E-DOC Medical Decision Support System

By

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A project Submitted in partial fulfilment of the requirements
for the Degree of Master of Science in Computer Science

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Submitted in partial fulfilment of the requirements for
the degree of Master of Science in Computer Science
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ABSTRACT

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This project is about medical informatics, and in particular, the aspect of Artificial Intelligence in the field of medicine, in the area of medical decision-making and diagnosis.

The system designed and implemented is a cradle with two modules running within it, the Mortality Risk Calculator (MRC) and the Cardiac Risk Decision Aid (CRDA), with an integrated sub-module called Coma Scale Calculator (CSC).

E-Doc is a cradle since it was designed and built in a way to cradle more than one module, and has all the requirements to accept and run more modules than the MRC, CRDA and CSC that were implemented. The name E-Doc has two meanings, one to reflect that this is an electronic doctor and the other is to reflect the evolution of medical science.

MRC is a "diagnosis tool" based on multiple inputs, ranging from type of admission to the hospital, to systolic blood pressure, passing by age, history of chronic diseases and heart rate that assesses the severity of illness of ICU (Intensive Care Unit) patients and predicts their mortality risk.

CRDA is a "decision aid", taking as input values ranging from age to cardiac failure history, type of operation and nature of surgery, in order to calculate the risk of cardiac complications a patient might run post non-cardiac operation.

CSC is a "medical calculator", based on the Glasgow coma index. It is a neurological scale used to assess a patient's state of altered consciousness immediately after trauma. The value obtained from the CSC is used within the MRC.

E-Doc was tested using real data obtained from local healthcare institutions in order to demonstrate the usefulness and accuracy of its component modules.

Acknowledgments

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I would also like to thank all those who aided in the success of this project, by encouraging me to work harder and sometimes even by lending a helping hand.
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Without you all, I would have never reached this point, thus THANK YOU!

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Chapter 1

Introduction

Studies have proven that all human beings are doubtful by nature. In the field of Medicine, this doubt is what pushes all to get second opinions, third opinions and sometimes keep doubting the diagnosis of physicians and even their decisions. This doubt, and the fact that physicians and medical institutions always strive to achieve better and more accurate results, led scientists to launch a quest, a quest for the creation of artificial intelligence based medical systems. Kawamoto K., Houlihan C., Balas A., Lobach D. (2005)

The use of CDSS and MDSS is slowly spreading all over the world, mainly in large medical institutions (hospitals, clinics, etc…). Thus more and more software companies are investing their time and effort in the creation of such systems, improving their quality and the quality of the results obtained.

There are two main branches of medical decision systems. One is the branch that deals with decision systems designed to support patients. For example, systems that help menopausal women make educated decisions about hormonal therapy. These systems provide information and help the user assign utilities to each available alternative. These systems have been successful and well received by their users and their physicians. The other branch of decision system deals with physician decision-making. Many of these systems rely on large historical databases containing several hundred categories of pertinent information, a subset of which is used to support the decision making of the user. These systems have found great success among physicians, and also the public, since they get a second opinion, generated by a computerised system.

Most of these latter systems are based on carefully calculated and formulated algorithms and complex mathematical formulas derived from years of research and clinical application.

Intensive research, testing existing software and viewing the manual implementation of medical decision making drove me into creating a medical decision support system that combines three modules, each designed for a specific region of healthcare.

Almost all three modules concentrate on intensive care patients, since time is of essence in their cases, as a quick and accurate diagnosis can differentiate between life and death.

The main objective of this project is to create "medical calculators", "diagnosis tools" and "decision aids" to help physicians in the assessment and decision making process in a quick and accurate manner.

Chapter two will cover an overview of Medical decision support systems, the syntax and modelling methods used, as well as medical algorithms. It will also discuss the benefits of such systems, as well as the drawbacks and issues that have risen from their use. The chapter ends with a brief rundown of the platforms on which such systems are built.

The third chapter is the core of the paper, as it presents the system in all its aspects, from the specifications, to the design, passing by the expectations. It includes the use case and activity diagrams, as well as rundown of all the modules, functions and algorithms that run in the background. The chapter resumes with a display of the input forms, the output screen, generated reports and the help module.

Experimental work, testing methods and result analysis form the fourth chapter, demonstrating the functionality of the system.

Chapter five contains the conclusion, personal notes and suggestions.

Chapter 2

Background

This chapter presents the various modeling methods and strategies used to develop and implement Medical and Clinical decision support systems, the medical algorithms and formulas on which they are based, some aspects of the implementation of such systems as well as the preferred platforms, technologies and programming languages.

2.1 Medical Decision Support Systems

Clinical and Medical Decision Support Systems are active knowledge systems which use two or more items of patient data to generate case-specific advice. Andreassen S., Jensen F.V. and Olesen K.G. (1991).

A medical decision support system is any collection of computer programs assembled to assist health care professionals in making clinical judgments on diagnoses and treatment options. MDM (2005).

Generally they assist in ascertaining the nature of a patient's disease, in formulating the necessary information and scenarios required for a differential diagnosis, and treatment planning.

Decision support programs separate into three strategic groups:

1) Instrument and data monitoring programs that assist in patient management.

2) Risk management and critiquing systems that guide physicians about important practice options for patient diagnoses and care.

3) Expert consultative systems which incorporate artificial intelligence technology to assist physicians with both difficult and routine differential diagnoses based on patient and physician generated data.

The evolutionary lineage of medical computing systems can be traced to 1890 when Herman Hollerith developed a punched card data processing system for use in the U.S. Census that year. With the appearance of the minicomputer in the 1970s and the availability of microcomputers in the early 1980s, a variety of complex computerized medical information systems emerged. Hollerith H. (1980).

The human cost of medical errors is high. Based on the findings of one major study, medical errors kill some 44,000 people in U.S. hospitals each year. Another study puts the number much higher, at 98,000. Even using the lower estimate, more people die from medical mistakes each year than from highway accidents, breast cancer, or AIDS.

One of the best ways to reduce these numbers is by using electronic medical records and more importantly using Medical and Clinical Decision Support Systems. The expert system in effect generates an independent diagnostic recommendation and therapy management recommendation to which physicians can compare their own thoughts.

These systems will reduce the diagnosis and decision making time drastically and also provide a second opinion for the physician or surgeon based on accurate formulas and algorithms.

2.2 Modelling methods and syntax

Let us review some of the methods for specifying computer-interpretable guidelines and associated software tools for authoring and executing guideline applications used. We will try to cover the main features of each, with a quick overview.

Arden Syntax: A rule-based procedural specification for encoding medical knowledge in knowledge base form as individual Medical Logic Modules (MLMs). The first standard for representing medical knowledge initially developed in 1990, by a group at the Arden Homestead in Harriman, New York State. CDSTC (HL7).

GASTON: A Generic architecture for the design, development, validation and implementation of guideline-based medical decision support systems. Developed by the Eindhoven University of Technology, Maastricht University and Medecs BV. Guideline-based decision support systems have been implemented in the areas of critical care, family practice, psychiatry, oncology, cardiology and chronic disease management. Medecs BV (2003).

GLIF: Guideline specification method and interchange format. GLIF3 provides a task model for patient management and decision making, and executable action specifications. Developed by Intermed Collaboratory. Funding of the InterMed Collaboratory ended in December 2003. GLIF research and implementation work continues however through the HL7 Clinical Guidelines Special Interest. The integration of GLIF and the GLEE execution engine with the clinical information system at the Columbia-Presbyterian Hospital as an infrastructure for clinical decision support is being explored. GELLO, an object-oriented query and expression language for clinical decision support, largely derived from GLIF research, was incorporated as an HL7 standard in 2004. GLIF (2004).

PRODIGY: It is a computerised clinical decision support system for general practice in the UK. The PRODIGY version 3 guideline model, 1998, uses a task-based formalism to represent the management of chronic diseases, particularly asthma and hypertension. Built on the EON model and earlier versions of PRODIGY. Developed by SCHIN: the Sowerby Centre for Health Informatics at Newcastle (at the time, a Newcastle University academic research centre; now a private company) research was incorporated as an HL7 standard in 2004. SCHIN (2005).

PROforma: Formal knowledge representation language for authoring, publishing and executing clinical guidelines. Developed by the Advanced Computation Laboratory, Cancer Research UK. PROforma technology for authoring and publishing executable clinical guidelines has been commercialised (under the Arezzo brand name) by InferMed Ltd. in London. Java-based authoring and execution tools (Tallis) have been developed at

Cancer Research UK and are available for research use. PROforma has been used to develop a wide range of prototype and routinely used clinical applications in domains including HIV, Cancer care and postoperative pain management. ACL UK (2005).

2.3 Medical algorithms

A medical algorithm is any computation, formula, survey, or look-up table, useful in healthcare. Medical algorithms include decision-tree approaches to healthcare treatment (i.e., if symptoms A, B, and C are evident, then use treatment X) and also less clear-cut tools aimed at reducing or defining uncertainty. An example would be an algorithm used to determine what next investigation or management to apply to a possible DVT. MDM (2004).

The intended purpose of medical algorithms is to improve and standardize decisions made in the delivery of medical care. Medical algorithms assist in standardizing selection and application of treatment regimens, with algorithm automation intended to reduce potential introduction of errors.

Computerized algorithms can provide timely clinical decision support, improve adherence to evidence-based guidelines, and be a resource for education and research. Medical algorithms based on best practice can assist everyone involved in delivery of standardized treatment via a wide range of clinical care providers.

Medical algorithms vary in complexity. The most commonly used are the area specific algorithms that concentrate on a specific disease or area of diagnosis, in order to provide a faster, easier to use and extremely accurate result, suiting the needs of the physician or surgeon.

Most of these algorithms are based on mathematical formulas, combining logarithmical and complex algebraic expressions, sometimes using multiple iterations to cover all possibilities.

2.4 MDSS benefits, drawbacks and issues

Clinical information systems, like decision support systems, are in many ways analogous to any other kind of clinical intervention. As with any medical treatment, such as the use of drugs, it is generally accepted that medical technologists must demonstrate efficacy, and the standard method is to use rigorous and objective clinical trials of applications.

The potential benefits of using electronic decision support systems in clinical and medical practice fall into a few categories:

- Improved patient safety e.g. through reduced medication errors and adverse events and improved medication and test ordering;
- Improved quality of care e.g. by increasing clinicians' available time for direct patient care, increased application of clinical pathways and guidelines, facilitating the use of up-to-date clinical evidence, improved clinical documentation and patient satisfaction;
- Improved efficiency in health care delivery e.g. by reducing costs through faster order processing, reductions in test duplication, decreased adverse events, and changed patterns of drug prescribing favouring cheaper but equally effective generic brands. Purcell G.P. (2005).

Looking at the long term and future benefits, considering the advances which are being made in the field, we could add to the above list:

- Cost-effective after initial capital costs and update and maintenance costs.
- Immediate feedback provided to patients.
- Maintain and improve consistency of care.

Decision aids, interactive guidelines and workflow management systems will depend for their efficacy on the quality of their design and implementation - covering both the quality of the knowledge content and the integrity of the software that delivers it.

Decision support systems that produce diagnoses and recommended therapy management are typically based on set formulas, straight forward algorithms and probabilities and as a result, neglect or minimize clinical goals that incorporate the patient's values and expectations. These are uniquely human qualities, the likes of which are not well understood, in any sense of the term, and are impossible to incorporate into artificial intelligence programs. Furthermore, there is no evidence that these techniques will ever evolve to approach the human mind's ability to deal with emotional, social, or ethical and legal issues that are often key determinants of proper medical decisions.

Another aspect that we have to consider is the over-reliance on software by the physicians, limiting their learning process and rendering them into mere computer operators, rather than using the system for a second opinion or decision aiding device, as it is intended to be.

We have reached the stage when medical treatment and procedures can be performed more efficiently and accurately by computers than by humans; thus offering increased patient safety. In these cases, no use could constitute negligence on behalf of the physician and/or hospital if the technologies are available. On the other hand, if physicians rely on the system when clinical signs are contra indicated this too may well constitute negligence, especially if the patient's condition is such that relying on the computerized output cannot be deemed reasonable by other physicians.

In summary, ethical and legal issues will dramatically influence the future role of medical information systems, in particular medical decision support systems. Thus, physicians and hospitals should not completely rely on these systems in their diagnosis or decision making, rather use them as a first or second opinion sources and combine them with the experienced human factor's decisions and diagnosis to reach a final result. The better of two worlds combined would satisfy the accuracy, experience, ethical and moral aspects and result in a better healthcare outcome, safer and better both for the provider and the patient.

2.5 Platforms for Medical Decision Support Systems

Medical information systems fall into three general categories which function independently but are closely interrelated:

a. Data management including input and output.

b. Communications.

c. Clinical/medical decision support.

As the data concerned is growing on a day by day basis, with the advancement of medicine, and the additions of new restrictions and requirements by the healthcare industry, reliable and large scale databases are becoming more and more in use for the data management section of medical information systems.

Communications being a key asset, especially when trying to formulate a high quality medical information system, a "self-educating" system, more and more systems are being based on the web. Thus, a web based system allows faster and easier access from almost anywhere is it for data retrieval or for the addition of expert opinion and diagnostics.

As for the decision support part of these systems, an object oriented approach is most commonly adapted. The modelling methods and syntax discussed earlier are used in conjunction with hypertext using the WWW, for more accessible and widespread systems. Nowadays, with the evolution and growing popularity of portable hand held devices, many MDSS developers are opting for systems that run on servers and which are accessible via hand held devices, insuring full mobility to the physicians and surgeons.

Some systems are even available on the net and open to the public, but those are simple, patient oriented systems, mainly giving a quick diagnosis based on one page questionnaire forms covering the symptoms for a specific illness or pain pattern.

In summary, we can say that most of the available decision support systems are windows based, some even Linux based, but the current trend is web based and portable hand held device based (Palm OS, Windows CE, etc.).

Chapter 3

The System

The system at hand is a web based MDSS split into two main modules and a sub-module, best described as "medical calculators", "diagnosis tools" and "decision aids". We will be dissecting these modules in order to understand their specifications, functionality, mode of use and benefits.

3.1 System Overview

E-Doc is a web based clinical / medical tool that contains two modules designed to provide accurate diagnosis and aid in the decisions made by physicians and surgeons.

The two main modules of the system are:

- MRC: Mortality Risk Calculator
- CRDA: Cardiac Risk Decision Aid

MRC is a "diagnosis tool" containing the sub-module called CSC, Coma Score Calculator. MRC is formulated by combining clinical findings and disease classification, and has been adapted to cater for prediction of mortality. This "medical calculator" is based on multiple input, ranging from type of admission to the hospital, to systolic blood pressure, passing by age, history of chronic diseases and heart rate, in order to assess the severity of illness of ICU (Intensive Care Unit) patients and predict their mortality risk. Lobo et al (2000).

CRDA on the other hand is a "decision aid", taking as input values ranging from age to cardiac failure history, type of operation and nature of surgery, in order to aid the surgeon in calculating the risk of cardiac complications the patient will run post non-cardiac operation. Deveraux P.J., Ghali W.A. et al (1999).

3.2 Mortality Risk Calculator

3.2.1 System Design

MRC has been developed and validated using logistic regression analysis. It must be calculated from the worst value of the physiologic variables recorded during the first 24 hours of admission to ICU.

The design of the system was done in a way as to be:

- User friendly
- Fast and reliable
- Accept input in multiple formats

User friendliness is insured by having a clear display, with the screen split into two parts, a part where the input is done and another where the already inputted data is displayed. (Ref. to Figure 1)

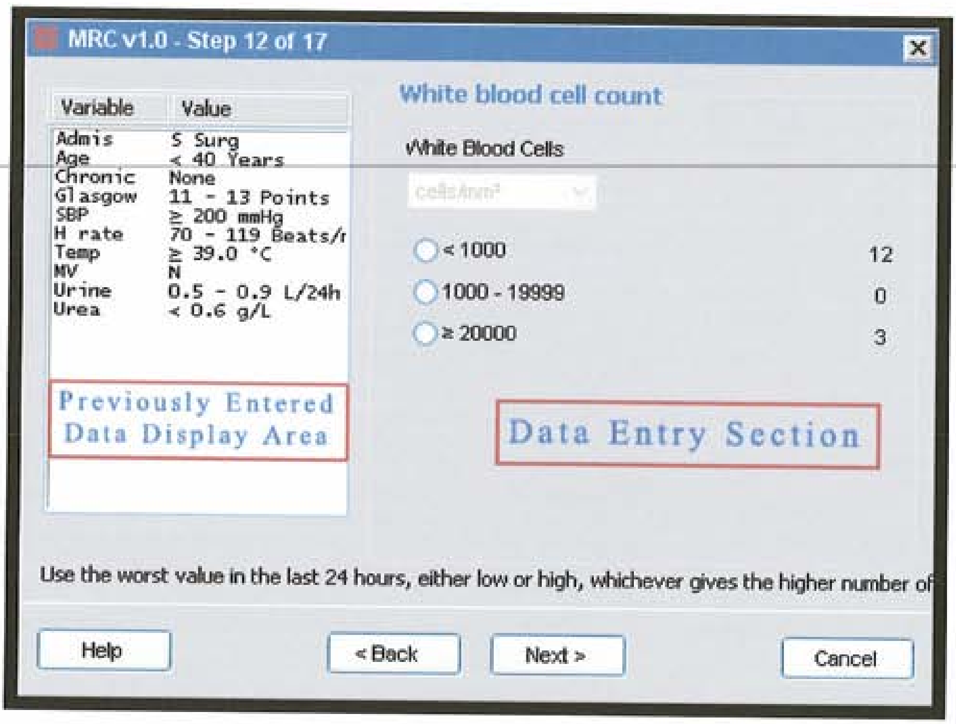

Figure 1: MRC data entry and display

As for the speed and reliability of the system, it is ensured by the use of JavaScript functions that handle each and every single action, and by the use of accurate mathematical formulas and medical algorithms.

The system accepts input in multiple formats, taking into consideration the various systems that hospitals and physicians may use, such as Fahrenheit and Celsius for temperature readings, as well as multiple measuring modes for serum levels and other measurements. The system also includes a brief description message which is displayed on every input page, specifying what is the input required and the range or various measurement modes that can be used for that given input value. (Ref. to Figure 2)

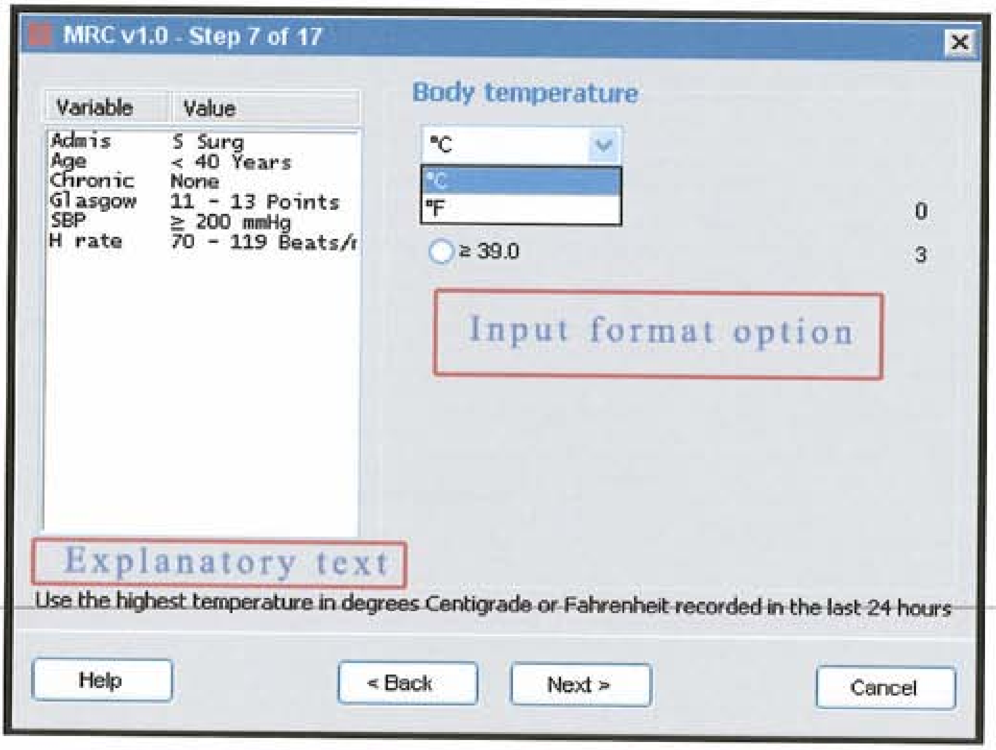

Figure 2: MRC input window

The system also shows the user where he is within the system, using a step counter displayed at the top of the module, right next to the title. Thus the user will know how many steps he has covered and how many are still ahead, since sometimes some steps are omitted, due to the input given to a previous question or step.

3.2.2 Diagrams

In order to get a better idea of the functionality of the MRC, we will take a look at the Use Case diagram and the Activity diagram of this module.

The Use Case diagram describes what the system does from the standpoint of an external observer. The Actor in this system is the physician or surgeon or nurse using the system, and the Use Cases concerned are data input and report retrieval. (Ref. to Figure 3)

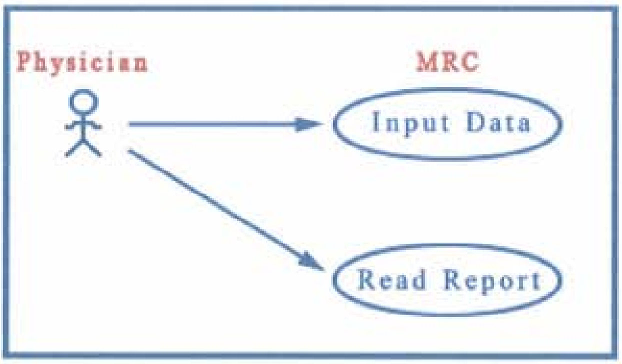

Figure 3: MRC use case diagram

The Use Case diagram proves the simplicity of the MRC, and shows that the communication between the actor (system user) and the system itself is rather straightforward and very user friendly.

In the Activity diagram, we will see the activities involved in the two main processes of the system, which are the data input and report retrieval.

For the data input, the user is asked to pass by a multitude of input steps, providing data required by the system in order to calculate the mortality risk factor. Every input passes by a validation module, if validated, it is given a certain weight coefficient, which will be later used in the algorithm and formulas that constitute the heart of MRC. (Ref. to Figure 4)

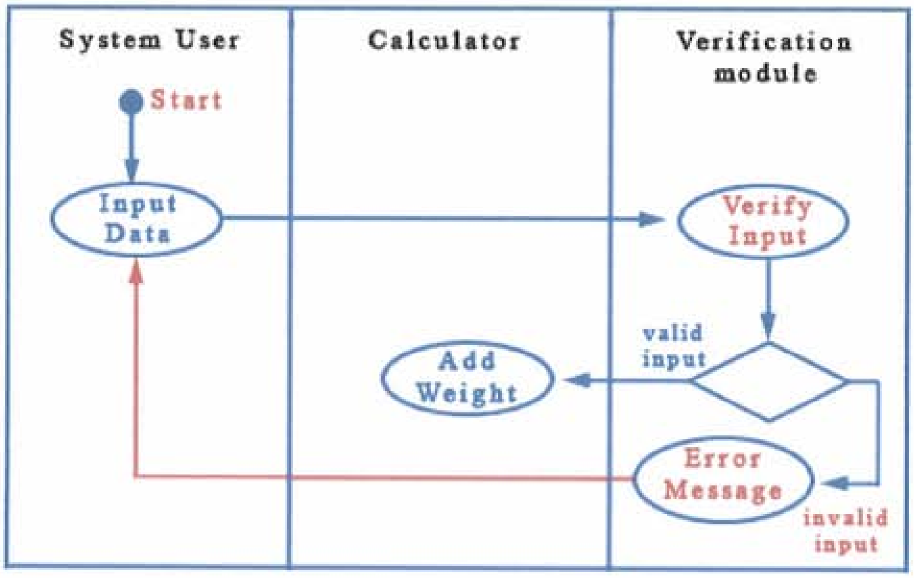

Figure 4: MRC activity diagram (input)

After the input phase is completed, the algorithms and formulas are implemented and a final result is displayed in the form of a score, which in turn is translated into a percentage representing the predicted death rate. (Ref. to Diagram 3)

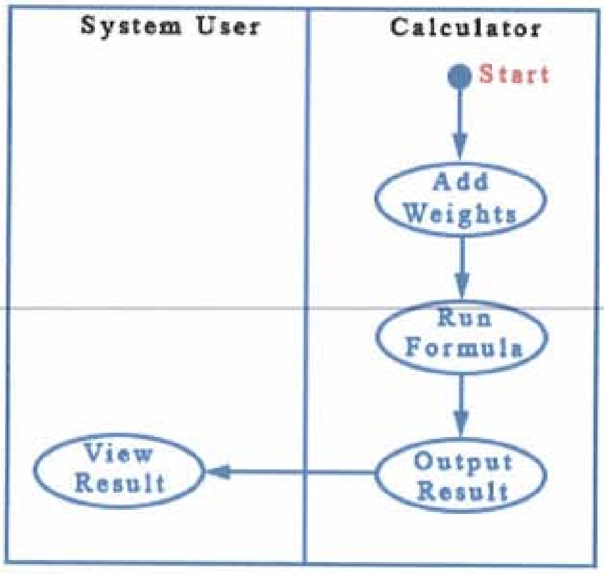

Figure 5: MRC activity diagram (output)

At the end of this process, a report can be generated by the system, if the user requests it, including data input, weight coefficients and the final result. The report will be discussed in detail in the Input and Output section of this chapter.

3.2.3 Input and Output

MRC is based on two main modules, one for data input and another for calculations and result output, as well as a sub module running in the back, which handles input validation.

As we have seen in section 3.2.1 of this report, the input module is structured in a manner as to split the screen into two, one part for input and the other for the display of previously inputted data.

A closer look at the input module lets us realise that there are values or weights listed on the side of every input module. These are the weights given by the system to each entry and that will be plugged into the algorithms and formulas at the final phase, in order to calculate the mortality risk. (Ref. to Figure 6)

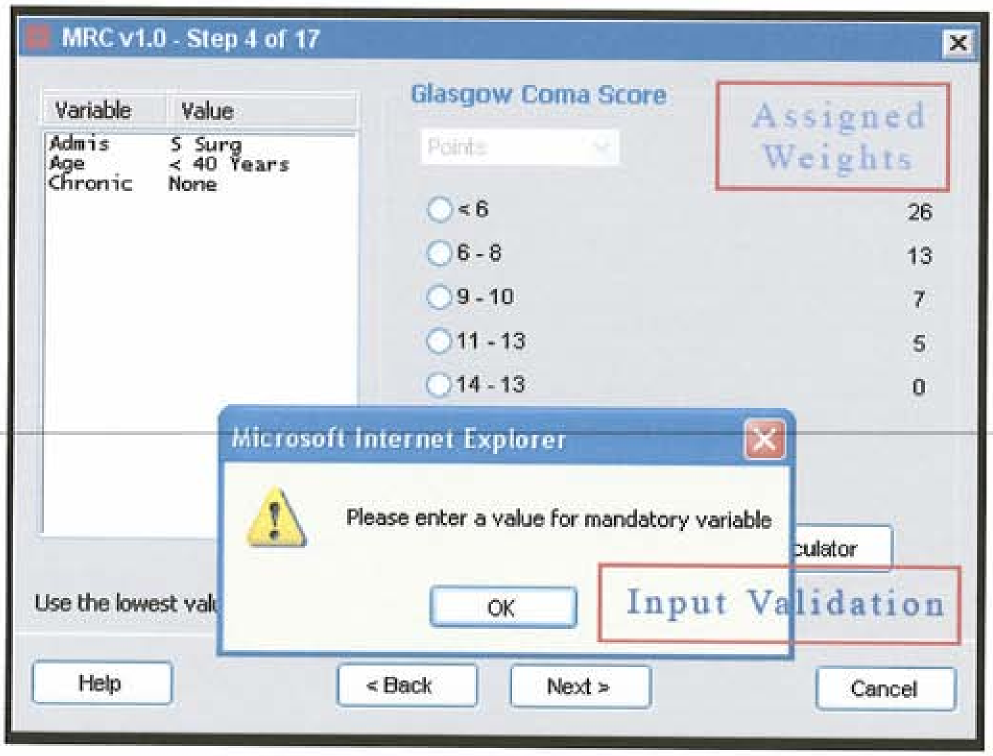

Figure 6: MRC input validation

After all the data is inserted into the system, the MRC will run it's algorithms and formulas in order to calculate the mortality risk and then display the result in two formats. (Ref. to Figure 7)

These two formats are the direct result of the algorithms and a percentage calculated accordingly, to make the result clearer and simpler to the user.

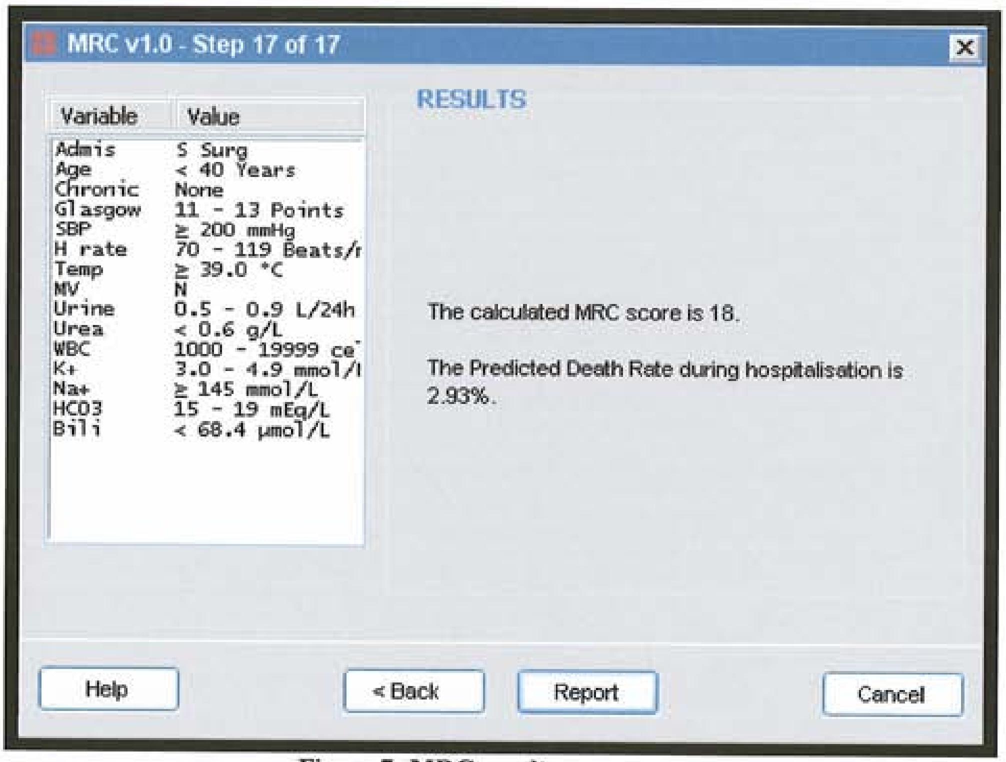

Figure 7: MRC result page

The user is also given the option to retrieve a report, which includes all the details, from the input data, assigned weights, date and time, to the final result and percentage, as well as a brief explanation. This gives physicians and surgeons a hard copy of the calculation to file in the patient. (Ref. to Figure 5)

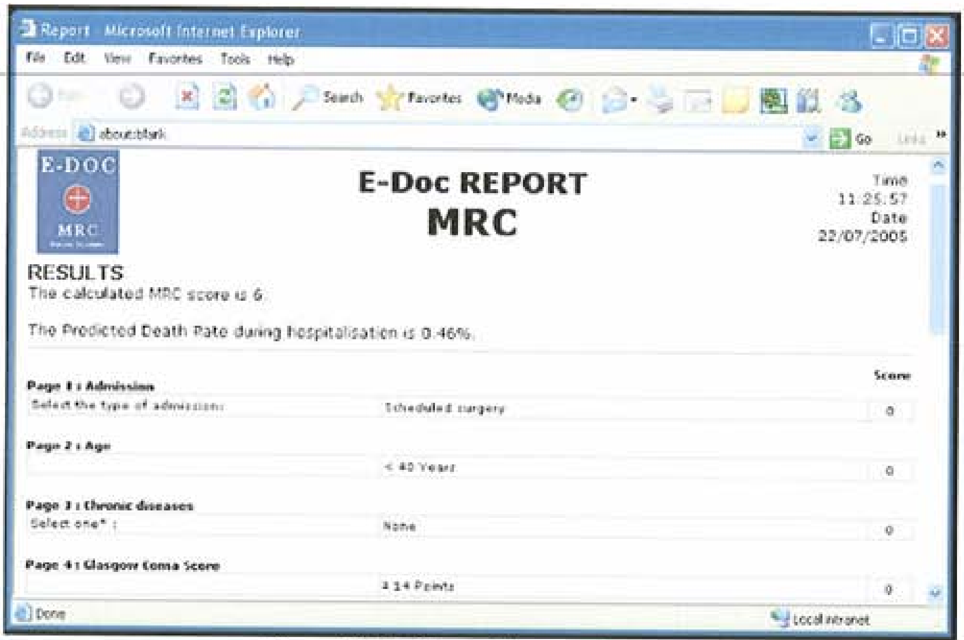

Figure 8: MRC results report

3.2.4 Functions and algorithms

The MRC module is totally dynamic. The various input pages, display area, output screen, help module, report and input validation are all generated by Java and JavaScript functions.

We will view a few of these functions, discuss their role within the system as well as review the source code.

The system is split into a variety of functions, which are grouped into a few sections, to make it easier for anyone to go through the source code and find the function or module he wants to edit.

Thus, we have the XSL functions, the control functions, the road map functions, the page control functions and last but not least, the formulas and algorithms and the calculation functions.

```
function printElem(position)

This function generates elements for use in forms

Get elements
Get positions

Switch for elements by type

-       case Radio:
o       get label
o       get text values
o       get numerical values
o       get short description
o       set text
o       set values
o       set description
o       format source code
return source code

          (same procedure for all element types)
```

Figure 9: Element printing function

This is a section of a function called “printElem”, part of the XSL functions; it generates the various elements displayed in the input forms, from radio buttons (code displayed), to checkboxes, ranges, list boxes, tree views and combo boxes. The function generates the source code required to display the given element. (Ref. to Figure 9)

This system of coding minimizes the amount of source code available on the main page of the module, and makes the system much faster, especially for use over the Internet.

Whenever an element is required, all the system has to do is call the script and provide it with the required variables. The XSL functions, combined with the page control functions are in charge of the display and visible part of the system.

The road map functions, formulas, algorithms and calculation functions are the heart of the system; they constitute the core of the AI, and include input validation functions, simple calculation functions and complex mathematical functions (exponential, floor precision, decimal precision, etc…). (Ref. to Figure 10)

```
function FloorPrecision(value,numDecPrec,precision)

This is the function called whenever we want to set the precision of
the floor and ceiling of a calculated value.


Set aux = value * numDecPow

If aux >= [floor(aux) + ceil(aux)/2]
-       aux = ceil(aux)
else
-       aux = floor(aux)

aux = aux / numDecPow

if precision > 0 (elminating overflow)
        remove precision from aux
        round aux

        if precision != -2 (completing decimals)
                complete decimal value of aux


        return aux.
```

Figure 10: Floor precision function

The list of functions is long and varied, but we will be satisfied by just displaying two of them, as our main focus is on the formulas and algorithms that constitute the core of the system.

MRC = Type of admission points + Chronic diseases points + Glasgow points + Age points + Systemic Blood Pressure points + Heart rate points + Temperature points + PaO2/FiO2 ratio points + Urine Output points +
Serum Urea or BUN points + WBC points + Potassium points + Sodium points + Bicarbonate points+ Bilirrubin points.

The above is a general image of the calculation of the primary value, called MRC, by adding up the weights given to each and every input field.

The MRC value is then plugged into the below stated formulas in order to output the MRC score, and thus the Predicted death rate.

LogIt = -7.7631+0.0737 * (MRC) +0.9971* ln ((MRC) +1)
Predicted Death Rate =e^ (LogIt) / (1+e^ (LogIt))

These formulas were calculated using complex medical algorithms and are the results of years of study and research. Each and every element of input is an indicator, and according to the importance of the indicator, the assigned weight varies. All the weights put together constitute a general value, called MRC, which is then submitted to the "LogIt" formula and later on passed through an exponential function to output the final result, the predicted death rate.

3.3 Cardiac Risk Decision Aid

3.3.1 System Design

Cardiovascular complications are important causes of morbidity following major non-cardiac surgery. The Cardiac Risk Decision Aid allows preoperative prediction of an individual patient's risk of such complications, using a combination of the Goldman and Detsky cardiac risk indexing system. The result can be used to help choose appropriate preoperative investigations and to indicate the need for particular efforts to prevent complications, such as invasive monitoring and intensive care. Goldman M., Caldera D., et al (1988).

The design of the system was done in the same way as MRC, with the difference that CRDA is intended to a more professional level of users, i.e. surgeons.

User friendliness is still present as a main feature, with the split window system, input and display of inputted data, so is the presence of multiple input formats to allow use of various measuring systems. (Ref. to Figure 11)

Speed and reliability of the system are ensured by the use of JavaScript functions that handle each and every single action, and by the use of two different and complimentary calculation modules, both based on precise medical algorithms that function via mathematical functions and formulas.

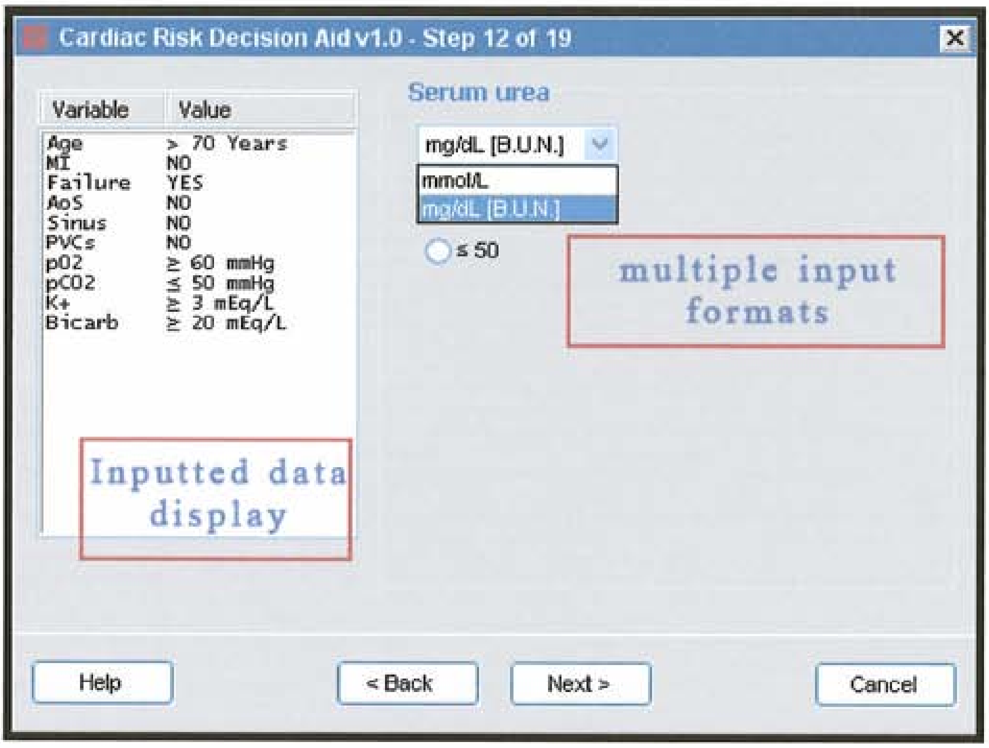

Figure 11: CRDA input screen

Like MRC , CRDA also includes a brief description message which is displayed on every input page, specifying what is the input required and the range or various measurement modes that can be used for that given input value. Sometimes a more detailed explanation is required to ensure that the data being entered is exactly what the algorithms require. In this case, the user is told to refer to the Help module by clicking on the button located at the bottom left corner of the module. (Ref. to Figure 12)

In the CRDA, a small step counter is available to show the user how many steps he has covered and how many are yet to come, since some of the input values generate more than one result, and at other times an input value might trigger the skipping of one or more steps. Thus the user can track his progress within the system, and know which input values are closely interlinked and trigger each other's existence. (Ref. to Figure 13)

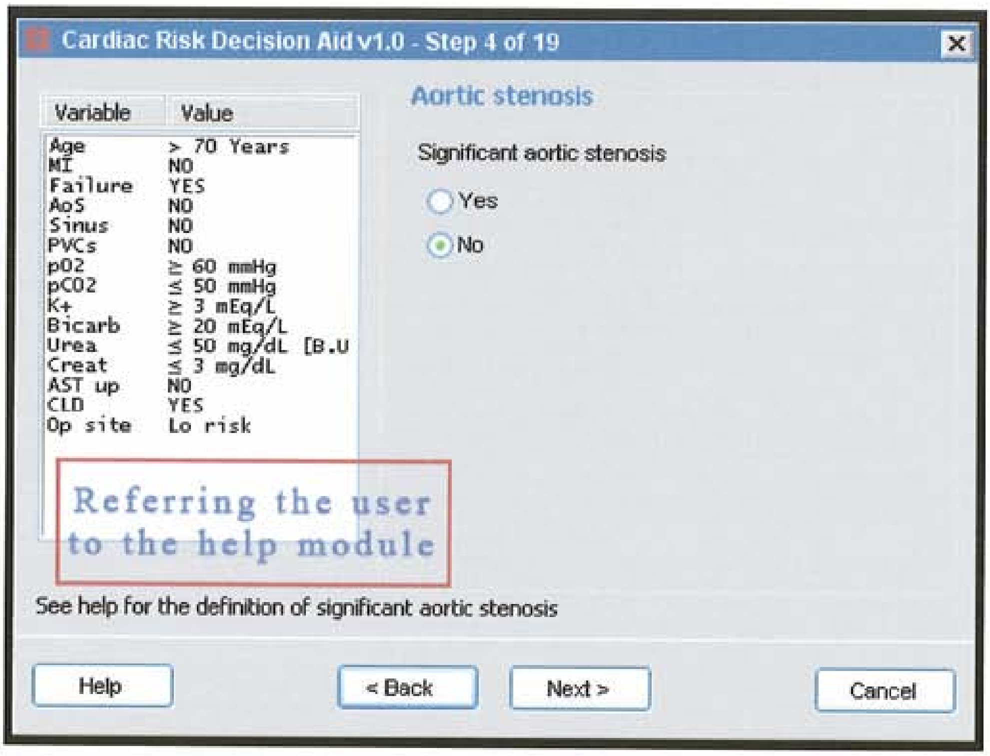

Figure 12: CRDA help referral

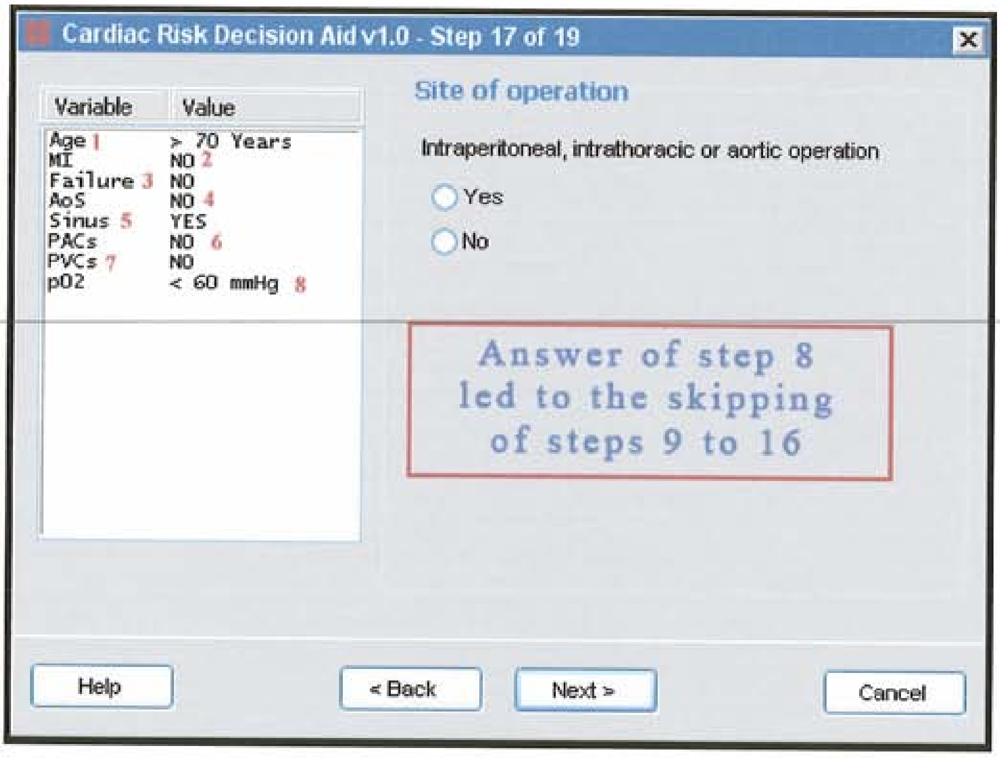

Figure 13: CRDA step skipping

3.3.2 Diagrams

In order to get a better idea of the functionality of the CRDA module, we will take a look at the Use Case and the Activity diagrams.

The Use Case diagram describes what the system does from the standpoint of an external observer. The Actor in this system is the physician or surgeon or nurse using the system, and the Use Cases concerned are data input and report retrieval. (Ref. to Figure 14)

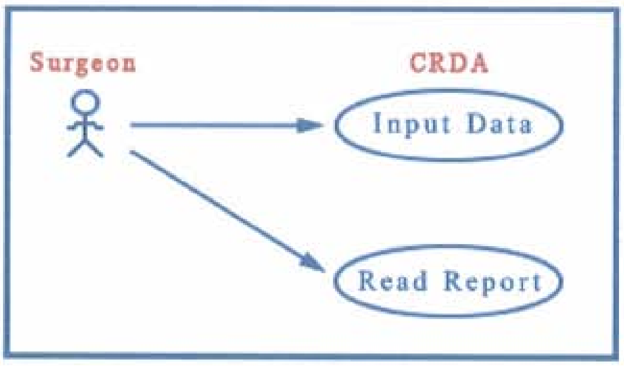

Figure 14: CRDA use case diagram

The Use Case diagram proves the simplicity of the CRDA, and shows that the communication between the actor (surgeon) and the system itself is rather straight forward and very user friendly. The only two main actions are data input and report reading (or retrieval).

An activity diagram focuses on the flow of activities involved in a single process and shows how those activities depend on one another.

In the first activity diagram for the CRDA system, we will focus on the process of data entry, i.e. input made by surgeon, including the input verification and weight assignment sub-processes involved within the main title of "data input". (Ref. to Figure 15)

The process itself is as such:

- the user is asked to input a given value, test result or answer a question
- input passes through verification module
- if valid, assigned weight is added to calculator module, and then:
  - choice 1: flow of data input continues
  - choice 2: steps are skipped and flow of input continues

This cycle continues until the last input page is reached. Then the algorithms and formulas step up as the so-called "calculator" module is called.

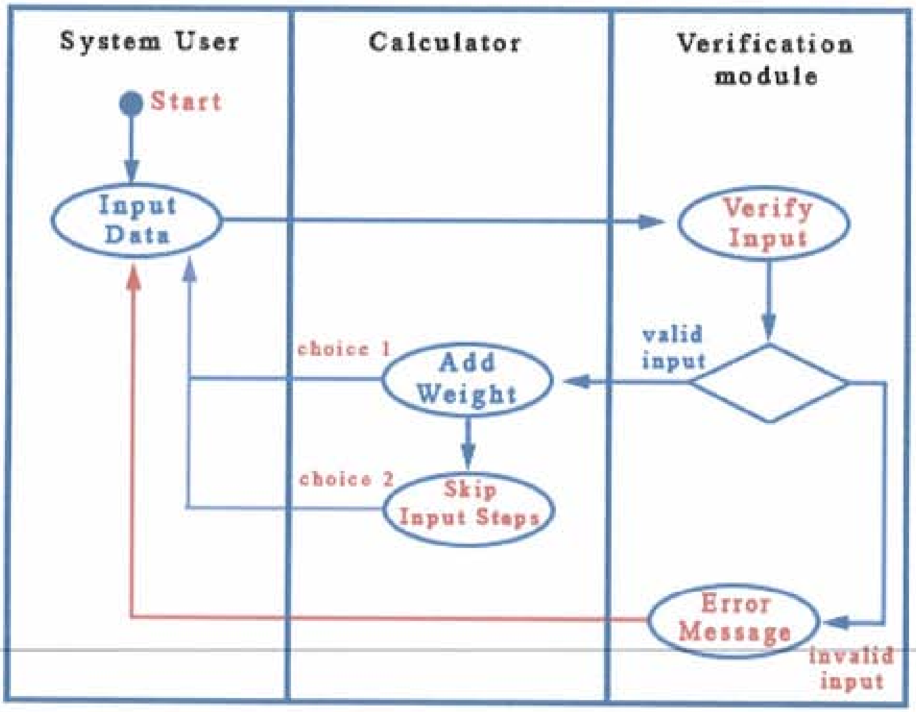

Figure 15: CRDA activity diagram (input)

The implementation of the formulas and algorithms generates a final result in the form of a Cardiac Risk Index (a score). The score, according to the Goldman and Detsky systems, places the patient in a risk class, indicating the severity of cardiac complication risk. (Ref. to Figure 16)

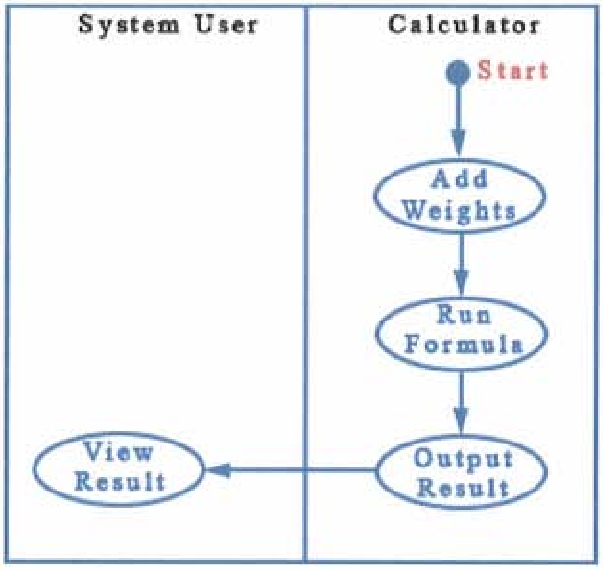

Figure 16: CRDA activity diagram (output)

When the above-mentioned process is completed, the surgeon can request a report to be generated by the system, in order to have a hard copy for quick reference and filing needs.

3.3.3 Input and Output

Previous sections have shown that the CRDA is split into two main modules, the input module and the output module. The input module in itself contains the validation module and weight assignment module, whereas the output module contains the calculation module as well as the report generation module.

The help module is somewhat of a standalone system, but is closely related to both the input and output modules, as it provides the user with explanations, details and precisions regarding the input fields, required data and output results and classes. It also provides a short descriptive explanation of the Goldman and Detsky indexes.

A closer look at the input module helps us better view the functionality of the validation module integrated into it and the display of the error message when an input is missing. (Ref. to Figure 17)

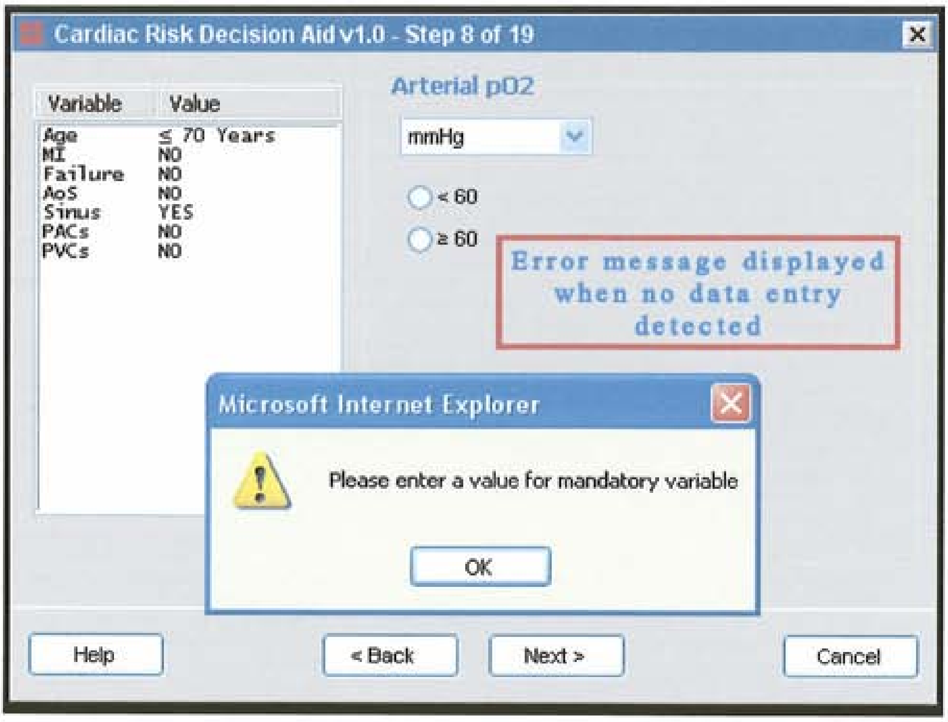

Figure 17: CRDA error message display

The CRDA calculation module is a bit different than that of the MRC, since it is based on two indexing systems, the Goldman and Detsky indexes, and outputs the final result as an index (Cardiac Risk Index) and then translates it into a class (Risk Class), rather than a percentage as in the MRC.

(Ref. to Figure 18)

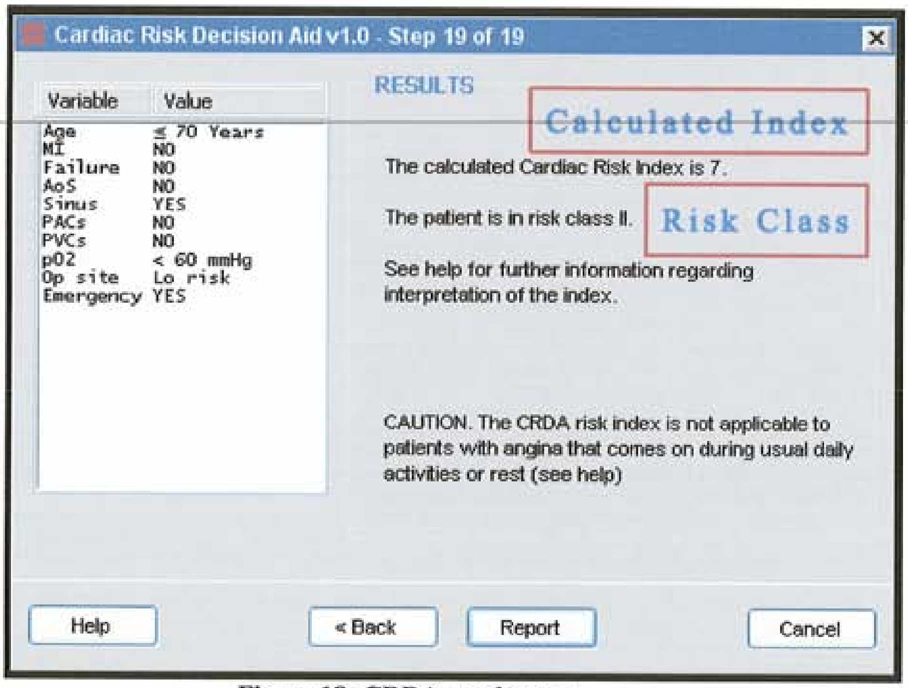

Figure 18: CRDA result page

The surgeon can now retrieve a report which includes all the details, from the input data, assigned weights, date and time, to the final result and class, as well as a brief explanation of what the index and the class are translate into. This could be used for filing purposes or simply to explain to the patient the result obtained, how was it reached and details about both Goldman and Detsky indexing systems. (Ref. to Figure 19)

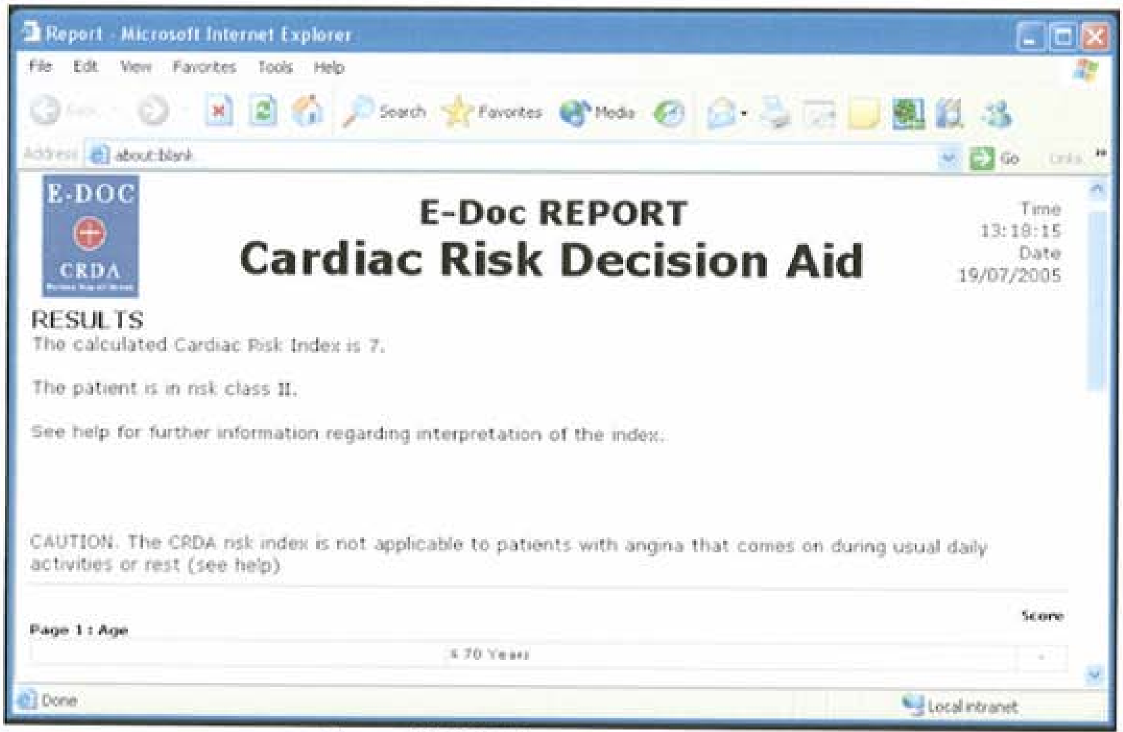

Figure 19: CRDA report

3.3.4 Functions and algorithms

Both the MRC and CRDA are totally dynamic. The various input pages, display area, output screen, help module, report and input validation are all generated by Java and JavaScript functions.

After reviewing a few functions in the previous sections of the report, we will go over another two in this section, in order to have covered the various sections of functions present in the E-Doc system.

The system is split into a variety of functions, which are grouped into a few sections, to make it easier for anyone to go through the source code and find the function or module he wants to edit.

One of the many functions within the system is the calcResult(pag) function. As we can see, it takes just one variable as input, which is the 'pag', i.e. the page of the system it was called from.

```
function calcRsult(pag)

This function is called when we reach the end of a page and it prints
the result, depending on its type.

Set name according to id and variable id
Set visible
Set typeR (type of result)


Switch for typeR

-       case Normal
o       check var length
o       get formula
o       run formula
o       round value
o       run complex mathematical functions
o       format expression
o       run expression

return result

-              case TxtData
o       non numerical value
o       set HTML code

return code
```

Figure 20: result calculation function

This small function is of major importance. It is called when we reach the end of a page and it prints the result, depending on the type of result. It is part of the page 'formulas' section of the list of functions. (Ref. to Figure 20)

This system of coding minimizes the amount of source code available on the main page of the module, and makes the system much faster, especially for use over the Internet.

Whenever an element is required, all the system has to do is call the script and provide it with the required variables. The XSL functions, combined with the page control functions are in charge of the display and visible part of the system.

Another of the key functions of the system is the evalForm(next) function. It takes as input the 'next' value, and is called upon everytime the next button is pressed within the system, asking it to take us to the next page. It evaluates the events that have taken place in the current page, and what has to be displayed in the coming page. The display window below shows just a section of the function, as the entire code of the function is long and split into parts, according to the page and what was displayed on it, the input forms and variables, the results that should be generated, etc… (Ref. to Figure 21)

The evalForm() function is one of the key functions of the system. It is the core function that moves us from page to page within every module, verifying the input given by the user and that sent by the system to the calculator module.

A closer look at this function's pseudo code will give us a better idea of its functionality and its value within the system itself.

The calculations involved in the CRDA are by far more complex than those in MRC, as the CRDA relies on two indexing methods, and many input fields require decoding and careful manipulation in order to output the final score. Lee Philip and Loo Grace (2001).

Calculating the CRDA is not as simple as calculating the MRC score. Many values, such as Sinus Rhythm and Premature Arterial Contractions are taken into consideration together in order to output one value to be added to the final calculations. Points are assigned to nine clinical variables and summed to give the final Index. (Ref. to Table 1)

```
function evalForm(next)

This is the function called whenever the next button is pressed on a
page.

It evaluates the actual form, verifying if the user has completely
filled it.

Check nature of the browser:
-       if Internet Explorer ('ie'),  then eval(doc) form
-       Else eval(doc) layer + form

Set values for nodes:
-       length
-       variable
-       type
-       description
-       variable ID
-       value
-       mandatory (flag)

Switch for types of nodes:
-       Radio
-       Checkbox
-       Ranges
-       Combobox
-       Listbox
-       Treeview

For every type:
-       Check if selected is open and inserted into list
If not:
o       set Value
o       set Text
o       call insList(variable ID, variable Name, Text, Value)
o       return 1

If form not complete:
- call AlertNotComplete:
o       display alert message
o       stop system progress
```

Figure 21: form evaluation function

Parameter	Points
History	
Myocardial infarction within six months	10
Age over 70	5
Physical examination	
S3 or raised central venous pressure	11
Significant aortic stenosis	3
Electrocardiogram	

	Rhythm other than sinus or sinus plus arterial premature beats on last preoperative electrocardiogram	7
	More than five premature ventricular beats/min at any time preoperatively	7
Poor general medical status *		3
Intraperitoneal, intrathoracic or aortic surgery		3
Emergency operation		4
	Total	**53**

Table 1: CRDA index parameters and assigned points

*Any of the following: $pO2 < 8$ kPa; $pCO2 > 6.6$ kPa; $K+ < 3.0$ mmol/L; $HCO3 < 20$ mmol/L;

The index can be used to separate patients into four classes from low (class I) to high risk (class IV). (Ref. to Table 2)

Index	Class
0 - 5	I
6 - 12	II
13 - 25	III
>= 26	IV

Table 2: CRDA indexes and equivalent classes

3.4 Coma Scale Calculator

The Glasgow Coma Scale (also known as Glasgow Coma Score or simply GCS) is a neurological scale used to assess head trauma and, importantly, to help keep track of patients' progress over a period of time. The scale is comprised of three tests: eye, verbal and motor responses. The three values separately as well as their sum are considered.

Emergency personnel use this test to evaluate a patient's state of altered consciousness immediately after trauma. The states measured range from normal to mild confusion to deep coma. Scores range from 3 to 15. Patients with scores of 3 to 8 are considered to have suffered severe injury; patients with scores of 9-12 are considered to have suffered moderate injury; and patients with scores of 13-15 are considered to have suffered mild injuries. Teasdale G., Jennet B. (1974).

The scale is often used as a predictor of survival. Patients with scores in the severe range often do not survive whereas almost all patients with scores in the mild range will survive.

Elements of the scale are:

Best eye response: (E)

- No eye opening
- Eye opening to pain
- Eye opening to speech
- Eyes opening spontaneously

Best verbal response: (V)

- No verbal response
- Incomprehensible sounds
- Inappropriate words
- Confused
- Orientated

Best motor responses: (M)

- No motor response
- Extension in pain (decerebrate response)
- Flexion in pain (decorticate response)
- Withdraws from pain (pulls part of body away when pinched)
- Localizes pain (pulls examiner's hand away)
- Obeys commands

The GCS has limited applicability to children, especially below the age of 36 months (where the verbal performance of even a healthy child would be expected to be poor).

The MRC has a built in system called Coma Score Calculator, based on the Glasgow coma scale, and whose score is used in the process of assessing the mortality rate of an ICU patient within the MRC. (Ref. to Figure 22)

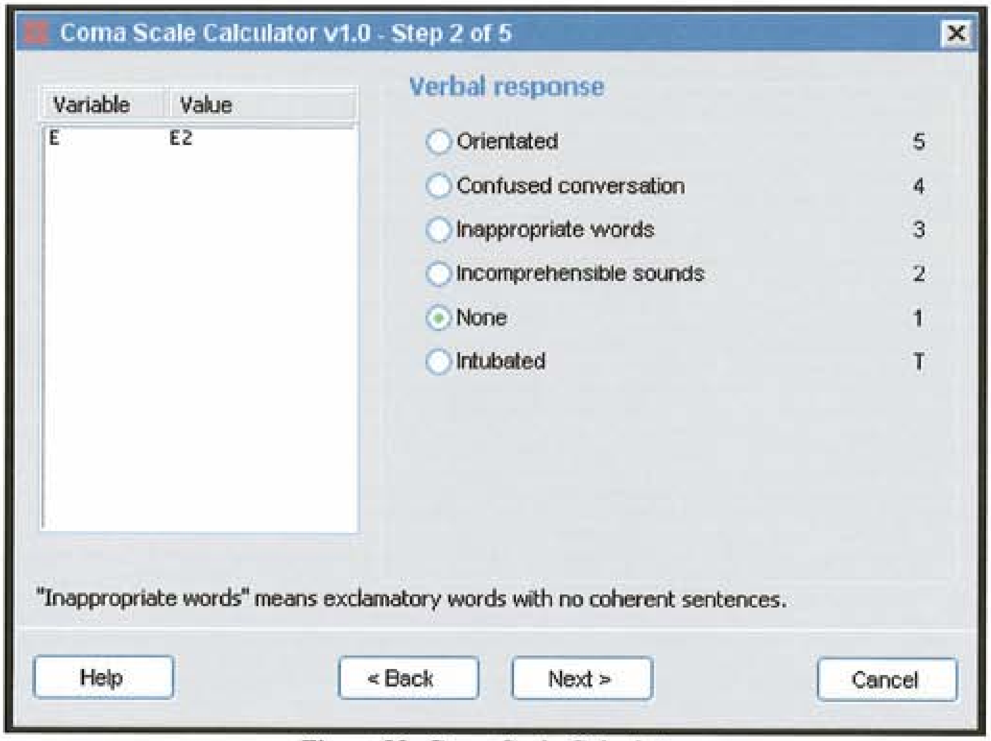

Figure 22: Coma Scale Calculator

As you see in figure 4, the scale elements are captured as input variables and named E, V and M and their values are represented accordingly as E, E2, E3….

Chapter 4

Experimental Work and Results

The three main steps in constructing a system are design, implementation and testing. After completing the first two phases, we move to the third and final, the 'moment of truth', to test and see the outcome of our work in the first two phases.

4.1 Experimental procedure and data description

Testing the E-Doc system is split into two main parts, each with precise steps:

- MRC testing
  - Tabulating data
  - Data input
  - Result retrieval (predicted death rate)
  - Comparison with actual results (over a 2 month period)

- CRDA testing
  - Tabulating data
  - Data input
  - Result retrieval
  - Comparison with surgeon's diagnostic pre-surgery
  - Comparison with post-surgery results (over 1 week period)

This testing method will provide us with enough insight on the functionality, accuracy and success rate of our system.

The data at hand was provided by two major healthcare facilities in the area, with patient confidentiality being insured by keeping the data anonymous.

Now that we know what the experimental procedure will be, we should get better acquainted with the data, how it was calculated, and what is the role of each input field in the final result.

We will start with the MRC module and the built in GCS mini module, and then move on to the CRDA.

MRC input fields

- **Type of admission:** an indicator of the type of admission to the hospital. This value shows if the patient was admitted for a Medical emergency, a Scheduled surgery or unscheduled (emergency) surgery.
- **Age:** the age of the patient. An important factor in all medical decision support systems and medical calculators. The older the patient is, the more risk prone he is.
- **Chronic diseases:** a selection of chronic diseases the patient is affected with. The available choices in this section are AIDS, Haematological malignancy, Metastatic cancer or none. If a patient is affected by more than one, the highest rated one will be selected. These chronic diseases increase the risk of fatality of the given patient.
- **GCS:** the Glasgow coma score. Ranges from below 6 to 13-14 are listed for the physician to choose from. The lowest recorded score in the 24 hours of testing will be chosen, since it weighs the most in the MRC.
- **Systolic Blood Pressure:** Blood pressure within the arteries when the heart muscle is contracting. Values are recorded by mmHg (millimetres of mercury), and range from below 70 to above 200.
- **Heart rate:** ranging from below 40 beats per minute to above 160. Again, the worst value recorded within the first 24 hours is entered.
- **Body temperature:** two choices are given, normal and less, or higher than normal, with the possibility of entering the values by degrees Centigrade or Fahrenheit.

- **Mechanical ventilation or CPAP:** mechanical ventilation is used when natural (spontaneous) breathing is absent (apnea) or insufficient. This may be the case in cases of intoxication, circulatory arrest, neurological disease, head trauma, paralysis of the breathing muscles due to spinal cord injury, or the effect of anesthetic or muscle relaxant drugs. CPAP (continuous positive airway pressure) is a method of respiratory ventilation used primarily in the treatment of sleep apnea and various lung diseases. The input in this case is a simple yes or no question.
- **PaO2 / FIO2 ratio:** this is the ratio of Oxygen pressure to the flow of Oxygen provided by the mechanical ventilator or CPAP. The range is from less than 100 mmHg to 200 mmHg or higher, and in this case, the lowest value of the ration is selected. This input is available if the answer to the previous was 'Yes'.
- **Urinary output:** the amount of urine collected from the patient within the first 24 hours of ICU stay, calculated in litres. The range is from 0.5 L to 1 L or higher.
- **Serum Urea / B.U.N:** Blood urea nitrogen (BUN) measures the amount of urea nitrogen, a waste product of protein metabolism, in the blood. Value of B.U.N. is given by mg/dL and the highest value within the 24-hour period is taken into consideration. Values range from less than 28 to 84 and higher.
- **White blood cell count:** The WBC count is used to suggest the presence of an infection or Leukaemia. It is also used to help monitor the body's response to various treatments and to monitor bone marrow function. Values range from less than a 1000 cells per cubic mm of blood to 20000 or higher.
- **Serum Potassium level:** Potassium is very important for normal heart and nervous system function. The serum potassium level is usually measured with several other blood factors to look for certain diseases. Values range from less than 3 mmol/L (millimoles per litre), to 5 mmol/L or higher.
- **Serum Sodium level:** Levels of serum sodium are used in risk assessment of patients hospitalized for heart failure. Ranging from less than 124 mmol/L to 145 mmol/L or higher, these levels constitute one of the major steps of the MRC.

- **Serum Bicarbonate level:** the amount of carbon dioxide (CO_2) in serum, since in the body, 95% of the CO_2 is present as HCO_3. The CO_2 levels in the blood are influenced by kidney and respiratory (lung) function. Represented by mEq/L (milliequivalents per litre), values range from less than 15 to 20 or higher.
- **Serum Bilirubin level:** Bilirubin is a breakdown product of haemoglobin. Total and direct bilirubin are usually measured to screen for or to monitor liver or gall bladder dysfunction. The highest recorded values are used, as to consider the worst case.

These are the input fields and required data by the MRC module. For more details concerning these items, the measuring modes and value representation modes, refer to the glossary at the end of the report, or follow the provided links in the references page.

CRDA input fields

- **Age:** the age of the patient. An important factor in all medical decision support systems and medical calculators. The older the patient is, the more risk prone he is.
- **Recent Myocardial infraction:** Infarction of the myocardium is accompanied by pain, increased enzyme values and EKG signs. If two of the three typical manifestations are seen it is assumed that an infarction has taken place. Dependent on the severity and duration of the oxygen shortage a more or less severe disturbance can happen in the electrical processes in the heart. We can distinct the following:
    - Ischemia
    - Lesion
    - Infarction

  The answer to this input section is a simple yes or no, taken over a period of six months.

- **Cardiac failure:** Elevated central venous pressure or third heart sound on auscultation. An elevated central venous pressure may be seen in right heart failure, constrictive pericarditis and obstruction of the superior vena cava. Third heart sound is caused by rapid ventricular filling in early diastole. Another simple yes or no answer question.
- **Aortic stenosis:** Aortic stenosis (AS), also called aortic valve stenosis, is a condition in which the aortic valve has become narrowed or constricted (stenotic) and does not open normally. Input is yet another yes or no question, asking if significant AS is present.
- **Sinus rhythm:** Sinus rhythm is indicative of normal electrical conductance of the heart. The electrical impulses from the SA node travel to the AV node with successful contraction of the two atria. The input question is if the patient is in sinus rhythm or if any arrhythmia, tachycardia, or bradycardia are reported on the last preoperative ECG.
- **Premature arterial contractions:** If the answer to the previous input question is yes, CRDA goes further as to check if there are premature atrial contractions on the last preoperative ECG.
- **Premature ventricular contractions:** checking if 5 PVCs/min documented at any time before operation. Another yes or no question.
- **Arterial pO2:** an indicator of the arterial Oxygen pressure by millimetres of mercury. Values are less than 60 mmHg or 60 mmHg and higher.
- **Arterial pCO2:** arterial Carbon Dioxide pressure. Combined with the pO2, they constitute a good indicator in the CRDA.
- **Serum Potassium:** The serum potassium level is usually measured with several other blood factors to look for certain diseases. Values range from less than 3 mmol/L (millimoles per litre), to 5 mmol/L or higher.
- **Serum Bicarbonate:** the amount of carbon dioxide (CO_2) in serum, since in the body, 95% of the CO_2 is present as HCO_3. The CO_2 levels in the blood are influenced by kidney and respiratory (lung) function. Represented by mEq/L (milliequivalents per litre), values range from less than 15 to 20 or higher.
- **Serum Urea:** Blood urea nitrogen (BUN) measures the amount of urea nitrogen, a waste product of protein metabolism, in the blood. Value of B.U.N. is given by mg/dL and range from less than 28 to 84 and higher.

- **Serum Creatinine:** Measuring serum creatinine is a useful and inexpensive method of evaluating renal dysfunction. Creatinine is freely filtered and therefore the serum creatinine level depends on the Glomerular Filtration Rate (GFR). Creatinine is a protein produced by muscle and released into the blood. The amount produced is relatively stable in a given person. The creatinine level in the serum is therefore determined by the rate it is being removed, which is roughly a measure of kidney function.
- **Aspartate transaminase:** An enzyme found in the liver, heart, and other tissues. A high level of aspartate transaminase released into the blood may be a sign of liver or heart damage, cancer, or other diseases. Also called serum glutamic-oxaloacetic transaminase or SGOT. System is asking if the level is raised or normal.
- **Chronic Liver Disease:** Chronic liver disease is marked by the gradual destruction of liver tissue over time. Several liver diseases fall under this category, including:
    - Cirrhosis of the liver
    - Fibrosis of the liver

  A simple yes and no question to verify the existence of signs of chronic liver disease.
- **Mobility:** asking if the patient is bed-ridden from non-cardiac causes.
- **Site of operation:** a question to determine if the operation is an intraperitoneal, intrathoracic or aortic operation, since these operations carry a higher risk.
- **Emergency surgery:** checking if the surgery to be performed is an emergency procedure or a pre-planned surgical procedure.

In order to view the importance of each and every one of these input fields or values, please refer to Table 1 in Chapter 3. There you can see how these fields are grouped, which affects which and what are the results that are derived from them.

Thus we have completed an overview of all the input fields and requirements for both the MRC and CRDA. We will now precede to the data section, where we will review the data received from the healthcare institutions, tabulate them and then run test and analyse the results.

4.2 Results

After carefully laying out the input fields and explaining each and every one of them, we move on with our testing process, as discussed in the previous section, and display the data in a tabulated format.

Data will be displayed by patient, in a table, with the results obtained from the system and a comparison with the real life results or surgeons' diagnosis, taken on a given period of time. (Refer to section 4.1 for more details)

We will start with the MRC, taking into consideration three patients. Then we will move to the CRDA and also consider three patients.

Input Field	Value	Measure	Weight
Type of admission	Medical	-	6
Age	40-59	years	7
Chronic Disease	None	-	0
Glasgow coma score	13	points	5
Systolic blood pressure	220	mmHg	2
Heart rate	128	beats/min	1
Body Temperature	38.8	°C	0
Mechanical Ventilation or CPAP	no	-	-
PaO2 / FIO2 ratio	-	-	-
Urinary Output	0.7	L/24h	4
Serum Urea / B.U.N.	13.6	mmol/L	6
White Blood Cell Count	860	Cells/mm³	12
Serum Potassium Level	2.6	mmol/L	3
Serum Sodium Level	96	mmol/L	5
Serum Bicarbonate Level	17	mEq/L	3
Serum Bilirubin Level	3.4	mg/dL	0
		The calculated MRC score	**54**
		Predicted Death Rate	**55.29%**

Table 3: MRC testing – Patient A

Patient A got an MRC score of 54, which translates into an almost 55.3% death rate prediction.

After an almost 6 day stay at ICU and another 12 day hospitalization, patient A went back home, and is still alive.

Input Field	Value	Measure	Weight
Type of admission	Unscheduled Surgery	-	8
Age	70-74	years	15
Chronic Disease	None	-	0
Glasgow coma score	7	points	13
Systolic blood pressure	76	mmHg	5
Heart rate	62	beats/min	2
Body Temperature	38.5	°C	0
Mechanical Ventilation or CPAP	no	-	-
PaO2 / FIO2 ratio	-	-	-
Urinary Output	0.4	L/24h	11
Serum Urea / B.U.N.	13.6	mmol/L	6
White Blood Cell Count	860	Cells/mm³	12
Serum Potassium Level	2.6	mmol/L	3
Serum Sodium Level	96	mmol/L	5
Serum Bicarbonate Level	17	mEq/L	3
Serum Bilirubin Level	4.8	mg/dL	4
		The calculated MRC score	**87**
		Predicted Death Rate	**95.74%**

Table 4: MRC testing – Patient B

Patient B got an MRC score of 87, which translates into an almost 95.74% death rate prediction.

Patient B was admitted to the EU and directly taken to the OR for unscheduled surgery. After being moved to the ICU, he passed away after almost 40 hours of hospitalisation.

Input Field	Value	Measure	Weight
Type of admission	Scheduled Surgery	-	0
Age	34	years	0
Chronic Disease	None	-	0
Glasgow coma score	15	points	0
Systolic blood pressure	105	mmHg	0
Heart rate	82	beats/min	0
Body Temperature	39.3	°C	3
Mechanical Ventilation or CPAP	no	-	-
PaO2 / FIO2 ratio	-	-	-
Urinary Output	0.8	L/24h	4

Serum Urea / B.U.N.	16.2	mmol/L	6
White Blood Cell Count	1600	Cells/mm³	0
Serum Potassium Level	5.2	mmol/L	3
Serum Sodium Level	160	mmol/L	1
Serum Bicarbonate Level	18	mEq/L	3
Serum Bilirubin Level	4.2	mg/dL	4
		The calculated MRC score	**24**
		Predicted Death Rate	**5.82%**

Table 5: MRC testing – Patient C

Patient B got an MRC score of 24, which translates into an almost 5.82% death rate prediction.

Patient B was admitted to the OR for a scheduled surgery, but had a few complications and was admitted to the ICU. After a brief 2-day stay, she was sent to the surgery ward for another 3 days and then checked out.
She is currently in perfect health after 2 weeks from her operation.

Input Field	Value	Measure
Age	40	**years**
Recent Myocardial Infraction	no	-
Cardiac Failure	no	-
Aortic Stenosis	no	-
Sinus Rhythm	no	-
Premature Arterial Contractions	no	-
Premature Ventricular Contractions	no	-
Arterial pO2	95	mmHg
Arterial pCO2	38	mmHg
Serum Potassium	3.9	mEq/L
Serum Bicarbonate	24	mEq/L
Serum Urea (B.U.N.)	30	mg/dL
Serum Creatinine	2.3	mg/dL
Aspartate Transaminase	no	-
Chronic Liver Disease	no	-
Mobility	no	-
Site of Operation	no	-
Emergency Surgery	no	-
	Cardiac Risk Index	**7**
	Risk Class	**Class II**

Table 6: CRDA testing – Patient A

Patient A is a 40 year old man scheduled to undergo knee surgery for a damaged ligament. The CRDA placed him at a Class II risk factor, giving him a 7% minor complication chance and a 2% cardiac death risk.

The surgeon in charge of patient A's operation gave us an almost 0% complication chance and 0% cardiac risk.

The operation was a complete success, with no complications at all. Patient A is now undergoing physical therapy after almost a month from the operation date.

Input Field	**Value**	**Measure**
Age	29	**years**
Recent Myocardial Infraction	no	-
Cardiac Failure	no	-
Aortic Stenosis	no	-
Sinus Rhythm	no	-
Premature Arterial Contractions	no	-
Premature Ventricular Contractions	no	-
Arterial pO2	100	mmHg
Arterial pCO2	39	mmHg
Serum Potassium	4.1	mEq/L
Serum Bicarbonate	22	mEq/L
Serum Urea (B.U.N.)	32	mg/dL
Serum Creatinine	2.1	mg/dL
Aspartate Transaminase	no	-
Chronic Liver Disease	no	-
Mobility	no	-
Site of Operation	no	-
Emergency Surgery	no	-
	Cardiac Risk Index	**7**
	Risk Class	**Class II**

Table 7: CRDA testing – Patient B

Patient B is a 29 year old young lady scheduled to undergo plastic surgery on her nose. The CRDA placed her at a Class II risk factor, giving her a 7% minor complication chance and a 2% cardiac death risk. **(Refer to table 9 for more details)**

The surgeon in charge of patient B's operation gave us a 0% complication chance and 0% cardiac risk.

The operation was a complete success, with no complications at all. No complications or problems were recorded in the 4 weeks that followed the operation.

Input Field	Value	Measure
Age	29	**years**
Recent Myocardial Infraction	no	-
Cardiac Failure	no	-
Aortic Stenosis	no	-
Sinus Rhythm	no	-
Premature Arterial Contractions	no	-
Premature Ventricular Contractions	no	-
Arterial pO2	100	mmHg
Arterial pCO2	39	mmHg
Serum Potassium	4.1	mEq/L
Serum Bicarbonate	22	mEq/L
Serum Urea (B.U.N.)	32	mg/dL
Serum Creatinine	2.1	mg/dL
Aspartate Transaminase	no	-
Chronic Liver Disease	no	-
Mobility	no	-
Site of Operation	no	-
Emergency Surgery	no	-
	Cardiac Risk Index	**50**
	Risk Class	**Class II**

Table 8: CRDA testing – Patient C

Patient C is a 76 year old man admitted to EU with chest pain. After diagnosis and tests, the patient's personal physician suggested emergency chest surgery.
The CRDA placed him at a Class IV risk factor, giving him a 22% minor complication chance and a 56% cardiac death risk. (Refer to table 9 for more details)
Patient C passed away during the operation after a heart failure that physicians and surgeons could not prevent and the patient could not recover from.

4.3 Result Analyses and Discussion

Careful examination of the results in section 4.2 shows us that both the CRDA and MRC systems are producing accurate results that match the diagnosis of surgeons and physicians and that are proven by monitoring the patient status on a period of time ranging between 24 hours and 6 weeks.

In the verbal analysis of the results obtained from the CRDA system, we mentioned a conversion or a so-called "translation" done by a certain table. This table is also known as the multifactorial index of cardiac risk in non-cardiac surgical procedures, as M. Goldman himself calls it.

Class	Point Total	None/Minor Complication	Life-threatening complication	Cardiac death
Class I	0-5	99%	0.7%	0.2%
Class II	6-12	93%	5%	2%
Class III	13-25	86%	11%	2%
Class IV	≥26	22%	22%	56%

Table 9: CRDA result translation
Goldman M, et al. (1988).

In the previous section we displayed three cases for each system, showing the data in a tabulated format as well as the results obtained and a rundown of the patient from the moment of admission or pre-operation, and post-operation or post-admission.

One case, in the MRC system testing, had an above 50% death rate prediction, yet survived his ICU stay and is still alive, proving that the system at hand, no matter how scientific, exact and accurate, still is not full proof and is not always correct. But if we compare the systems with the real life diagnosis and procedures, we notice that the major advantage is time saving and accurate calculations.

The results displayed in this chapter are part of the testing phase, as we ran more than twenty cases for each system, in order to obtain a result we could rely on and a system we could put to use.

Chapter 5

Conclusion

We have designed and developed a radical MDSS, called the E-Doc, a cradle of medical modules, serving as create "medical calculators", "diagnosis tools" and "decision aids".

E-Doc currently contains the MRC diagnosis tool, the CRC medical calculator and the CRDA decision aid. It was tested and subjected to experimental work using real data provided by local healthcare institutions, and showed that the results obtained are accurate and helpful, both in giving a second opinion to the physicians and surgeons and in giving quick and accurate results and aids in the process of decision making.

E-Doc was conceived following many ideas and thoughts that were already talked about in many magazines, dissertations and studies, and the reason that led me to this domain is my work in a medical environment and love of new challenges.

It is designed and built in a way to run under windows as a web based module, being able to serve more than one terminal at a given time. That's not all the E-Doc was designed to do. During the design and preliminary implementation phases, the initiative to make the E-Doc adaptable to be used on Palm OS and Windows CE systems was taken, meaning it can be easily ported to hand held and other portable device.
This can be achieved by adding a few simple functions and small modules to the system itself.

E-Doc is fast, accurate and reliable, making it ideal for use in the Intensive Care Unit and Operating Rooms, giving physicians and surgeons a quick and reliable diagnosis, aid and help tool in providing better healthcare.

The need for speed is obvious in the medical field, especially in the intensive care and surgical sectors, where time in a way is equivalent to life. E-Doc is able to achieve that to a certain extent, as its use is limited to a few cases and a not so broad spectrum of patients.

Further development can lead to the creation of similar modules, based on the numerous medical algorithms available, in order to turn the E-Doc into a complete E-Hospital, able to serve all physicians and surgeons in all sectors of a healthcare institution, from the ER to the ICU to the OR and all other units.

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Glossary

MDSS: Medical Decision Support System. A software system that aids medical decision taking.

CDSS: Clinical Decision Support System. Similar to MDSS but for use in clinical environments.

MRC: Mortality Risk Calculator. A medical diagnosis tool for the prediction of death rate in ICU patients, based on the worst values obtained from various tests done during the first 24 hours of hospitalization.

CRDA: Cardiac Risk Decision Aid. A medical decision support system based on the Goldman and Detsky indexes, or decision aid, to asses the risk of cardiac complication post non-cardiac surgery.

CSC: Coma Score Calculator. A medical calculator based on the Glasgow coma scale, to evaluate a patient's state of altered consciousness immediately after trauma.

Ischemia: It is the condition suffered by tissues and organs when deprived of blood flow, mostly the effects of inadequate nutrient and oxygen.

Lesion: A lesion is a non-specific term referring to abnormal tissue in the body. It can be caused by any disease process including trauma (physical, chemical, electrical), infection, neoplasm, metabolic and autoimmune. Lesion is derived from a Latin word which means "injury."

Infraction: Lack of blood supply (and thus oxygen) to an organ or tissue resulting in tissue death.

AV node: A small mass of tissue that forms a conductive path between the Atrial myocardia and the Penetrating Bundle. Normally, the AV node provides the delay between the activation of the Atria and the Ventricles. This stunningly designed system generates electrical impulses and conducts them throughout the muscle of the heart, stimulating the heart to contract and pump blood.

ECG: Electrocardiogram. A record of the electrical activity (function) of the heart, used to diagnose cardiac arrhythmias, myocardial ischemia and myocardial infarction.

Cirrhosis of the liver: The result of long-standing inflammation and damage in the liver, such as may be caused by chronic HCV infection or alcohol abuse. In cirrhosis of the liver, scar tissue replaces normal, healthy tissue, blocking the flow of blood through the organ and preventing it from working as it should. Cirrhosis is one of the top ten causes of death by disease, killing about 26,000 people each year.

Fibrosis of the liver: It is the growth of scar tissue due to infection, inflammation, injury, or even healing. The overgrowth of scar tissue can occur in almost any organ. Fibrosis in the liver can inhibit the organ's proper functioning. Liver fibrosis is usually results in Cirrhosis.

mmol/L: Millimoles per litre. The unit of measurement of how much of a substance (such as sugar) is in a specific amount of fluid (such as blood or urine). Most of the world uses mmol/L; however, in the United States, mg/dl is used as the unit of measurement. (Note: To convert blood sugar to mmol/L from mg/dl, divide by 18.)

mEq/L: Milliequivalents per litre is another method of expressing concentration, when the analytes are dissolved and disassociated in solution. mEq/L is also equal to millimoles of charge per litre (mM+/L or mM-/L depending on valence).

ICU: The ward or nursing care area in a hospital that provides intensive observation, diagnosis, and therapeutic procedures for adults and/or children who are critically ill.