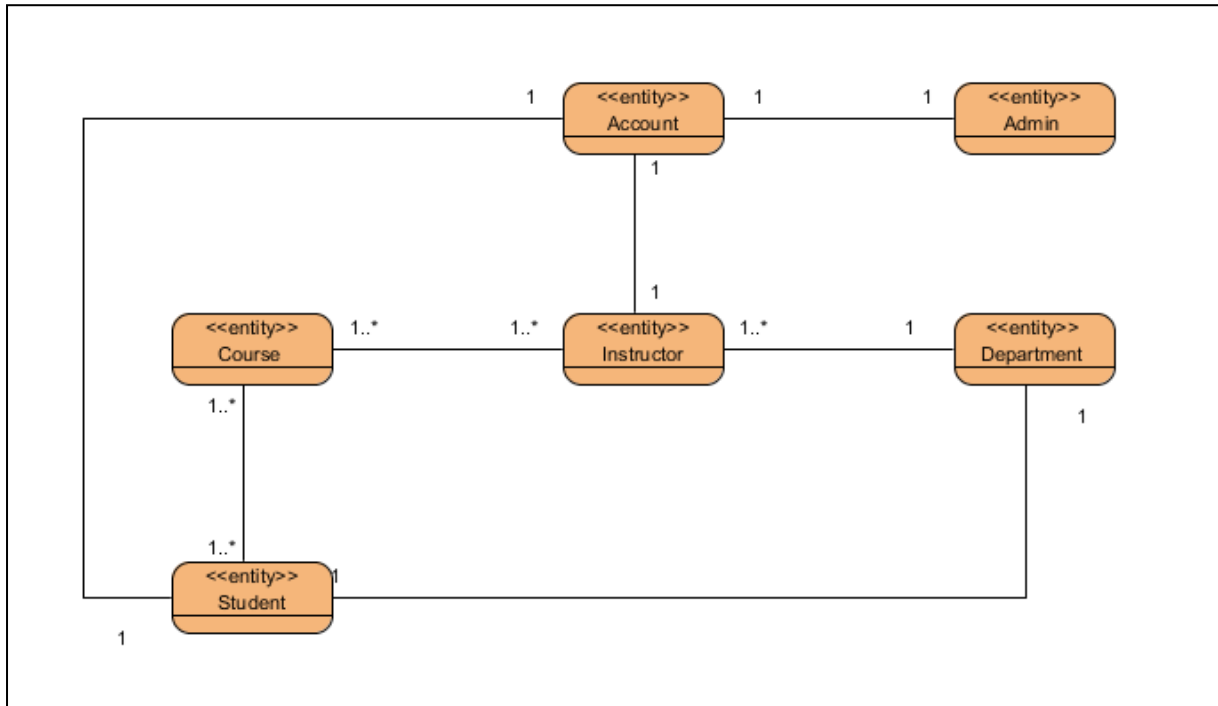


Figure 26 Data Model View of Smart Board System

Figure 26 represents Data Model Style of Smart Boards in Bilkent project. Data Model Style explains the relationship between data model, for this project the relationship between entities are as follows;

- One Admin can only have one Account, one Instructor can just have one Account and one Student can only has one Account.
- One or many Instructor can give one or many Course.
- One or many Instructor can have only one Department. An Instructor can only pertain to one Department.
- One or many Student can attend one or many Course at the same time.
- One Student can only have one Department. A Student cannot have different departments at the same time.

10. COMPONENT AND CONNECTOR VIEWS

Component and Connector View shows that how the architecture of a software system is structured as a set of elements that have run-time behavior and interactions. In of “Smart Boards in Bilkent” project; Client-Server View, Publish-Subscribe View and Repository View are used in order to explain the run-time processes.

10.1. Client-Server Style

Client-server Style is used in Smart Board System in order to show computational flow of the system. In case Client-Server Style provides a synchronous service invocation, this style is convenient for our project. In Client Server Style the requester of a service waits, until a requested service completes its actions, possibly providing a return result. The same procedure is applied in Smart Boards in Bilkent project that client (Student) sends content-requests from server port to server (MainServer) and waits until getting services.

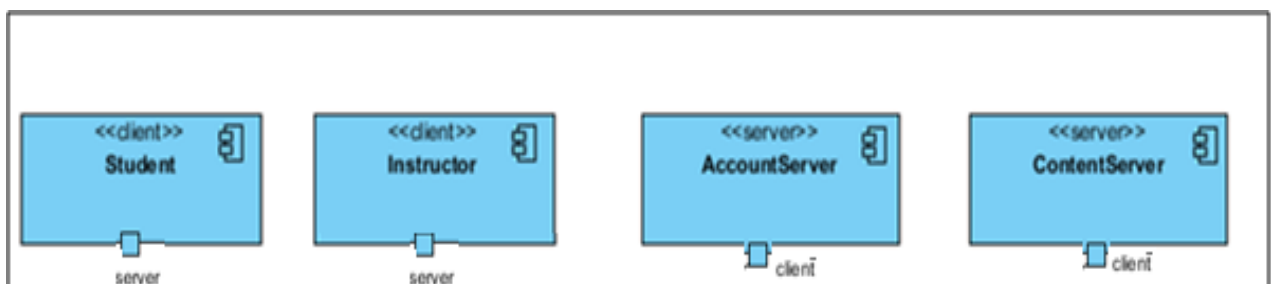


Figure 27 Client-Server View Type Definitions

Figure 27 represents Elements of Client-Server Style of Smart Boards in Bilkent. Client is a component that invokes services of a server component. Student and Instructor components are defined as a client typed components. Server is a component that provides services to client components. AccountServer and ContentServer are defined as a client typed components. Student/Instructor and AccountServer/ContentServer components include content-request/login-request-reply connectors to communicate with each other. This mechanism is used by a client to invoke services on a server. Request/reply connectors have two roles: a request role and a reply role.

The relationship between Student/Instructor and AccountServer/ContentServer components are *attachment* relation, associates client service-request ports with the request role of the connector and server service-reply ports with the reply role of the connector.

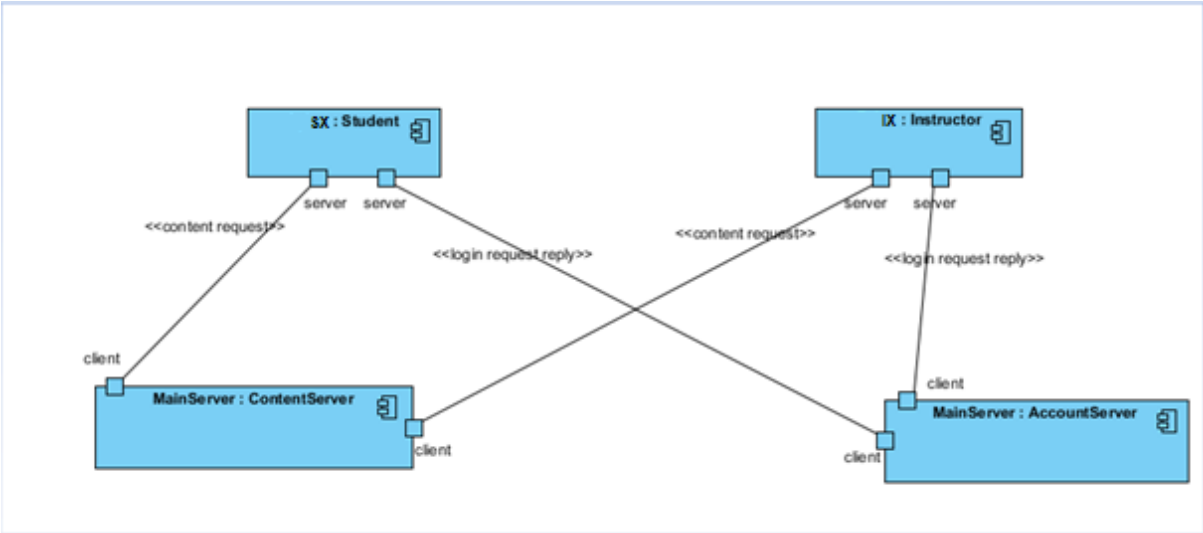


Figure 28 Client-Server View of Smart Board System

Figure 28 shows the client-server style of Smart Boards in Bilkent. The Student includes two server ports, which allows Student to send and take requests from the servers ContentServer and AccountServer. The Student sends content-request from server port to MainServer in order to get the course contents such as slides, lecture notes etc. from ContentServer. Student also sends login request/reply messages from server port to AccountServer in order to login to the system.

The Instructor includes two client ports, which allows Instructor to communicate and send requests to Instructor and Student components. Instructor sends content requests to MainServer in order to get the course related contents such as course slides, lecture notes, videos etc. from ContentServer . It also sends login request/reply messages to AccountServer in order to login to the system.

10.2. Publish-Subscribe Style

Publish-Subscribe Style is used in Smart Board System in order to share the course materials with the students registered to a course of the system. In Publish-Subscribe Style the subscribers of the system are the students and they subscribe to the material shared by the publisher of the system which is the instructor of the course in our case. The content published by an instructor is delivered to all the students subscribed to the course of that instructor automatically.

Types:

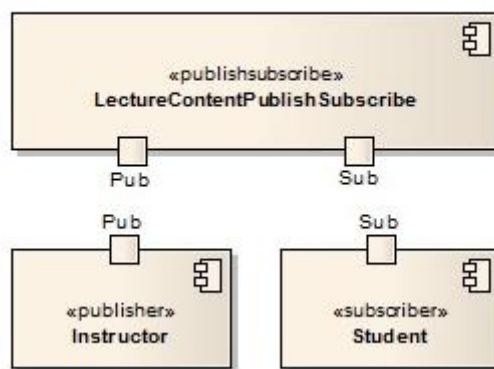


Figure 29 Publish-Subscribe System Type Definitions

Figure 29 represents the component types of the Publish-Subscribe Style of the Smart Board system. Publisher is the component that publishes data to the common repository by defining its topic. In our case, the only publisher is the instructor of a course and s/he shares the course material using this publisher component. Subscriber is the component that gathers the data published by a publisher and subscriber only gets the data that it is interested in or registered. In our case, the only subscriber is the students of a course and they get the related course material using this subscriber component. LectureContentPublishSubscriber component represents the common repository between the publishers and the subscribers. The publishers publish the data to this component and subscribers get the data they are interested in from this component.

Publish-Subscribe Style

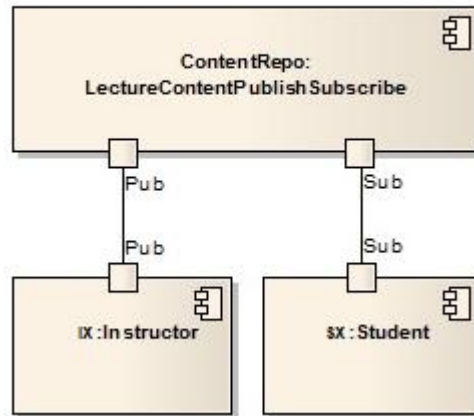


Figure 30 Publish-Subscribe Style of Smart Board System

Figure 30 shows the publish-subscribe style of the Smart Board System. The Student includes one subscribe port, which allows Student to get the data published in LectureContentPublishSubscribe repository by an instructor of a course that s/he is registered. The Instructor includes one publisher port, which allows Instructor to publish the course material to the LectureContentPublishSubscribe repository where the subscribers can access the shared data.

10.3. Repository Style

Repository Style is used in Smart Board system in order to show which data accessors are connected to which data repositories. Components of this view are data accessors and repositories. In repository style, components are Content Server, Account Server, Main Content Database and Main Account Database.

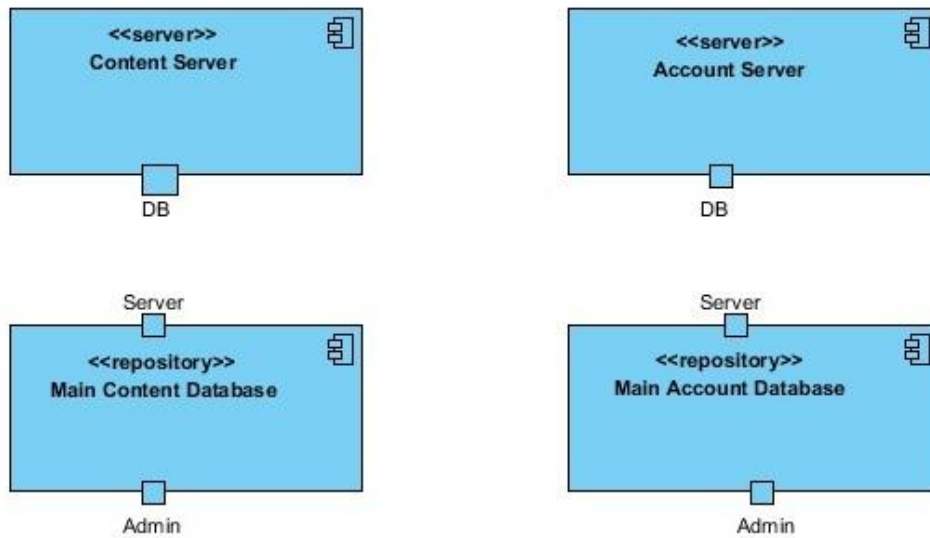


Figure 31 Repository Style Type Definitions

Figure 31 shows the two types of “server” and two “repository” types. Server types are Content Server, Account Server each has a DB port and repository types are Main Content Database and Main Account Database each has a Server and an Admin port.

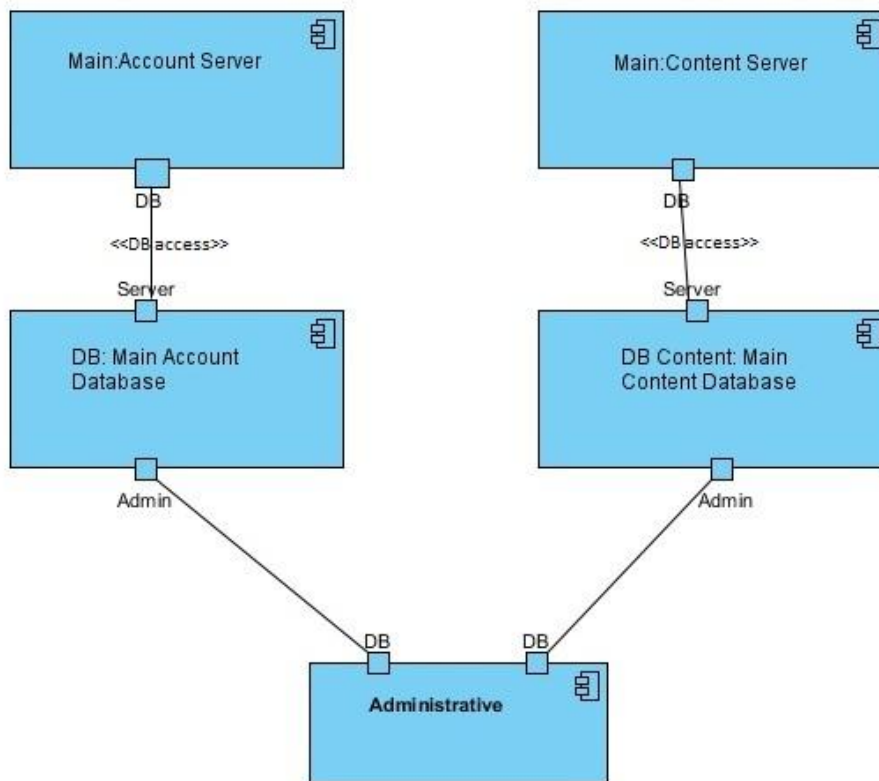


Figure 32 Repository Style of Smart Board System

Repository View of the Smart Board system has shown in the Figure 32. “Main” is an Account Server that accesses to Main Account Database called “DB”. Administrative connects to Main Account Database via DB port and also Administrative can connect to Main Content Database named DB Content via DB port. Content server accesses to DB Content with DB port.

11. ALLOCATION VIEWS

The allocation style presents a mapping of the architecture to its environment. Allocation views present a mapping from the elements of either a module or component and connector style onto elements of the environment. As their relations allocated-to relation is used to show which software element is allocated to which environmental element.

11.1. Deployment View

Deployment View is used in Smart Board system to show the allocation relations of the software elements of Smart Board system to their environment. Which software elements are used to deploy which environmental elements are shown in deployment diagram. This deployment diagram serves to model the physical deployment of software artefacts on deployment targets.

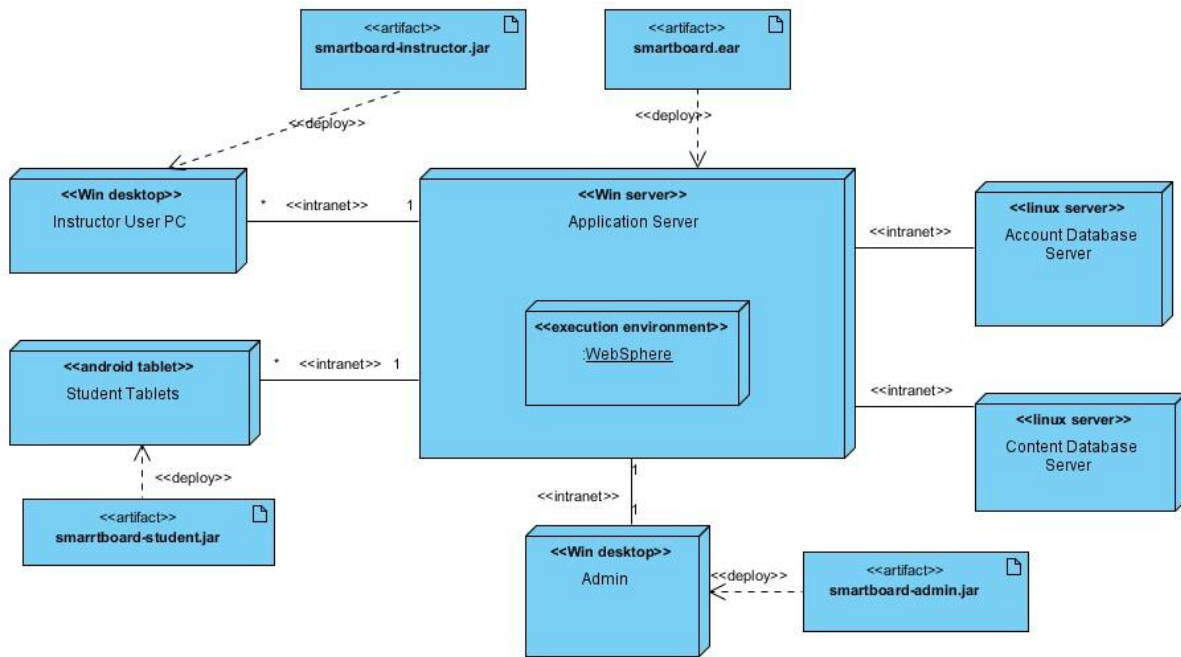


Figure 33 Deployment View of the Smart Board System

Deployment view of the system has shown in the Figure 33 that shows the mapping between the software’s components and connectors and the hardware of the computing platform on which the software executes. The nodes in this view are Application Server which is a windows server, Instructor User Pc is Windows based computer, Student Tablets which are android tablets, Admin which is the a Windows based computer for the Admin user, Account Database Server and Content Database Server are the Linux servers. These nodes are communicating with the main node which is the Application server that executes on the WebSphere. The communication between Application Server and the other nodes is supplied with Intranet which is a network connects local area networks and wide area networks to each other. Many Instructor PCs and Student Tablets can connect to Application Server via Intranet. Application Server is deployed by “smartboard.ear” which is a single archive that contains many files to execute many modules on Application Server simultaneously. “smartboard-instructor.jar” an artifact that to load on the Instructor PCs and “smartboard-student.jar” is another artifact to load on the tablets of the students. “smartboard-admin.jar” deploys the desktop computer of the Admin.

Context diagram for deployment view shown in Figure 34 represents “deploy” relation between Smart Board System and the university resources. The database of the system which

contains the account information and the lecture content is deployed to the Windows Servers of the university. In addition, the software of the system is installed to the computers in the classrooms of the university to run the Smart Board Application.

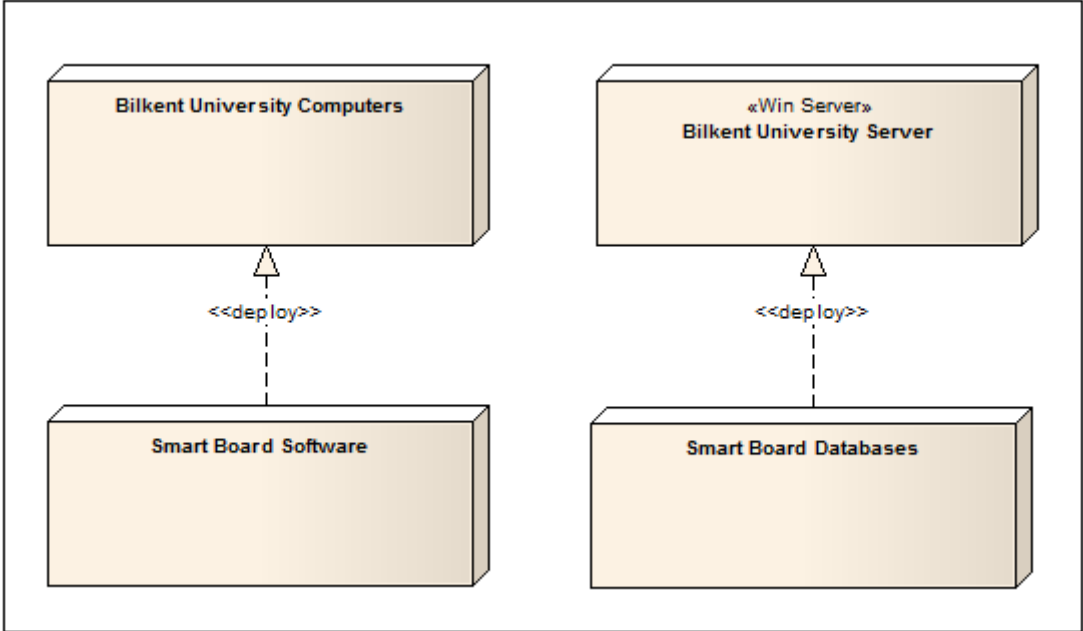


Figure 34 Context Diagram for Deployment View

11.2. Install View

Install view is the view of the system in production environment and it allocates the C&C components of the system to a file management system. Another element of the Install view except C&C components is the environmental elements such as files or directories. Install view is used in Smart Board system to show how the installed system is organized as a structure of files and folders and describes how software elements map to that structure.

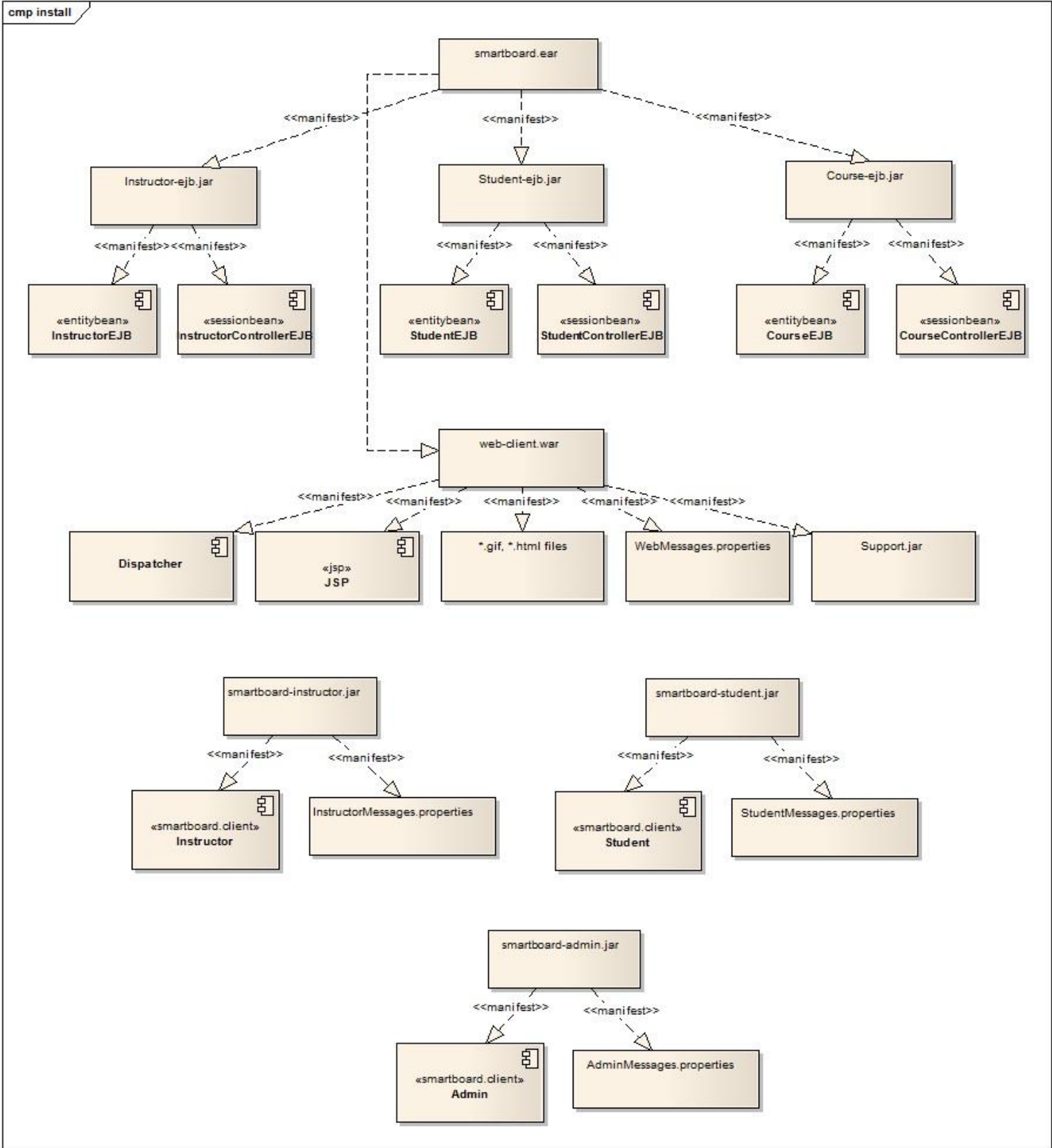


Figure 35 Install View of Smart Board System

Figure 35 shows the Install view of the Smart Board system. Install view shows how the installed system is organized in Smart Board system. The software is going to be deployed to the Application Server is called “smartboard.ear” which is a package consisting of three jar files and a .war file. Java applications are usually deployed in .jar files. First java application inside the enterprise archive smartboard.ear is “instructor-ejb.jar” which is an application for instructors when they are logged into the smartboard. It consists of two components InstructorEJB and InstructorControllerEJB. InstructorEJB is an entity bean which is used for persistent data storage for instructor in the smart board. InstructorControllerEJB is a session bean which is used when only one instructor has access to the smart board instances. Second Student-ejb.jar is a java application in smart board when students are using the smart board like if instructor allows student to answer the question written on the board. This java application consists of an entitybean called StudentEJB and a sessionbean called StudentControllerEJB. . StudentEJB is an entity bean which is used for persistent data storage for students in the smart board. StudentControllerEJB is a session bean which is used when only one student has access to the smart board instances. Third java application is Student-ejb.jar in smart board which is to control and hold the course contents in smart board. This java application consists of an entitybean called CourseEJB and a sessionbean called CourseControllerEJB. CourseEJB is an entity bean which is used for persistent data storage for course contents in the smart board. CourseControllerEJB is a session bean which is used to control course content. The Web archive file web-client.war is used to add web services to the smart board system. This archive consists of dispatcher, Java Server Pages JSP, *.gif, *.html files, and a java application to support web services Support.jar.

“smartboard-instructor.jar” is the java application to be installed into the computer of the instructor. It consists of InstructorMessages.properties and Instructor component which is a smartboard.client. “smartboard-student.jar” is the java application to be installed into the tablets of the student. It consists of StudentMessages.properties and Student component which is a smartboard.client. “smartboard-admin.jar” is the java application to be installed into the computer of the administrative. It consists of AdminMessages.properties and Admin component which is a smartboard.client.

11.3. Work Allocation View

Work Allocation view is used in Smart Board system to describe the allocation of a module to a configuration item. Items are teams which are for developing, design and testing the system. Work Allocation view is to show the major units of the system that must be present to form a working system and who will produce them. Developing teams are for sketching, content display, interface, communication. Designer Teams are Sketch Designer Team, Content Display Designer Team, Interface Designer Team, and Communication Designer Team. Testing teams are Sketch, Content Presentation, Communication tester teams. In this view software elements are modules and their relations between configuration items are showed.

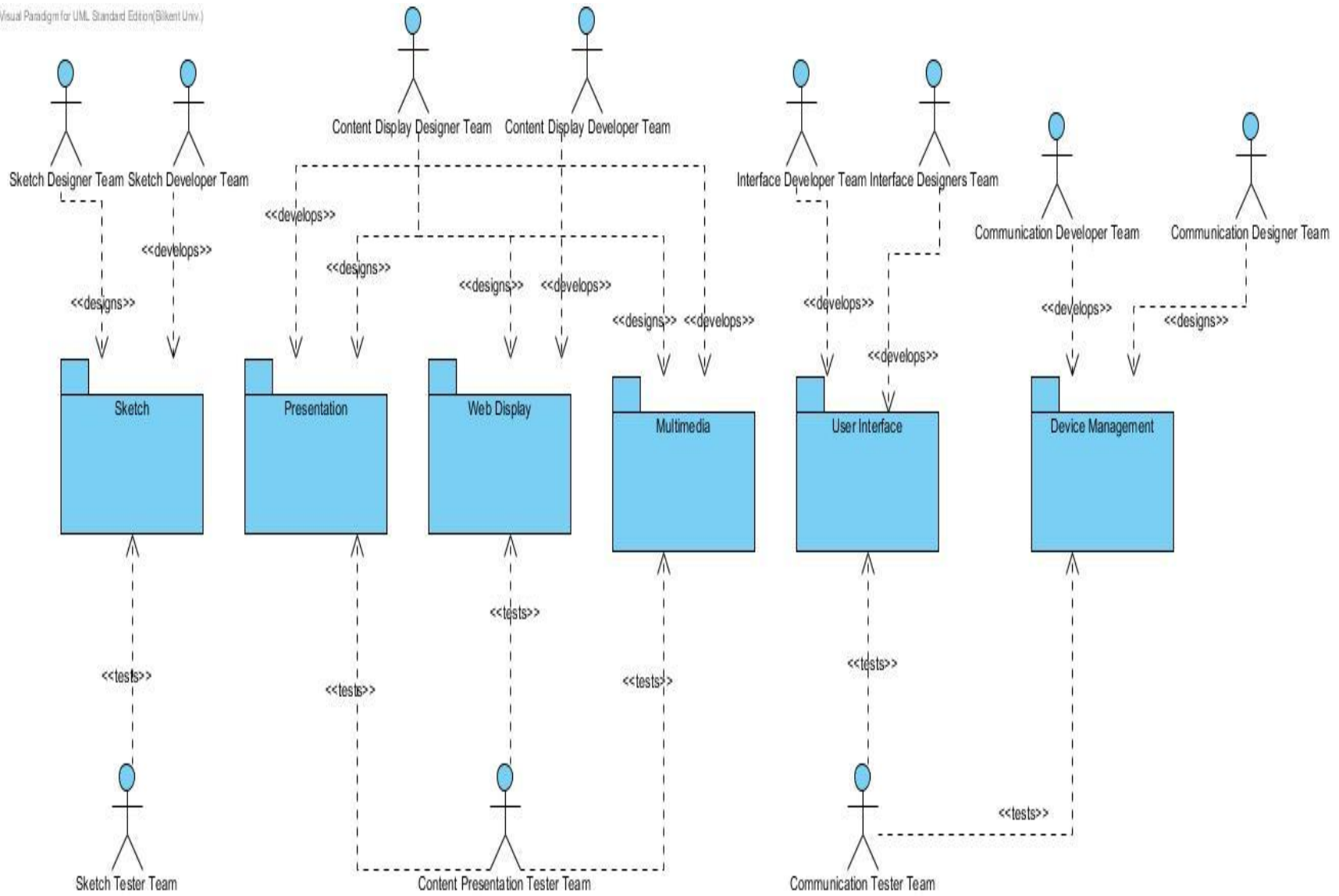


Figure 36 Work Allocation View of Smart Board System

There are three teams for testing and four teams for developing and design the system. Figure 36 shows each team and major units of the system as packages. Sketch module is the part of the system that is related with sketching and this module is designed by Sketch Designer Team, developed by Sketch Developer Team, and tested by Sketch Tester Team. Presentation module is one of the most frequently used parts of the system that is used in the lectures for presentations by instructor. Presentation module is designed by Content Display Designer Team, developed by Content Display Developer Team, and tested by Content Display Tester Team. Web Display module is a unit of the system for displaying web contents and connecting to the internet. This part is designed by Content Display Designer Team, developed by Content Display Developer Team, and tested by Content Display Tester Team. Multimedia module is to play videos for lectures. Multimedia part is designed by Content Display Designer Team, developed by Content Display Developer Team, and tested by Content Display Tester Team. User Interface module of the system is for designing and developing all the interfaces of the smart board that user is facing with. User Interfaces are designed by User Interface Design Team, developed by User Interface Developer Team, and tested by Communication Tester Team. Device management is the module that makes the system connected to a local network to be connected to instructors' computer, admin's computer and students' tablets. Also device management module should provide the device with connection to the internet. This part is designed by Communication Designer Team, developed by Communication Developer Team, and tested by Communication Tester Team.

12. EVALUATION OF THE SOFTWARE ARCHITECTURE

Software architecture is considered as one of the most significant design tool for understanding a software system, which determines whether the system is in preliminary design, active deployment or in maintenance process. Evaluation of Software architecture is needed in order to analyze system qualities early in the life cycle and to predict the quality of system before it has been built. Evaluation provides a mechanism for understanding of how the system will evolve by identifying potential *risks*. To do this, we evaluated smart board system with scenario based architectural analysis (SAAM) and ATAM.

12.1. Scenario Based Architectural Analysis (SAAM)

“Smart Board in Bilkent” project has a large and complex scope that it is hard to understand the architecture from gross level to detailed parts. Because of the complexity of project, software architecture is evaluated step by step. First step is to determine what the stakeholders are and what their requirements from the “Smart Boards in Bilkent” project are. Second step is to investigate all of the requirements with use cases. The basic components of the project and extension of the scope are defined according to these use cases. The general architecture is defined as a result of these main steps. General architecture is defined as a result of consecutive iterated processes. However there might appear some problems and missing crucial concepts in the architecture of a complex project such as “Smart Boards in Bilkent”, it is decided to make an evolution on the “Smart Boards in Bilkent” project’s architecture. For evaluation phase, the most efficient way, Scenario-Based Evaluation is chosen, in order to analyze system’s qualities early in the life cycle and to predict qualities of the “Smart Boards in Bilkent”.

12.1.1. Description of Candidate Architecture

The whole report before the section 12 includes the architecture of the smart boards system.

12.1.2. Developed and Prioritized Scenarios

“Smart Boards in Bilkent” is a huge project which has a number of stakeholders. The most important stakeholders who are mainly interested in the software architecture of smart board

system are instructor & student (customers), administrator, software/hardware engineer, network administrator and user interface designer. Therefore, the system should respond the needs of these stakeholders and should capture all the relevant scenarios. Below there are scenarios which are relevant with each stakeholder and arranged according to their priorities.

- Instructor:
 - Login to system
 - Add/delete course content
 - Change course content
 - Share course content
 - Add a presentation to the system in different format
 - Add a video to the system in different format
 - Change identity information
- Student:
 - Install the software
 - Access course content
 - Take notes on course content
 - Change identity information
- Administrator:
 - Change access permission to the system
- Software Engineer:
 - Add a new feature to the system.
 - Port to another operating system
- Hardware Engineer:
 - Add a new device compatible with smart boards.
- Network Administrator:
 - Change the network system
- User Interface Designer:
 - Make modifications in user interface

12.1.3. Scenario Evaluation

The table shown in below indicates the priority of the scenarios mentioned in section 12.1.2, their impacts on the architecture of the system and required changes to implement some scenarios.

Scenario	Description	Direct/ Indirect	Changes required
1	Login to system	Direct	
2	Add/delete course content	Direct	
3	Change course content	Direct	
4	Share course content	Direct	
5	Add a presentation to the system in different format	Indirect	This will require changing presentation manager module in application layer to support different presentation formats.
6	Add a video to the system in different format	Indirect	This will require changing multimedia manager module in application layer to support different video formats.
7	Change identity information	Indirect	This will require changing a options manager in application layer to keep the identity information of each user and allow each user to reach their identity information.

8	Install the software	Direct	
9	Access course content	Direct	
10	Take notes on course content	Indirect	<p>This will require a change in presentation and multimedia managers.</p> <p>The change is related to the feature which has also been included in sketch layer to provide users take notes on an empty sketch.</p>
11	Change access permission to the system	Direct	
12	Add a new feature to the system	Indirect	This will require adding new modules to the application layer.
13	Port to another operating system	Direct	
14	Add a new device compatible with smart board	Indirect	This will require adding a new component to the deployment view representing this new device.
15	Change the network system	Direct	
16	Make modifications in user interface	Indirect	This will require adding new modules to the user interface layer.

Table 22 Scenarios and their relation with the system

12.1.4. Scenario Interactions

For the indirect scenarios, the corresponding changes required in the system are defined. Then, the number of changes for each component which requires modifications are identified and a table indicating this relation is constructed (Table 23).

Component	# Change
Options Manager Module	1
Presentation Manager Module	2
Multimedia Manager Module	2
Application Module	5
Display Module	1
Sketch Module	1

Table 23 Number of changes required for each component

In table 23, the component with the largest scenario interactions is Application Module. Also, Multimedia Manager Module and Presentation Manager Module interact with more than one scenario. The other components are not affected by the same scenarios.

12.1.5. Overall Evaluations

At the end of the evaluation phase, we have defined the scenario interactions and identify bad and good scenarios. We want the architecture that we defined for smart board system provide high cohesion and low coupling. However, some of the scenarios affect the same component, especially Application Module. In order to prevent this, Application Layer could be separated into smaller layers. Also, there are two components which are Presentation and Multimedia Manager Modules which are affected by more than one scenario. These modules should be reviewed once again to prevent conflicting scenarios. Apart from those, there are not any semantically unrelated scenarios which affect the same architectural component which is also illustrated in table 23. As a result most of the scenarios that require change correspond to only one component of the system, which appears to prove the validity of software architecture of the smart board system. Minor changes in the architecture would be adequate to create high-quality software architecture of the smart board system.

12.2. UTILITY TREE (ATAM)

ATAM is used to assess the consequences of architectural decision based on multiple quality attribute requirements and also to understand how those quality attributes interact with each other. ATAM helps to understand how quality attributes of Smart Board system trade off against each other. Participants in ATAM of the Smart Board system will be evaluation team, project decision makers and architecture stakeholders. The utility tree is represented in the table 24.

Quality Attribute	Attribute Refinement	Scenarios
	Transaction Response Time	Instructor makes a small change in one of the course slides and transaction completes in less than 0.75 seconds.
		Instructor changes his/her password and transaction completes in less than 0.25 seconds.

Performance	System Response Time	Instructor tries to show a presentation to the students, and the presentation is loaded in less than 2 seconds.
		Instructor tries to show a video to the students, and the video is loaded in less than 4 seconds.
		Instructor tries to load a website to the students, and the browser is executed in less than 1 seconds.
		Instructor makes a change in a presentation slide; the modified slide appears in the tablet of the students in less than 2 seconds.
Usability	Normal Instructor Operations	Instructor displays a presentation, makes changes on it, asks question to the student, and the system completes all of these operations without any delay.
	Normal Student Operations	If an instructor allows students to make changes on the lecture material, Students make changes on the lecture material and system makes it possible to all students immediately.
	Training	A new person who knows using computer/tablets becomes proficient in less than one week.
		A help button is available on each screen which provides relevant information with that screen.
Maintainability	Bugs	Maintainer finds a bug in the system, fixes it and distributes the bug fix to all available systems.
	Software Updates	Software engineer releases the new version of the system that must be installed in a minimum amount of time.

Modifiability	New feature	A new feature is added less than 24 person-months to the system.
	New User Interface	A new user interface is added less than 2 person-months to the system.
Security	Data Confidentiality	Nobody is able to access the user information and passwords of the instructors and students.
		Uploaded course content is secure and only reachable by the instructors and the subscribed students.
	Data Integrity	99.999% of the time the course material added to the system is correct.
Availability	Hardware Failure	If the board runs out of electricity, the system starts all over again.
	Software Failure	If the connection between board and tablets are lost, the tablets logs in to the system again.
	Database Failure	Access denied for requesting the course content.

Table 24 Utility Tree of the Smart Board System

13. CONCLUSION

This report is prepared in order to design qualified software architecture for the “Smart Boards in Bilkent” system. In the design phase of the system, first step was the requirements analysis. Stakeholders and their needs/expectations from the system are identified. Analysis of the project is strengthened with use case diagrams, architectural scenarios and prototypes. Then, the technical problems which are identified according to the requirements are analyzed. Next step is to analysis of the solution domain where mapping the domains of each technical problem. Knowledge sources and derived concepts are identified. Description of software architecture process of the project continues with figuring out suitable styles from Views and Beyond Approach to model software architecture. As Module Styles; uses view, decomposition view, generalization view, layer view, aspect view and dataflow views are used in order to document a Smart Board system’s principal units of implementations. As Component and Connector Styles; client-server view, publish-subscribe view and repository views are realized in order to show how the architecture of the system is structured as a set of elements that have run-time behavior and interactions. Architectural design process is successfully completed in order to realize aim of Smart Boards in Bilkent project. As Allocation Styles; deployment view, install view and work allocation views are realized in order to map software architecture of the system to environment. Finally, software architecture evaluation processes such as SAAM and ATAM are applied in order to understand the missing and incorrect parts of the architecture of smart board system.

In the technical problem analysis part, we had some difficulties while we were identifying the problems. However, we had a chance to improve our creativity and increase our knowledge about technical problem analysis. We learned how to identify the mathematics and application domain, computer science and quality problems. Moreover, while we were doing domain analysis we investigated the solution domains that we identified according to the technical problems, which were challenging. The reason is, we searched the description of domains from various sources from internet and books, and we spent a lot of time. We also encountered some problems at phase of modeling software architecture while were choosing the right view to apply. However, we had a chance to improve our creativity by doing research and examining similar projects in order to increase our knowledge about architectural views and modeling software architecture. Lastly we investigated all the views

in detail then chose suitable views of Views and Beyond Approach then we could easily applied them into our software architecture.

We earned a lot of experience and we had a chance to practice our knowledge while we were realizing this project. As a result, this project, we encountered with some obstacles however we overcame all of them and increased our knowledge about software architecture design steps. In the future, we will revise our architecture according to the information we get from software architecture evaluation process; we need to add new modules to our system and improve it accordingly. In general, we fulfill the requirements of high quality architecture and achieved a successful one for the Smart Boards in Bilkent project.

14. REFERENCES

- [1]. <http://en.wikipedia.org/wiki/Database>
- [2]. http://en.wikipedia.org/wiki/Database_management_system
- [3]. <http://www.cs.ucl.ac.uk/staff/ucacwxe/lectures/ds98-99/dsee3.pdf>
- [4]. <http://www.cl.cam.ac.uk/~rja14/Papers/SE-06.pdf>
- [5]. <http://www.domainhostingall.com/glossary/Computer-network.htm>
- [6]. http://en.wikipedia.org/wiki/Computer_network
- [7]. <http://www.buzzle.com/articles/computer-networking-types-of-computer-networks.html>
- [8]. <http://www.w3.org/UI/>
- [9]. <http://uxdesign.smashingmagazine.com/2009/01/19/12-useful-techniques-for-good-user-interface-design-in-web-applications/>
- [10]. <http://www.ambysoft.com/essays/userInterfaceDesign.html>