Diabetes Risk Assessment Expert System

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1. Project Description

MAS, Medical Advisory System was a Computer Science Honours project undertaken at UCT in 2012. It was a prototype expert system that aimed at providing a Diabetes management tool, targeting illiterate rural communities as primary users. This system was developed by Kulani Makhubele and Kevin Brenkel, under the Supervision of Dr Audrey Mbogho. This system was a stand alone, text based system that offered advice on Diabetes. A downfalls to this is that it limits user accessibility because the system needs to be installed on a computer before use. The fact that is is text based means that there is a great potential of usability improvements that can be made by incorporating graphical elements into the system.

The aim of this year's honours project is to improve upon this system by developing an enhanced web-based expert system for Diabetes assessment and advice with improved usability, using MAS as a foundation and basis. This expert system will have the ability to give an accurate risk assessment of an individual having or developing Diabetes through an in-depth analysis of the individual's risk factors and symptoms .Furthermore the graphical interface shall be a lot more intuitive and interactive.

2. Problem Statement

2.1 What type of problem is it?

This is a research project: the aim is to have a fully functioning system that can be utilized by both patients and doctors to establish whether a person has a high risk of having/developing Diabetes through evaluating the following:

1. Risk factors.
2. Symptoms experienced by the patient.

This system shall also offer comprehensive medical advice with regards to the treatment and the long term management of Diabetes. The expected outcome of this project is determining how accurate our system is, how usable it is and also a significant improvement to the previous system (MAS). These conclusions shall be derived from the user testing.

2.2. Development Challenges

This project brings together many different fields: namely medicine, HCI,web development and knowledge based expert systems. Thus, there are a lot of challenges to be faced through their integration.

- Giving an accurate risk assessment of Diabetes.
  The main aim of this project is developing a system that can accurately determine the likelihood of a user having/developing diabetes. The same way that a medical professional would. This result shall be in percentage form. All the users input will need to be considered and unanswered questions should not derail the final result.

- Offer comprehensive information with regards to Diabetes.
  The system will need to be able to offer comprehensive information with regards to Diabetes. This means gathering a sufficient amount of information on Diabetes from different sources and representing it appropriately.

- Dealing with the uncertainty factor in answers.
  To incorporate the uncertainty factor of answers input into the system we will need to make use of fuzzy logic. This is a method that deals with reasoning that is approximate rather than fixed. This system will need to accurately simulate human reasoning and uncertainty is a typical challenge faced in problem solving.

- Development of a web-based system.
  We will need to ensure that our system uses minimum bandwidth and that it is compatible in different web browsers as well as quick and efficient. There are problems we face with regards to different internet speeds in different regions as well as high internet costs, all of this must be taken into consideration.

- Ensuring the interface is intuitive and usable.
  The aim is to have an interactive and intuitive interface. We will need to ensure that we cater for the different types of people in our user base, as well as different literacy levels.We need to do extensive user testing before we can release a final product.

2.3. Why is this problem important

The International Diabetes Foundation states that currently 50% of the diabetic population worldwide are unaware that they have the disease. This coupled with the limited access to medical professionals in certain parts of South Africa; along with the high costs of receiving professional medical advice amounts to a major crisis. This crisis can be alleviated through the development, deployment and wide spread usage of medical expert systems.

Expert systems allow us to capture the knowledge of human expertise into a computer system through knowledge engineering and in turn use that computer system to act in an advisory capacity and to also eventually have the capability to diagnose patients all in the absence of a medical doctor. This system would have to be simple, easy to use, interactive and a have high level of affordance to ensure that illiterate users are able to understand the basics of the user interface.

Furthermore by developing a web-based system this ensures that users can access the system through an internet connection, without the need to install specialized software or hardware on their workstation device. The success of such a system could have a great impact on the medical industry in South Africa.

3. Procedures and methods

The following procedures and methods are being proposed.

3.1 Knowledge Engineering deficient

In order for our system to be able to give an accurate Diabetes along with providing advice on treatment and management we will need to be able to gather and represent this domain specific knowledge. This process is known as knowledge engineering and has the following components.

1. Knowledge acquisition.
2. Knowledge representation.
3. Knowledge validation.
4. Inferencing.
5. Explanation and justification.

We will need to make use of an expert in the field of Diabetes, known as an endocrinologist. We will need to have interviews and question and answer sessions to gather all the required information. Along with this human expert we can also make use of other sources, such as the internet and other reliable publicly available information.When this information is gathered we will need to ensure that this knowledge can be well represented in the system and that it is of an acceptable standard, it will be difficult to effectively represent all parts of the knowledge in the actual code.The inferencing process would involve us designing the software in the system to make decisions based on the stored knowledge, this is the core aspect of the expert system. To complete the knowledge engineering process we need to ensure that the system is able to justify its reasoning through an explanation facility.

3.2 Interface Design

The interface will be developed using HTML5 and careful attention will be given in designing a minimalistic and user-friendly user-interface. The user interface will be web-based, thus a web host will be required.

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Human computer interaction will be utilized in inspecting the usability and efficiency of the interface. User testing will be carried out throughout the design process of the interface to maintain good user satisfaction.

Testing will involve quality assurance regarding usability as well as performance of the interface:

a. Usability

   Usability testing will involve designing multiple prototype interfaces which conform to existing design heuristics. The prototype design which achieves the best user-satisfaction selected for the final design. Further refining of this interface will then be performed, and the proposed methods and procedures used to evaluate the interface are discussed in 4.

b. Performance

   The performance of the user interface needs to be tested in order to assess the amount of bandwidth that it requires for a satisfactory user experience.

3.2 System Components

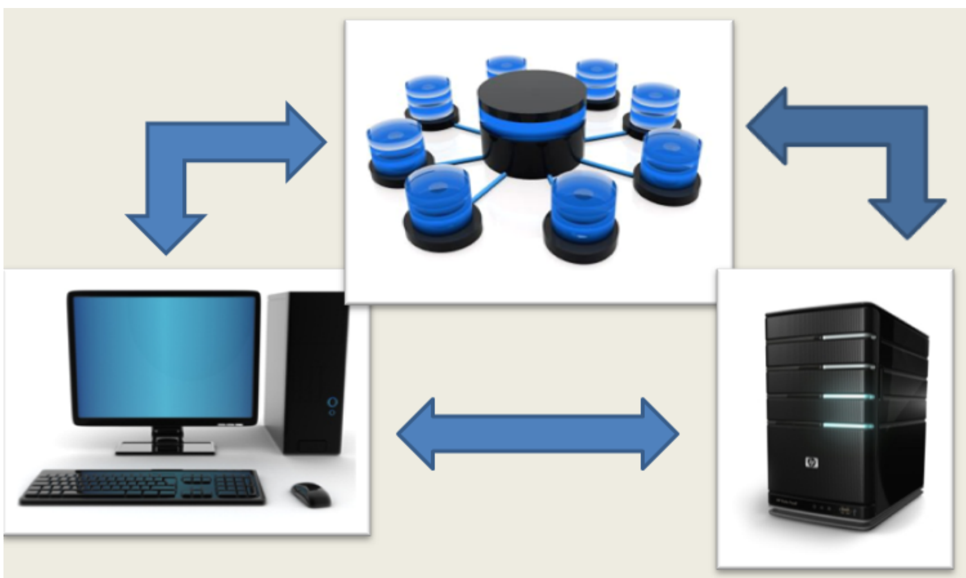

Figure 1- The components of the expert system.

This system has the following parts to it.

1. Back-End - The knowledge-based expert system.
2. Front-End - The web-based user interface.
3. Web Server.

The expert system shall make up the back end and the user interface shall make up the front end of the system. For our system to function correctly these components will need to integrate well with each other. They shall be developed separately to ensure that our system is modular and has low coupling.

3.3 The knowledge based expert system

This medical expert system shall be acting in the role of a medical doctor, by doing the Diabetes risk assessment and also offering comprehensive advice on diabetes treatment and management. This shall be done through a real-time two-way interaction between the user and the system, through the graphical user interface.

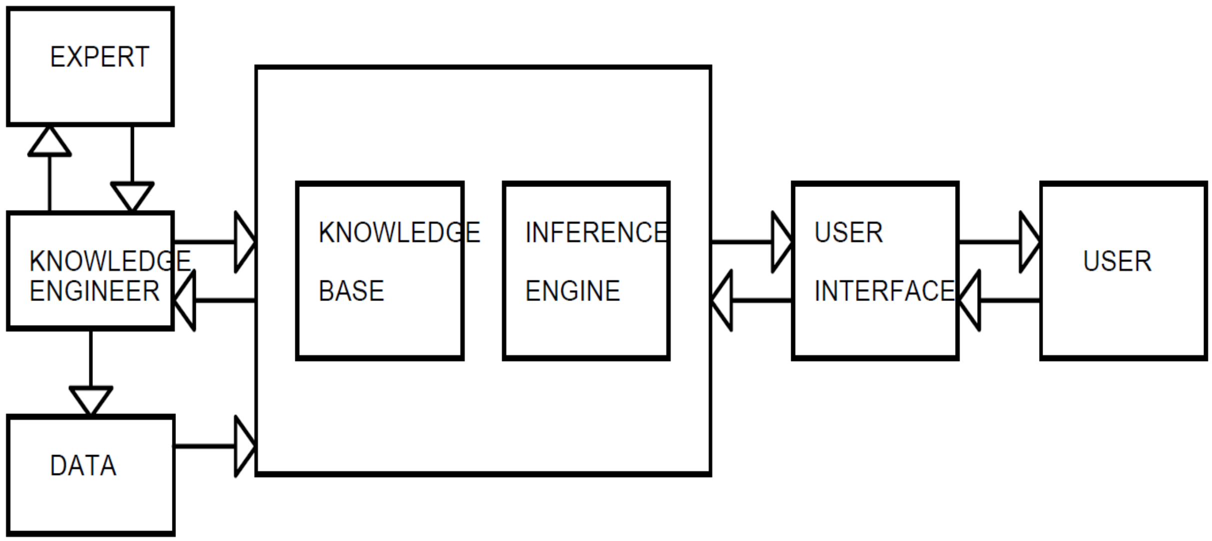

Figure 2 - Basic structure of a knowledge based expert system.

Our knowledge based expert system will be comprised of four distinct modules.

3.2.1. The knowledge-base

Also called the rule base, if rules in the form of *"IF A THEN B"* are used. These rules are fired when information in the working memory corresponds to the information in the "IF " part of the rule (antecedents). Actions executed by the rules could include

a. Modifying data in the working memory.
b. Adding/deleting data in the working memory.
c. Performing actions like printing messages to the user and asking more questions.

In our system we will need to take into consideration uncertainty factors with answers input into the working memory, this will lead us to make use of fuzzy logic; a form of logic that deals with values that are more approximated that exact. I.e the use of bounded continuous numbers (eg ,01,0.2,0.3 etc.) to express certainty, as opposed to the discrete values of typical boolean logic(0 or 1) .

3.3.2. The inference engine

This is the cognitive aspect of the expert system, analogous to human reasoning. The inference engine uses the information in the working memory and the rules in the knowledge base to solve a problem.

3.3.3 The working memory

The working memory is a collection of facts about the problem being dealt with, in our situation this would be the patients personal data and information (past and present). The expert system uses the working memory in conjunction with the rules in the knowledge base to derive additional information about the problem being solved.

3.4 User interface

We are planning on developing a web based, touch-enabled user interface for the front-end of this medical expert system. This will allow for ease of access, intuitive interactions and enhanced usability.

3.4.1 Web-based system

The system will be made accessible to the users through the internet, this ensures that there is widespread access to this service, this also means that there are no location constraints to the usage of the system provided the users have access to a computer and a decent internet connection. There will be a desktop and mobile interface.

3.4.1.1 Graphical User Interface

The graphical user interface will facilitate interactivity between the user and expert system. The use of text, images and animations allow for a rich user experience as opposed to a simple and tedious text-based user interface. The interface should be minimalistic, to achieve a look and feel that is simple, comprehensive and fully functional.

3.4.1.2 Touch-based

The graphical user interface will be touch enabled to keep up with the trend of current technology. A touch user interface requires the user to select on screen objects by touching the display at a point where the object of interest is located. This will make it easier for users to interact with the system without having to type extensively or drag the mouse in order to communicate with the system and navigate the interface.

An interface of this nature can simplify interaction between the user and the system significantly as it stimulates the user’s metaphorical reasoning and is a lot more intuitive than a text based interface.

3.5 The Web Server

A web server will facilitate online access for the Diabetes advisory system. The server will support html, javascript and java-server pages.

3.6 Expected Challenges

3.6.1 Obtaining sufficient expert knowledge

The biggest challenge is acquiring a sufficient amount of knowledge from an expert in order to make the expert system effective.

3.6.2 Effectively linking the back-end to the front-end

In order to integrate the front end and back end of the system, we may need explicit permission from the software developers to obtain the source code of their development platform.

3.6.3 Giving an accurate Diabetes risk assessment

Our system should be able to give an accurate risk assessment in the form of a percentage. Ideally it should be very high for users who have Diabetes and low for users who do not.

3.6.3 Testing the system

In order to produce a system that is effective and accurate, user testing is essential. We will need to be able to measure our success through the testing and evaluating of the system. Because of the lengthy testing process we may need to offer incentives to users.

4.Testing and Evaluation

To ensure the validity of our project we will need to test the following parts of the system.

1. **a. The expert system**
   Users with an adequate medical background will be required to test the system in order to assess the quality of the rules in the knowledge base. We will need human resources like medical doctors and medical students to ensure that the rules used in the knowledge base are valid. Because of the nature of the system a lot of work must be put in to ensure its validity, this needs to be done extensively before we finalize our project.We will need to have both diabetics and nondiabetics test our system in order to check the accuracy of the results produced by the risk assessment.

   b. The user interface
   The main challenge concerning the interface is to design a user-friendly interface that will cater for users of different literacy levels.
   i. We will first need to agree on the main design of the interface for this we will present users with a few alternative designs and select a main design to work with.
   ii. We will then have the final user testing

2. **The Testing Procedure**

a. Software test cases.
Test cases shall be used to ensure that the system performs the tasks as expected.

b. System run-through
Users will use the system from the beginning to the end and the performance and the results will be recorded. Users will be testing both the UI and the expert system simultaneously.We will have users test both the older system (MAS) and the current system (DA2) in order to determine if the improvements made are significant and necessary

c. User questionnaires.
In order to obtain qualitative feedback on the system we will need to have the users fill out questionnaires. These questionnaires shall be a combination of both multiple choice and open ended questions..

d. Comparative testing between desktop interface and mobile interface
The desktop interface will be tested against the mobile interface to determine which is more convenient in terms of usability. This comparison will assist in establishing a benchmark to which the interface which is less usable needs to reach as much as possible. The benchmark will be based on time taken on average to complete tasks.

e. Heuristics evaluation.
The interface will be tested against user interface heuristics such as Ben Shneiderman's eight golden rules and Nielsen’s Heuristics for interface design. This will assist in identifying any shortcomings the interface may have relative to what is expected from conventional interface design principles.

5. Ethics, professional and legal implications

5.1 User testing

In order to have users test our system we will need to seek explicit permission from the UCT Science Faculty Research Ethics Committee. In order to ensure that this process does not delay the completion of our project we will need to initiate it well in advance.

5.2 Software and licences

The software that we are using for the system development does not come with any usage restrictions.

6. Related work

6.1 MAS

Medical Advisor System; the basis of this current project, is a prototype expert system that was developed by Kulani Makhubele and Kevin Brenkel under the Supervision of Dr Audrey Mbogho of the Computer Science department in 2012 at UCT[1]. The targeted user base of the system being illiterate users in rural communities who have limited access to professional medical doctors. This system focused on offering comprehensive advice on Diabetes management and treatment without offering any diagnosis/assessment facility at all, but rather a recommendation. The system would refer users to contact a medical professional if they seeked more than it could offer, like diagnosis of Diabetes.The system made use of a text-base user interface to interact with the user. Initially the developers' aim was to develop a fully functional speech-based interface to act as the front end for this expert system, unfortunately this never materialized. Towards the end of their project the developers failed to link the back end and the front end of the system as the had initially proposed. This system was developed solely using the JESS programing language.

6.2 MYCIN

The MYCIN expert system was developed at Stanford University in the mid 1970's. It was designed to assist doctors in the diagnosis and treatment of meningitis and bacteremia infections [2]. The role of MYCIN was to take the place of a consulting physician that specializes in blood disease. To be able to diagnose patients, MYCIN would engage in an extensive real-time dialogue with the doctor, asking a host of questions consecutively until eventually providing a diagnosis and a drug therapy recommendation. MYCIN's key selling points were the ability to factor in uncertainty; the ability to manage with incomplete information and the incorporation of an explanation facility which allowed the doctor to questions its reasoning at any time during the process.This system was used purely for research and it was never actually commercially deployed. It was written in the LISP programming language, which was considered *"the language of artificial intelligence"*.[3]

6.3 ESDD

ESDD; Expert System for Diabetes Diagnosis is a prototype rule based medical expert system for the diagnosis of Diabetes [4]. It is not able to identify the type of diabetes but it can identify the level of diabetes risk in the patient through an analysis of patient symptoms..ESDD makes use of a text-oriented menu-based user interface to interact with the user, communicating in simple English. ESDD has a 'trainer' option that can be used to provide diabetes awareness amongst the public. This expert system was developed in 2010 as part of a research project and it was written in the CLIPS programming language.

7. Anticipated outcomes

The anticipated outcome for this project would be a medical advisor system that is fully functional and is approved by the users testing it in terms of interface design and the accuracy of the output it produces. The system should require minimal bandwidth for it to function, without compromising on the overall performance and experience. The system should be able to give an accurate risk assessment of Diabetes and offer comprehensive advice to patients.

c. Key valuation criteria

- Will our system be able to give an accurate risk assessment to users with Diabetes.
- Will our system offer comprehensive advice and information that is equal to or even better than a medical expert?
- Will users feel inclined to use our system as opposed to going to their nearest clinic?

8. Project Planning

8.1 Risk matrix and mitigation strategies

#	Risk	Probability	Impact	Mitigation Strategy
1	Group member unable to continue with project.	Low	Medium	The work allocation has been split up such that there is low coupling.
2	Medical expert is not available to provide knowledge required by the expert system.	Medium	Low	Knowledge on diabetes can be acquired from medical students or from online medical advisors.
3	Failure to conduct enough user testing in order to evaluate the system	Medium	High	Perform user testing as soon as possible throughout the project duration rather than towards the end.
4	Unfamiliarity with certain technologies and paradigms, leading to time used up learning rather than implementing the system	Low-Medium	High	Use technologies we're familiar with as opposed to trying new ones out as well as researching on the best possible way to tackle a problem and stick to the one solution rather than continue searching for alternatives..
5	Data Loss	low	High	Consistently use cloud storage to backup as well

				as edit the data within the cloud
6	Ethical Clearance Delay	low	High	Apply for ethical clearance as soon as possible
7	Scope creep	High	High	We need to ensure that we have a well defined list of objectives.And that we do not take in more than we can handle.
8	Unable to keep up with project milestones	low	High	Have weekly meetings in order to stimulate a constant work rate as well as work on deliverables way in advance.

8.2 Milestones and Deliverables

8.2.1 Gantt Chart

See appendix X for Gantt Chart

8.2.2 Deliverables

#	Milestones	Date
1	Literature Synthesis	30 April 2013
2	Project Proposal	13 May 2013
3	Project Proposal Presentation	23 May 2013
4	Presentation feedback	24 May 2013
5	Revised Proposal Finalized	10 June 2013
6	Project Web Presence	11 June 2013
7	Initial Feasibility Demonstration	17 July 2013
8	Background/Theory Chapter	19 July 2013
9	Design Chapter	26 August 2013
10	First Implementation	16 September 2013
11	Final Prototype	25 September 2013

12	Implementation and Testing Chapter	30 September 2013
13	Complete Report Outline	7 October 2013
14	Final Project Report Draft	21 October 2013
15	Project Report	28 October 2013
16	Poster	31 October 2013
17	Webpage	4 November 2013
18	Project Demonstration	5 November 2013
19	Reflection Paper	8 November 2013
20	Final Project Presentation	14 November 2013
21	Final Project	20 November 2013

8.3 Resources required

8.3.1 Software

a. JESS, JSP

JESS, Java Expert System Shell is is the software we will use to develop the expert system.JSP will be used to integrate the front-end with JESS.

b. HTML5, Javascript

The interface will be web-based, therefore HTML5 is used for development. Javascript will be utilized to ensure our content is dynamic.

c. Apache Tomcat

Tomcat, an application server, will be used in order to implemented Java-server pages specifications and provide means of running java code in a java HTTP web server environment.

8.3.2 Hardware

a. Computer
b.Tablet/Touch-enabled device
c.Server to host the system.

8.3.3 People

a. Doctor(s)

To give us in-depth medical information with regards to Diabetes risk assessment and treatment.

b. Medical students

We are fortunate to have our own medical school at UCT, which we can use to receive direct assistance from medical students to test the accuracy and effectiveness of our system from a medical perspective.

c. System users

To test the usability and reliability of our system, it will need to go through extensive user testing.

9. Work allocation

The project workload will be divided into two distinct parts between the two group members. Benjamin Mmari will be working on the Knowledge based expert system and Halatedzi Matidza will be working on the Web based User interface and Java-server pages (JSP).

10. References

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3. Lindsay R.K, Buchanan B.G, Feigenbaum E.A, Ledergerg J. DENDRAL: a case study of the first expert system for scientific hypothesis formation. Artificial Intelligence 61 1993; 209-261.

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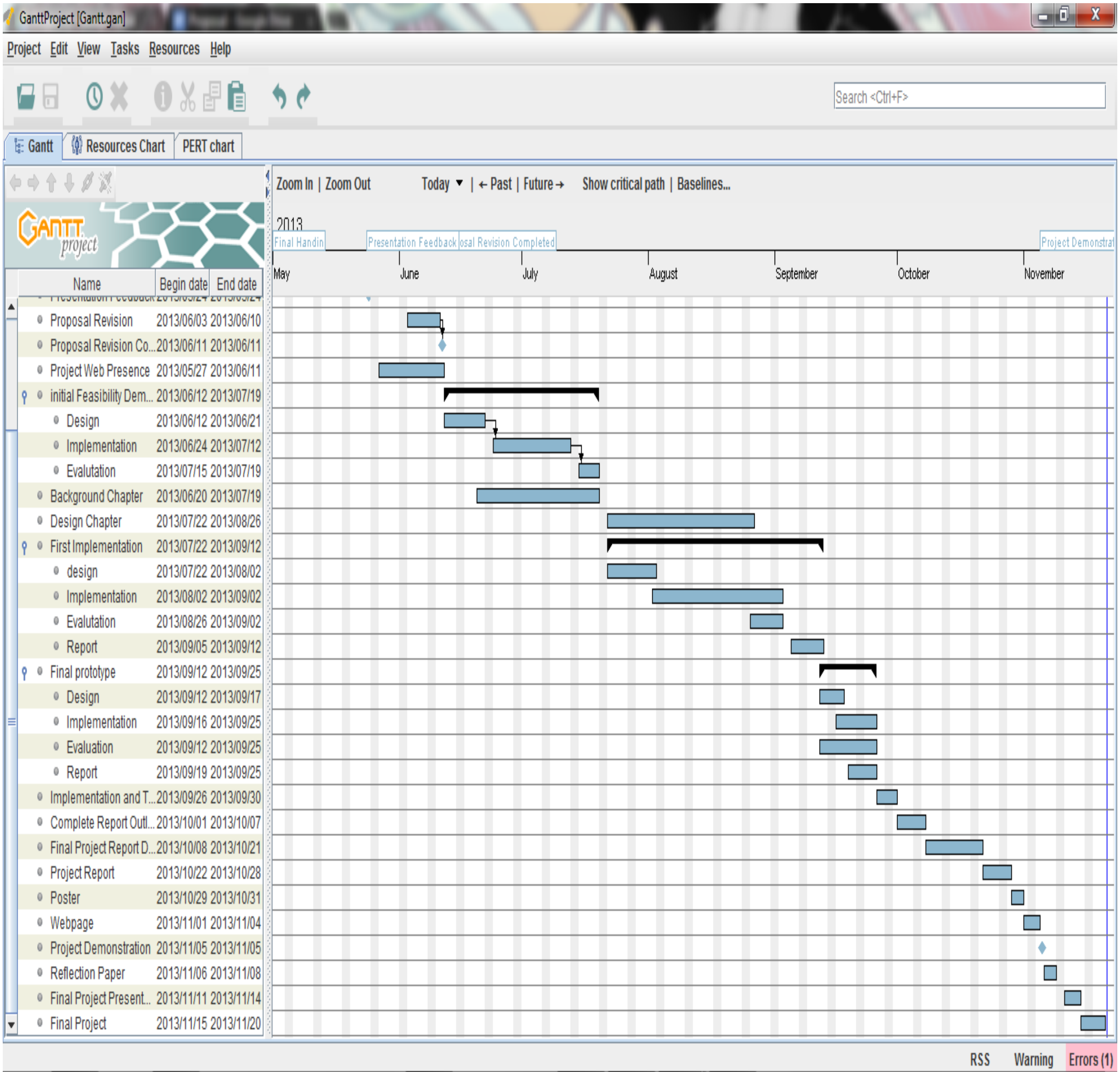
11. Appendix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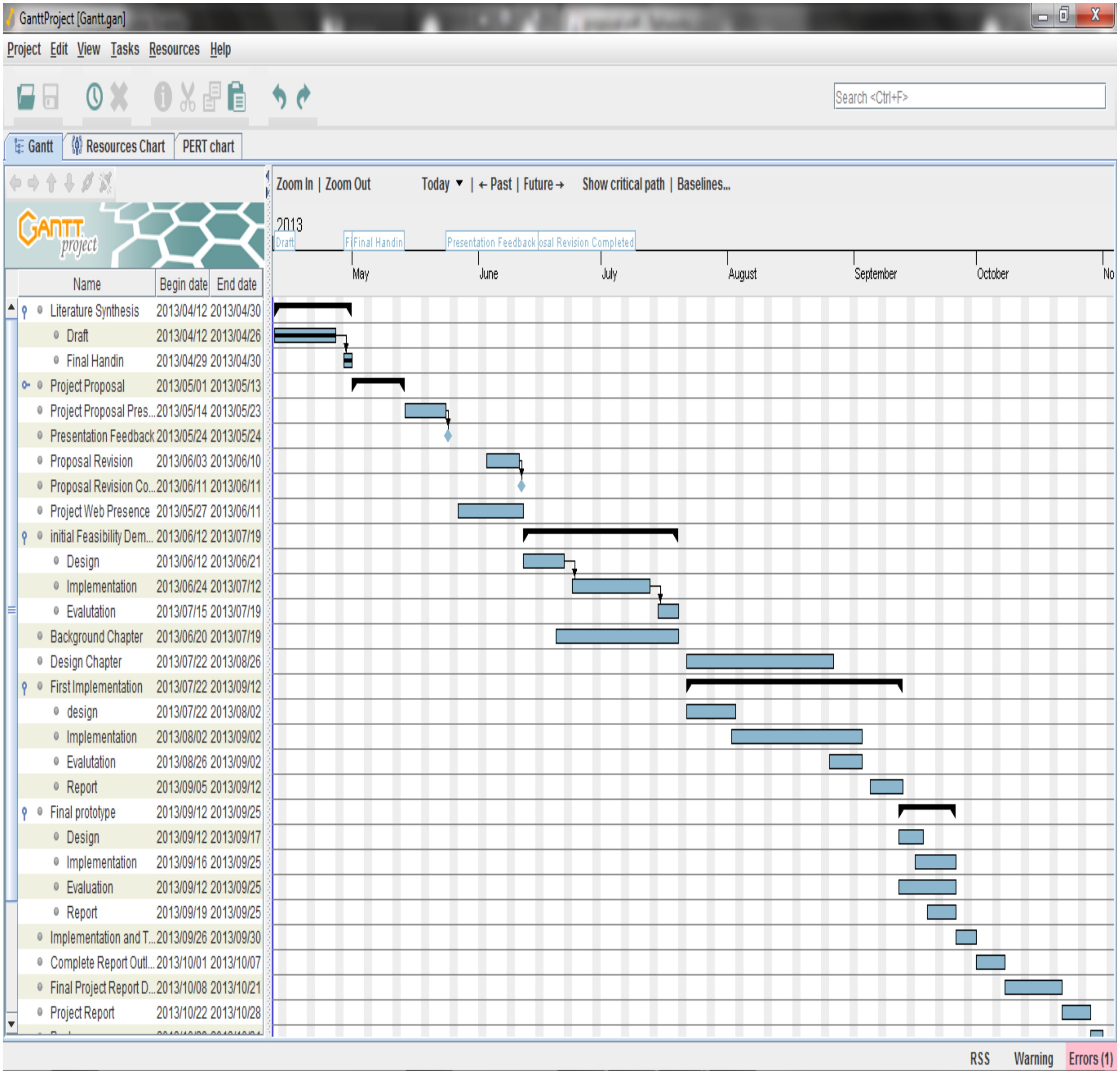
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