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BW-Eye

***Ophthalmologic Decision Support System based on Clinical Workflow
and Data Mining Techniques***

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obtain the degree of Master of Biomedical Engineering

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To my grandmother...

ABSTRACT

The importance of technology in the medical field is becoming increasingly prominent. Physicians are relying more and more on the benefits of computer science and engineering areas in order to maximize productivity and relieve some of this field's inherent subjectivity.

This report describes the work carried out for the Biomedical Engineering's Project class. This work, integrated in BlueWorks' Ophthalmologic Decision Support System on Clinical Workflow and Data Mining Techniques project, was centered in the software development component.

This system's goal is to be a robust and extremely reliable tool able to aid the physician's diagnostic decision by utilizing data analysis techniques and image processing routines. However, creating such a complex solution requires a phased development and, since data analysis techniques resort to large amounts of data for optimal return, it is necessary to first acquire and store that medical data.

Due to the solution's development priorities, this project focused in the creation of software for equipment integration and data retrieval. From the previous work, this data retrieval is achieved by using a modular application that integrates the medical equipments. This application acquires the medical data, either in file format or video stream, from medical equipments and stores it in a database in a structured fashion.

In addition, due to some equipments' export restrictions, an optical character recognition engine, able to retrieve any alphanumeric data contained within an image, was developed. This engine is characterized for its perfect accuracy and reasonable speed.

KEYWORDS

Ophthalmology, Interoperability, Optical Character Recognition (OCR), Neural Network, Floodfill, Directshow, Video Capturing, C#.

RESUMO

A importância da tecnologia no campo da medicina tem-se tornado cada vez mais importante. Os médicos dependem cada vez mais nos benefícios que as áreas de informática e engenharia oferecem de forma a maximizar a produtividade e atenuar a subjectividade inerente deste campo.

Este relatório descreve o trabalho desenvolvido para a cadeira de Projecto do curso de Engenharia Biomédica. Este trabalho, integrado no Sistema de Suporte à Decisão em Oftalmologia baseado em técnicas de Workflow Clínico e Data Mining por parte da BlueWorks , é centrado na componente de desenvolvimento de software.

Este sistema tem como finalidade fornecer uma ferramenta robusta e fiável capaz de assistir o diagnóstico médico utilizando técnicas de análise de dados e rotinas de processamento de imagem. Contudo, criar uma solução tão complexa requer um desenvolvimento faseado e, visto que técnicas de análise de dados recorrem a grandes quantidades de dados de forma a obter resultados óptimos, é primeiro necessário adquirir e armazenar esses dados médicos.

Devido às prioridades de desenvolvimento desta solução, este projecto foca a criação de software para integração de equipamentos e obtenção de dados. Considerando o trabalho já desenvolvido, esta obtenção de dados é conseguida usando uma aplicação modular que integra equipamentos médicos. Esta aplicação adquire os dados, seja num ficheiro ou numa “stream” de vídeo, dos equipamentos médicos e armazena-os numa base de dados numa forma estruturada.

Para além disso, devido a algumas restrições de exportação de certos equipamentos médicos, um motor de reconhecimento de caracteres ópticos, capaz de obter qualquer informação alfanumérica contida numa imagem, foi desenvolvido. Este motor é caracterizado pela sua precisão perfeita e velocidade razoável.

PALAVRAS-CHAVE

Oftalmologia, Interoperabilidade, Reconhecimento de caracteres ópticos (OCR), Redes Neurais, Floodfill, Directshow, Captura de Vídeo, C#.

ACKNOWLEDGMENTS

There are several people that were instrumental to the accomplishment of this project.

First of all, I would like to thank Eng. Paulo Barbeiro for the opportunity of integrating the BlueWorks team; for the innovative ideas that effectively contributed to the success of this project; for consenting project deviations requested by me in order to enrich my work, disregarding the initial planning that was optimal for Blueworks; and, above all, for the superior guidance and leadership throughout the year that prepared me so well for what I have to face from now on.

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I'm especially grateful to my parents, grandparents and little brother whose love and wholehearted belief in my success gave me the confidence to pursuit my dreams. Without their unreserved encouragement and comprehension during the ups and downs of my life's endeavours I wouldn't be where I am today.

It just isn't possible to refer all the people that have significantly contributed to all the accomplishments I've achieved, to who I am today. Even though their names are not referred here, I will never forget who they are and how each one, in his/her unique way, helped shape my being.

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ACRONYMS & ABBREVIATIONS

| | |
|-------------|-----------------------------------|
| 3N1 | Three-in-one |
| ANN | Artificial Neural Network |
| API | Application Programming Interface |
| AVI | Audio Video Interleaved |
| BMP | Bitmap |
| BW | BlueWorks |
| C# | C-Sharp |
| CCC | Centro Cirúrgico de Coimbra |
| COM | Component Object Model |
| DAL | Data Access Layer |
| DB | DataBase |
| DLL | Dynamic-Link Library |
| EPR | Electronic Patient Record |
| GDI+ | Graphics Device Interface |
| GIF | Graphics Interchange Format |
| GUI | Graphical User Interface |
| HTTP | HyperText Transfer Protocol |
| JPEG | Joint Photographic Experts Group |
| LAN | Local Area Network |
| MLP | Multi Layer Perceptron |
| NN | Neural Network |
| OCR | Optical Characters Recognition |
| OS | Operating System |
| PC | Personal Computer |
| PDF | Portable Document Format |
| PNG | Portable Network Graphics |
| SCR | Point Screening Test |

| | |
|-------------|-------------------------------|
| SFA | Single Field Analysis |
| SLO | Scanning Laser Ophthalmoscope |
| SOAP | Simple Object Access Protocol |
| SP | Stored Procedures |
| SQL | Structured Query Language |
| TIFF | Tagged Image File Format |
| UDF | User-Defined Functions |
| USB | Universal Serial Bus |
| XML | eXtensible Markup Language |

1. INTRODUCTION

The constant evolution of computer power has proved to be advantageous in several fields. Medicine is no exception.

The increased computational power and technologies have already been successfully implemented leading to better medical practices and assessments. Not only computers have the capability of performing tasks that no human can perform but also have an impartial approach to any problem at hands. Thanks to this objectivity and problem solving abilities, computer science has become an invaluable tool.

In addition, digital storage is indescribably better than the usual storage methods that rely on paper and handwritten material. By digitalizing medical information and store it in central repositories, not only the entire medical system becomes more scalable but also more organized and much easier to access. The main foundation of this digitalization action is the Electronic Patient Record (EPR) that comprises, for a given patient, all the relevant textual data as well as multimedia elements.

By combining both digital data and computational power it is possible to develop tools that can improve the medical workflow and, ultimately, its effectiveness. Such tools, based in data analysis methods and image processing routines, can extract unprecedented relations and conclusions that otherwise could go unnoticed.

It is important to note that this is not a perfect solution; it also has its own disadvantages. The medical data is only accessible while the system is online; i.e., in case of power failures or network disconnections events, the data is inaccessible. In addition, computerization requires a change of habits in the physician's work that might not be well accepted.

1.1 PROJECT OVERVIEW

Blueworks (BW), Medical Expert Diagnosis, Lda, is a technological start-up committed to bring the advantages described above to the ophthalmology field. Headquartered in Centro Cirúrgico de Coimbra (CCC), BW was founded by three biomedical engineers and the major associates: Centro Cirúrgico de Coimbra, ISA and NeuroEye.

Being located in such a renowned ophthalmologic clinic is advantageous. Not only it is possible to conveniently interact with the clinical processes and state-of-the-art medical equipments, but also obtain invaluable feedback from a group of renowned ophthalmologists, known nationally and worldwide for the quality of their work.

Even though BW is currently involved in several ophthalmologic projects, the work described in this document is inserted in the foremost solution, the *OphthalSuite*. *OphthalSuite* is a software solution for clinical management and, ultimately, diagnosis support. Its main applicability is in the area of systems integration as it can be viewed as an intermediary element in charge of retrieving medical data from ophthalmologic equipments and storing it in a database (DB). Considering that data analysis methods for decision support require data in the first place, it is easily perceivable that data acquisition is the preliminary phase of the objectives overall.

Therefore, this project is solely a continuation of the preceding work where the main emphasis is given to software development and essential algorithms for that purpose.

1.2 OBJECTIVES

The main objective of this project is to contribute to the constant evolution of Blueworks' *OphthalSuite* solution.

Falling under the systems integration field, the major component of this project is integrating medical equipment in order to retrieve its data and store it in a database as EPRs. For that reason, this project is intended to add new software components to the main solution that can link specific equipments for that purpose.

Furthermore, it is common to have alphanumeric data contained within an image manually digitalized by having a person to do that work. Providing automated tools that retrieve that data quickly and, more importantly, accurately is also one of the main objectives proposed for the work described in this document.

1.3 DOMAIN & AUDIENCE

This project is integrated in the Biomedical Engineering course of the Faculty of Science and Technology of the University of Coimbra. It started on the 10th of September of 2008 and ended on the 9th of September of 2009, the report submission deadline.

This document is targeted for Blueworks and CCC members, project coordinators, physicians and jury elements.

1.4 REPORT LAYOUT

The structure for this report comprises six major chapters.

In the first chapter, a project overview is made and the main objectives and audience outlined.

Subsequently, chapter two refers to the project management elements composed by the team, the supervision and the planning.

Chapter 3 contextualizes this project in Blueworks' global picture by pointing the current state of development.

Afterwards, the developed software for this project is described in detail.

The next chapter complements the previous one by presenting the developed algorithms.

Finally, project conclusions and further work analysis are made.

2. PROJECT MANAGEMENT

2.1 PROJECT TEAM

The team that carried out the project was composed by two students, an engineering supervisor and project coordinator. However, precious help was also provided by the other members that compose the BW team.

Table 1 - Project Team

| Name | Designation | Contact |
|-----------------------|-----------------------|-------------------------|
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| Prof. Miguel Morgado | Project Coordinator | miguel@fis.uc.pt |
| Eng. Edgar Ferreira | Software Collaborator | eferreira@blueworks.pt |
| Eng. Armanda Santos | Software Collaborator | asantos@blueworks.pt |

2.2 PROJECT SUPERVISION

During this project several measures were taken in order to ensure accomplishment of each obligation. The initial progress was tracked using time trackers and Gantt charts that were reviewed by the project supervisor and other team elements.

After attending a SCRUM (1) workshop, some of the retained ideas were applied. For each of the sub-components of this project sprint backlogs were kept giving a better understanding of the work rhythm and inherent setbacks that were encountered.

2.3 PROJECT PLANNING

In a business environment, the necessities that arise aren't static. In this specific case, those necessities resulted from the environment where we were inserted (CCC) and the priorities established by CCC's physicians.

At first, the project tasks were outlined in a Gantt chart that at some point was abandoned in order to fulfill other priorities. Additionally, after attending SCRUM training, the planning for the last tasks followed a similar approach to the SCRUM teachings. This planning strategy couldn't be followed exactly as intended to due to the fact that the Blueworks team does not contain enough elements to play all the necessary roles in a SCRUM development management.

The original Gantt chart and an example of a sprint backlog can be seen in the attachments.

3. PROJECT ANALYSIS

Before entering in greater details about the accomplished work, it is necessary to briefly explain the level of development of *OphthalSuite* when this project started.

3.1 BACKGROUND

As stated before, for medical diagnosis it's common to resort to several medical examination equipments. The data generated from those equipments isn't always made available to the physician thus implying the lack of systems interoperability.

The current workarounds are far from perfect; there is loss or corruption of data and the whole process is very slow. This occurs due to the fact that each equipment manufacturer applies proprietary communication mechanisms. As a result, integrating several equipments from different manufacturers can be an arduous task.

Moreover, the need of operating the equipment on location, obtain the machine data in paper and the need to master different remote software for each equipment are also workarounds of the ideal solution.

Blueworks has solved these issues by developing *OphthalSuite* that works by connecting and adapting each equipment. This way, an equipment is perfectly connected with the EPR system that exists in the medical unit allowing two things:

- Easy access to vital medical data.
- Storage of data with less relevance is stored in order to allow possible studies.

Having different applications that remotely access each equipment is undesirable; the user would delay the clinical workflow by switching between applications or even rooms. The approach to this problem consists in using modular software – *Module* - that integrates *OphthalSuite* where the user is able to access connected equipments from any location within the network.

OphthalSuite is a multi-modular application developed for the .NET Framework 2.0 primarily written in C#. It has been developed according with the inputs provided by the pilot installation at CCC in which all the developed components are and will be tested.

3.2 EXAM & EXPORT WORKFLOW

The clinical process of performing an examination and consequently export its information follows a constant pattern:

1. The patient arrives
2. If the patient is unregistered, the technician will register the new patient
3. Examination is carried out
4. The technician defines and prints the report
5. Finally, the examination data is exported

3.3 APPLICATION ARCHITECTURE

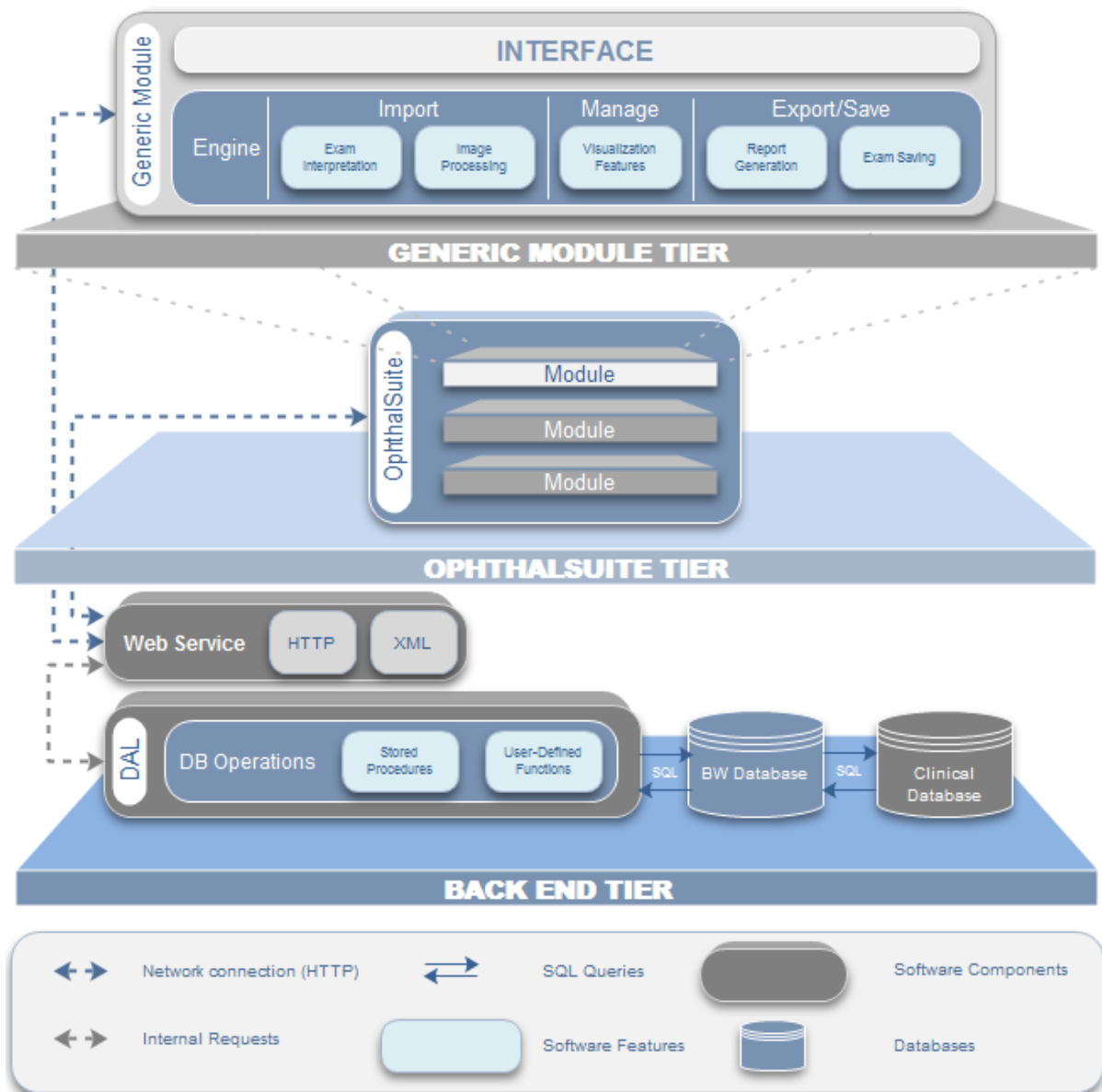


Figure 1- OphthalSuite solution's structural architecture

The *OphthalSuite* solution structure can be represented in a tier based architecture.

The topmost layer represents a module that is used for data acquisition. All data processing, exam visualization and other perceptible features occur at this level. This module can access the database by directly calling a web service.

The *OphthalSuite* tier can be seen as a middleware layer since it is used to connect software components. This layer holds several modules, each one with its specific functions, and contains database access channels.

Lastly, the back end tier comprises all the database operations and the databases themselves. It is perceivable that the database operations are provided by the web service using network channels to transfer Simple Object Access Protocol (SOAP) messages by means of Hypertext Transfer Protocol (HTTP) and eXtensible Markup Language (XML) serialization (2).

In addition, the BW database is also connected to the clinical database in order to retrieve medical data that is not comprised by the solution's database. This connection is based on DB triggers that are activated on specific events, propagating the information between both DBs.

3.3.1 EXAM ACQUISITION MODULES

Each medical device is integrated using specific software modules inserted in the main application - *OphthalSuite*. A specific module can be viewed as an interface that allows the user to interact between the equipment's examinations and the features provided by *OphthalSuite* and comprises all the necessary algorithms for exported examinations interpretation, database operations and visualization features.

The user, usually a physician, expects that the application won't hinder the medical workflow, thus it is important that the module is as simple and straightforward as possible. Mainly, it is used as a mean to save medical examinations to the central database following *OphthalSuite*'s philosophy. In other words, it must extract the largest amount of information possible and save it while requiring minimal interaction by the user and, if necessary, allow for more complex actions.

Each module has specific tools depending on the equipment at hands. Tools like advanced image filtering & viewing or report generation can be very useful for the physician. By providing such tools, the user is no longer limited to the existing functionalities in the equipment's proprietary software which, in some cases, do not allow saving processed images. A module also tries to replicate some of the features of the proprietary software in order to release the user of unnecessary swapping between applications. This way, the proprietary application is only responsible for the acquisition action and, if required, exporting the examinations, whereas the module is in charge of any processing tasks, report generation and, ultimately, DB storage.

OPHTHALSUITE INTEGRATION

Each module is integrated with the main application by utilizing a plug-in solution that consists of a single Dynamic-Link Library (DLL) file implementing a specific interface with *OphthalSuite*. This solution is beneficial for the module developer, that is only required to write an application somewhat independent from all the other modules minding the application's philosophy and tools, and clinical workflow point-of-view, where a workstation would have installed only the necessary plug-in modules.

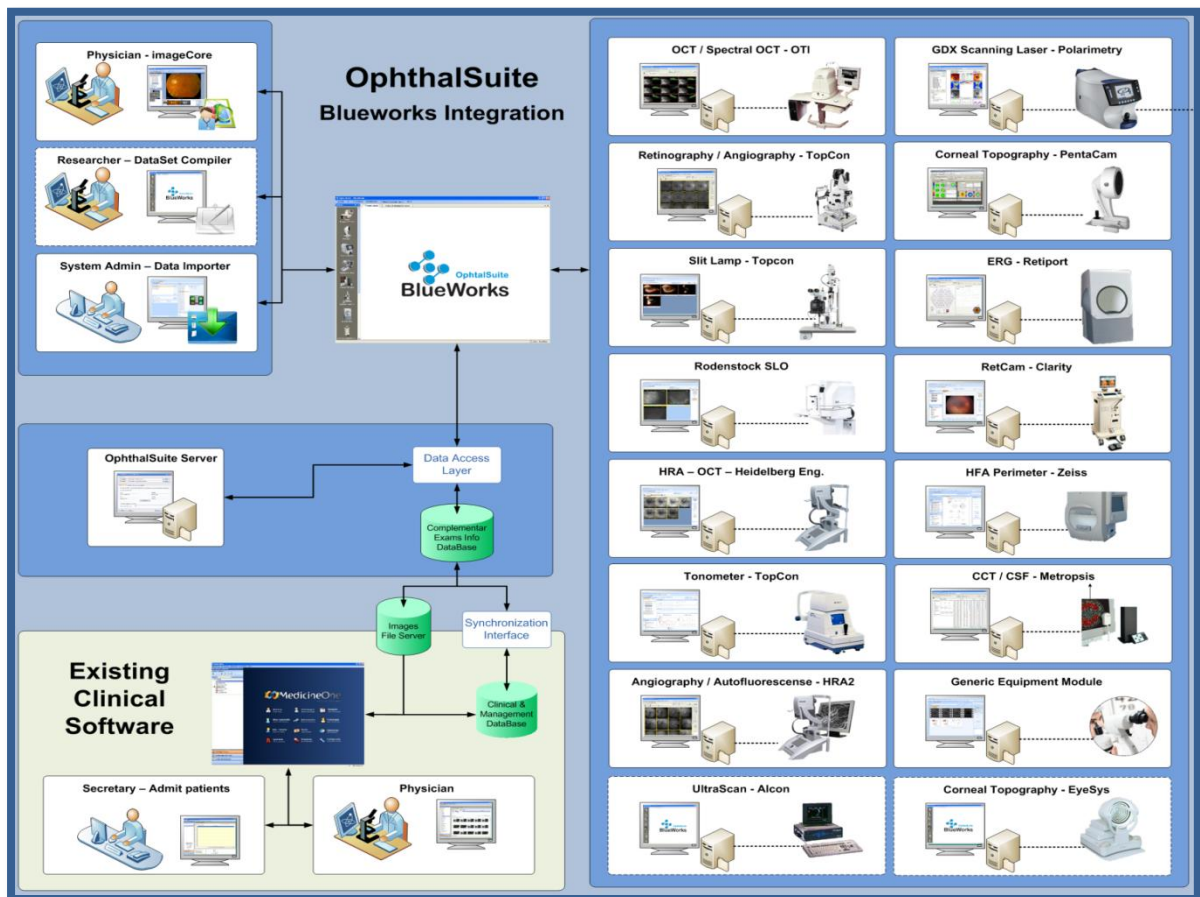


Figure 2 - *OphthalSuite* current state

Figure 2 illustrates *OphthalSuite*'s current state of development. Besides having a large amount of acquisition modules developed, it is successfully connected with the clinical management software databases and provides three additional tools:

- imageCore – this is an exam visualization module that allows the user to search for a patient and visualize all the saved exams.
- DataSet Compiler – this is a wizard-like tool that allows the user to create datasets by querying the DB.
- Data Importer – this tool is used to index images from equipments that do not allow integration. Using it, it is possible to catalogue all those images and access them using imageCore.

3.3.2 CLINICAL DATABASE

Another aspect of this solution is its connectivity between the software components and the proprietary and clinical databases.

Through this communication route, the application is able to write or read all the elements that compose a medical examination, whether they are image, video or simply text data, in an organized fashion.

The communication is made using a Data Access Layer (DAL) stored in a Web Service, containing DLLs that provide specific DB access methods recognized by *OphthalSuite* as well as the DB. The DAL methods use Structured Query Language (SQL) written Stored Procedures (SP) and User Defined Functions (UDF) that are completely transparent to the methods which the main application/module will access. This facilitates any modification that needs to be made in the SQL queries, has better performance and allows better administration, centralized management and security(3)(4) (5).

By using this layer, any connected *OphthalSuite* instances communicate with the DB using a common gateway thus being a much more flexible solution. If any SQL query needs change, it will be modified in a unique location without requiring any change at the module level.

In addition, since *OphthalSuite* may hold multiple modules, each module can utilize the same Patient/Physician and Exam/Image type lists provided by the main application, thus preventing multiple queries that would slow down the entire system and could lead to possible outdated lists.

It is important to note that most of the DB writing operations are triggered by the module using the authentication provided by *OphthalSuite*. Each module contains the necessary methods for accessing the DAL and save the acquired examinations in the DB.

FLOWCHART

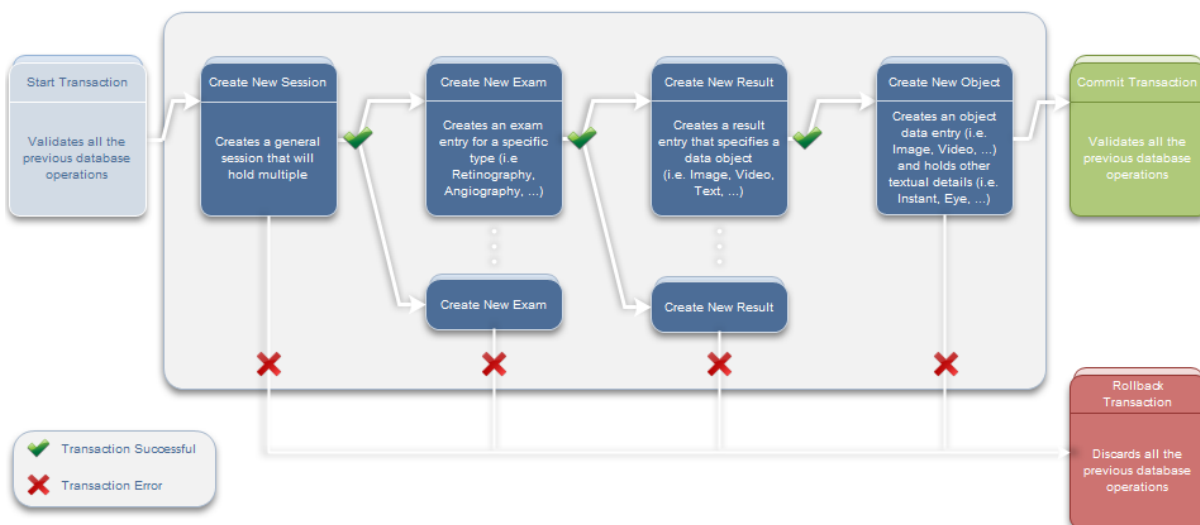


Figure 3 - Module examination save flowchart

4. SOFTWARE DEVELOPMENT

4.1 OVERVIEW

Software development was the major component of this project. As a continuation of the previous work, all the development is made under Microsoft's .NET Framework 2 using C# language. This section will describe the developed modules for the *OphthaSuite* application.

4.2 RETCAM II ACQUISITION MODULE

4.2.1 EQUIPMENT OVERVIEW

The Clarity RetCam II is a wide-field digital pediatric retinal imaging system, oriented for neonatal and pediatric study cases, that allows the capture of wide-field, high resolution, digital, images and videos of the eye.

HARDWARE

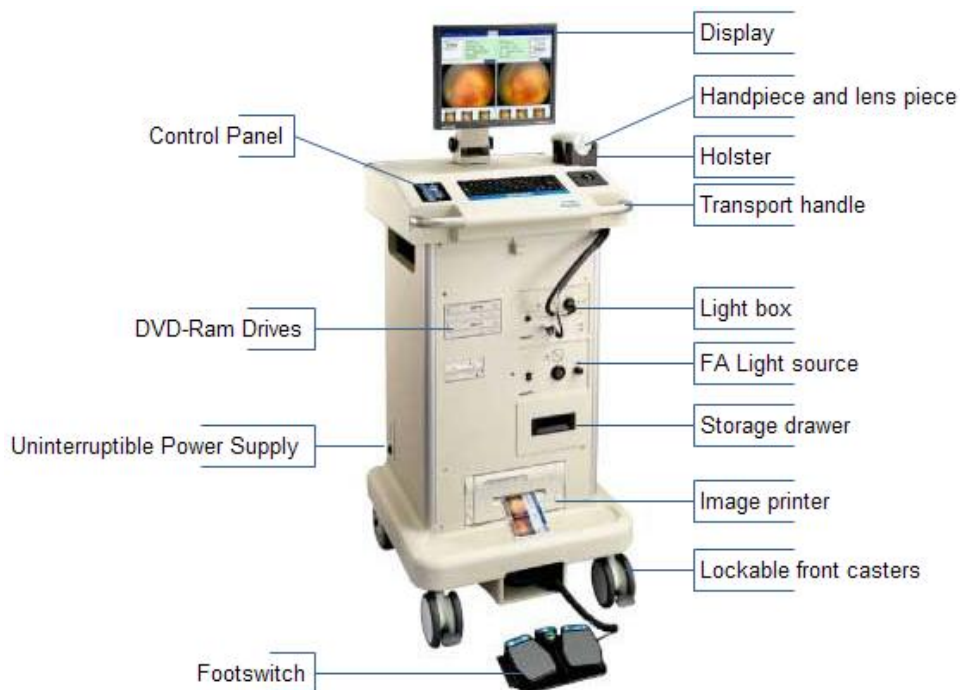


Figure 4 - Clarity RetCam II

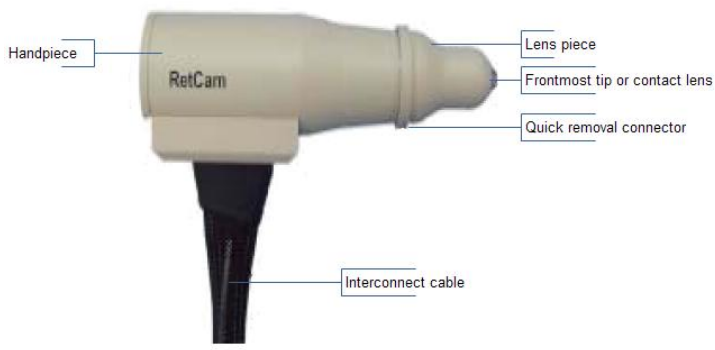


Figure 5 - RetCam II Camera



Figure 6 - RetCam II Lenses

Table 2- RetCam II Lenses Chart

| Lens Model | Application | Common Field of View |
|------------|---------------------------------|----------------------|
| D1300 | ROP & Anterior Segment | 130 Degrees |
| B1200 | Children & Anterior Segment | 120 Degrees |
| E800 | High Contrast Children & Adults | 80 Degrees |
| C300 | High Magnification | 30 Degrees |
| PL100 | Portrait Lens | N/A |

The equipment case also holds a Personal Computer (PC) with a Cat5 connection allowing LAN connections that are used for examination exports.

SOFTWARE

The PC comes with a Windows XP embedded Operating System (OS) where the proprietary application, apparently developed using the .NET Framework, is installed. The application keeps a proprietary DB with all the saved patients, sessions and media. Using this application, the user can:

- Manage Patients/Sessions;
- Acquire radiography, anterior segment and fluorescein angiography images and videos;
- Apply image filtering;
- Save the data into DVD's or USB-drives;
- Manage network connections;
- Export data to a folder;
- Add Session/Image notes;
- Print images;

4.2.1.1 EXAM EXPORT

The first step in this equipment's integration consists in obtaining the data. Ideally, the equipment would be connected at all times to the clinic's Local Area Network (LAN) and, using a small application installed in the equipment that detects new files, when a new examination file was detected it would automatically import it to the module. This surely is the most autonomous solution but, unfortunately, the only files that the equipments' software produces at the acquisition moment are in an unreadable proprietary format, the equipment isn't always connected and the fact of having an embedded OS complicates third-party software installations.

Several requests were sent to Clarity in order to provide us with the necessary documentation or interpretation routines in order to interpret their files but no response was received. Therefore, the RetCam II's export feature was the place to start.

The equipment provides several exporting options (Figure 7). Ideally, in order to ensure that all exams are available in the module, a full export should always be made. This step's is completely dependent on the machine operator; the export action should be consistent and periodical.

After choosing the items to export, the operator must select the exporting formats, location and several other fields.



Figure 7- RetCam II Export Selection Menu

The user must ensure that:

- The path is the one the module is expecting;
- Create subfolders, Overwrite existing data and Organize patients into subfolders are unchecked in order to avoid file duplication. The creation of identical files in subfolders won't affect the module functioning but will hinder its speed (it has to process more files which were previously processed);
- The export format must be Open Standard, in which images are in Portable Network Graphics (PNG) format and the data in XML format. It is possible to extract the images in other formats but PNG grants the best Size/Quality ratio. XML parsing is better in XML files as it is a structured file type, so this is the obvious choice. Videos are always exported in Audio Video Interleave (AVI) format.

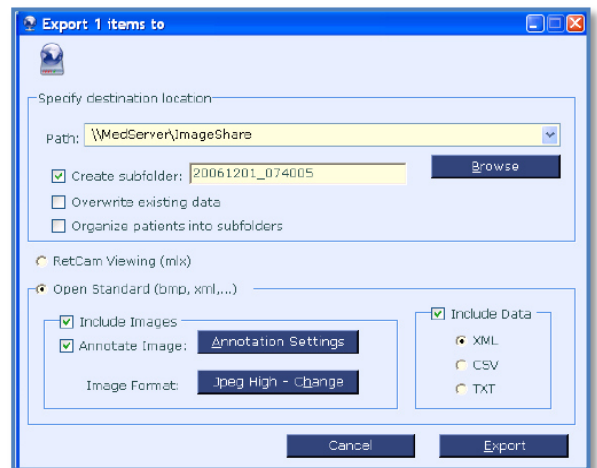


Figure 8 - RetCam II Export Window

4.2.1.2 EXAM XML ANALYSIS

By following XML data as the chosen alternative, the first step is to analyze the XML file that complements each exported image.

HIERARCHICAL STRUCTURE

```

<Header>
  <Patient>
    <Notes>
    <Sessions>
      <RetCamSession>
        <Notes>
        <SessionItems>
          <OphthalmicImage/OphthalmicVideo>
  
```

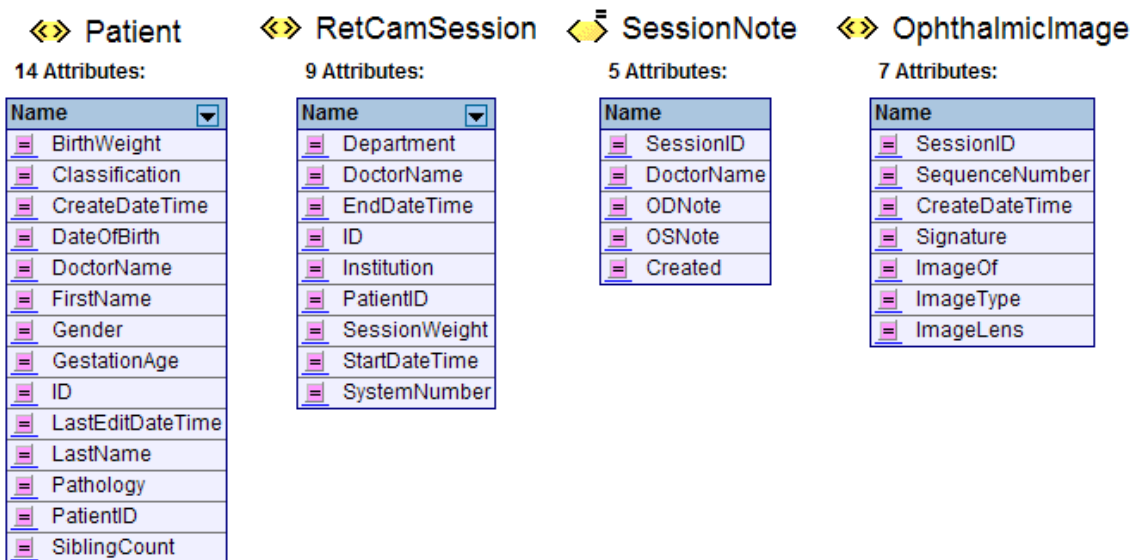


Figure 9 - RetCam II XML Tables

By analyzing the hierarchical structure in a vast number of files, the rules for parsing the XML file were established. These rules account structure variations (image/video) and interpret every field to pre-established formats (e.g. DateOfBirth is parsed to a DateTime object).

This kind of data retrieval is the cornerstone of a module. It must be as accurate and complete as possible. Unfortunately, during the problem analysis, we encountered an issue regarding the angiography image XMLs that do not contain the instant field. The value is only present in the image itself. This issue is covered later on in chapter 5 as it requires more advanced algorithms to allow its extraction.

4.2.2 REQUIREMENTS ANALYSIS

Before starting developing any piece of software, a general idea of the required functionalities should be outlined. We must analyze the functionalities wanted given the problem's context, that is, the module must comprise ways to reach the solution's objectives and provide additional tools if necessary. As the module is being developed and tested it is common to perceive additional functionalities that are later added; it is a constant evolving solution.

Table 3- RetCam II Module Requirements

| # | Requirements |
|-----|--|
| R1 | Modular integration with the main application (Plug-in) |
| R2 | Simple, appealing and easy-to-use environment |
| R3 | Automatically import image/videos (PNG/AVI) and corresponding XML after each RetCam II backup |
| R4 | Automatically identify a patient by associating the XML's patient ID with the known patient ID DB |
| R5 | Simple/Advanced patient choice |
| R6 | Simple/Advanced physician choice |
| R7 | Simple/automatic exam type choice |
| R8 | Multiple tabs for different exam types |
| R9 | Image selection by click or checkbox |
| R10 | Allow image deletion |
| R11 | Image previewing with zoom capabilities |
| R12 | Report layout configuration |
| R13 | Add/remove images from report |
| R14 | Multiple report pages |
| R15 | Automatic and complete report info |
| R16 | Add comments to each exam type |
| R17 | Save report in the DB and server folder as a (Portable Document Format) PDF file |
| R18 | Report preview window |
| R19 | Images and report are saved in a pre-defined server folder; image thumbnails and complementary information saved in the DB |
| R20 | Application settings window |
| R21 | Tooltip notifying new images |
| R22 | Possibility to discard current exam or patient |

4.2.3 IMPLEMENTATION

The module was developed using previously developed modules as guidelines. It must follow the same layout, user interaction and hidden tasks in order to bring coherence to the global solution.

4.2.3.1 OVERVIEW

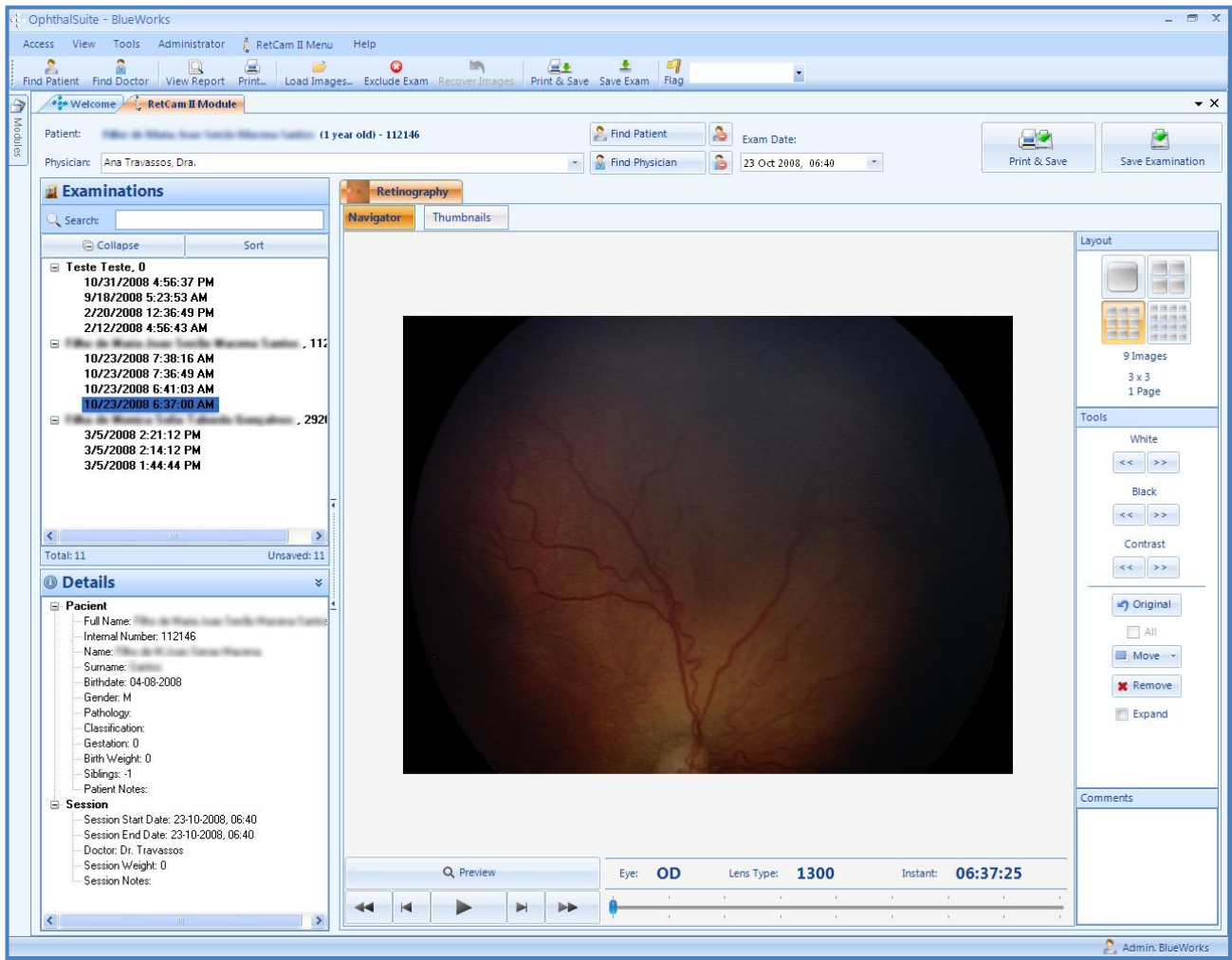


Figure 10 - RetCam II Module Overview

The image above is the module's main interface. The interface, following the same layout as the previously developed modules, tries to dispose every section and tool as intuitively as possible granting a faster and easier use. The features available in these sections are explained next.

4.2.3.2 ENGINE CONSIDERATIONS

It is important to explain some underlying engine properties in order to understand the module's features.

Firstly, the module's dataflow depends on two primary objects: the *RetCamImage* and *RetCamExam* (in order to simplify the writing, each object will be addressed in this chapter as *Image* and *Exam* respectively). The first consists of an image and the corresponding XML data; it represents an exported image. The last represents a session and is an assembly of multiple *Image* objects and some additional information.

The module works by importing, interpreting and displaying the images/XML to the user. Similar to other modules, the import action should be conducted in two distinct ways: an automatic where the module is periodically checking for new files in a user-defined folder; importing image manually from any accessible location.

Usually, the watch folder acts as a buffer where each saved exam is removed from that folder. This is not a viable solution given the equipment's exporting features. Since full backup is recommended, deleting those files would be pointless as they would be created in every export action. Thus, by maintaining those files, not only the full backup is quicker but it will also prevent duplicated entries in the DB.

PATIENT/PHYSICIAN CONTROL

Patients and physicians datasets can be retrieved from *OphthalSuite*. However it is useful to provide some Patient/Physician searching and selection features. This is done by using an existing control that is present in every module.

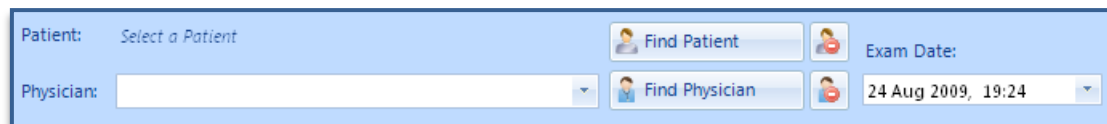


Figure 11 - ControlPatientDoctor control

It displays, for the current *Exam*, the selected Patient and Physician and Date that are either automatically interpreted from the exam's data or by manually selecting them. Whatever modification occurs, the current exam is automatically updated.

Behind this control are two datasets, one for patients and other for physicians, provided by the main application. These datasets are retrieved at every *OphthalSuite*'s startup and, at a configurable time interval, updated if any modifications occurred during that window.

IMAGE PROCESSING

Some of the image processing that is conducted in this module depends on existing methods that resort on the Microsoft's Graphics Device Interface (GDI+) library. The GDI+ is an Application Programming Interface (API) and core operating system component that provides two-dimensional vector graphics, imaging, and typography (6).

MODULE'S DATABASE

The module runs its internal XML database. This DB is stored in a XML file and is loaded at every module's startup.

It is used to store removed exams that, supposedly, are no longer required. Every time the module is launched, it will analyze all the files within the watch folder. Analyzing such a large number of files is time-consuming. By preventing the module from analyzing deleted examinations, the module processing time is greatly reduced.

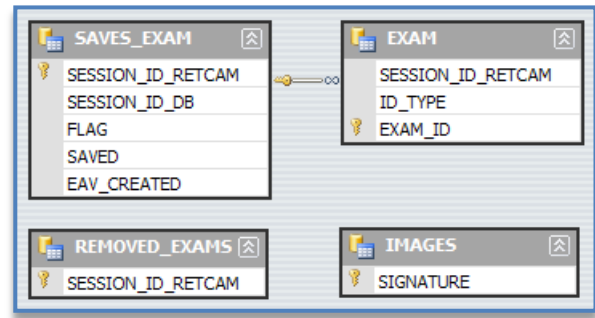


Figure 12 - RetCam II Module Database structure

In addition, the DB also holds entries for the details of all saved examinations as well as the images saved in each one. This way, the user can update examinations considering new images are added by using the same DB entry IDs. The storage of saved examinations is also used when the module analyzes the watch folder files. When the examination list is populated, the saved exams are classified as such, preventing duplicated entries in the main database.

Not only is it faster to use this local DB instead of querying the main DB for all the saved examinations but also prevents excessive network traffic, freeing up resources for more important tasks.

VIDEO VISUALIZATION

It has been explained that the RetCam II can generate videos. It is important to allow the user to view those videos. In order to do that, Microsoft's DirectXAUDIOVideo Playback library was used. This is a very simple library with few but sufficient features for the module's video playing needs.



Figure 13 – RetCam II Module Video control

For controlling video, an interface, similar to the one in the Generic Video module, was used. It simply allows playing, pausing and stopping the video. It also lets to view the video in full screen mode.

4.2.3.2 FEATURES

EXAMINATION IMPORT

Whenever a new image and its XML are created in the watch folder, these will be automatically interpreted and added to the list in the left side. Alternatively, by clicking the *Load Images* button (Figure 14-A), the images can be imported manually. Note that at every module's startup, all the files within the watch folder are imported.

The list on the left side (Figure 14-B) – Exam List - is where all the exams are made available to the user.

The exams are grouped by Patient in a tree-like structure where the parent nodes are Patients and, their children nodes, the corresponding examinations.

The patient is automatically chosen. Automating the patient/physician selection is advantageous speed and reliability wise. Nevertheless, it is important that the user verifies both fields at the Patient/Physician Control and, in case the fields are either blank or incorrectly chosen, manually select those using the search Patient/Physician feature.

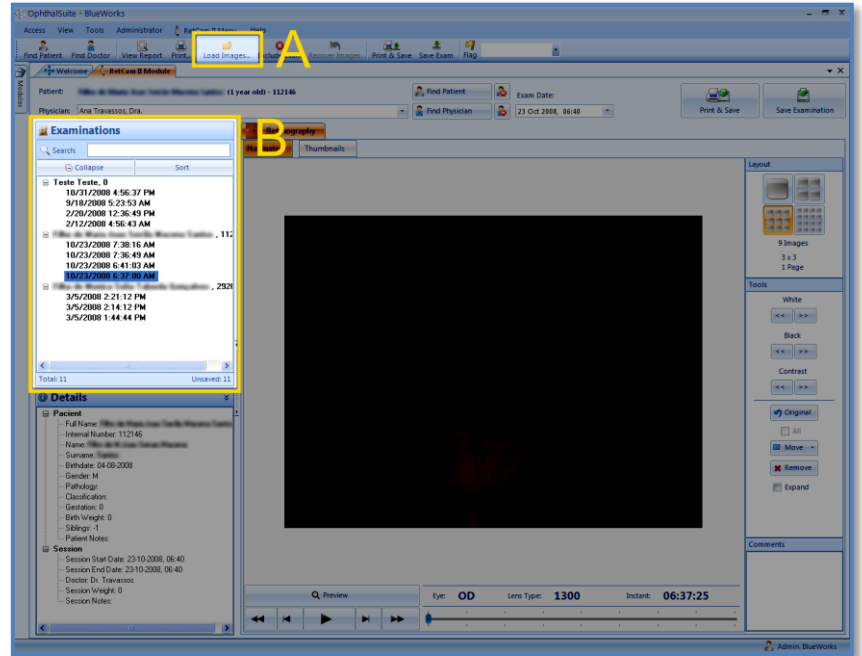


Figure 14 - RetCam II Module import elements

DETAILS

Confidential Section

EXAMINATION VISUALIZATION & MANAGEMENT

For viewing a patient's exam(s), the user has two key views:

EXAMINATION VIEW

When choosing a single examination from the list (Figure 14-B), the images are loaded onto the main section and split in tabs according to its examination type. Here the user has two modes:

- In Navigator mode it is possible to view a slideshow of all images from that type (i.e. useful for angiographies in order to view the contrast's agent progression) (the elapsed time between each slide is modifiable). The acquisition time, eye and lens used is shown to the user.

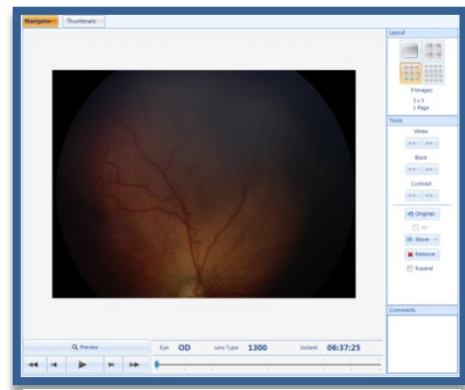


Figure 15 - RetCam II Module Navigator mode

- In Thumbnail mode, the user can view selectable thumbnails of all the images and obtain a general view of the examination. In this mode, the user can choose which images will compose the report. The number of thumbnails per row is user-defined.

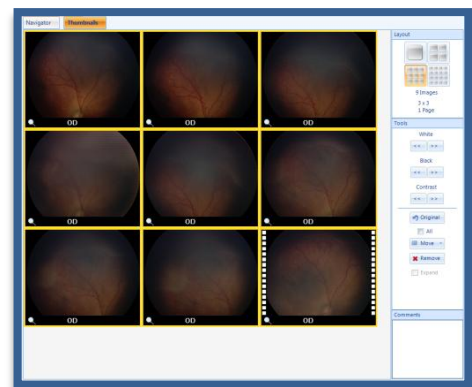


Figure 16 - RetCam II Module Thumbnail mode

In addition, this view allows the user to delete images or change image types by using the *Move* button that lists all the available types and add comments to the exam.

PATIENT VIEW

If a patient node from the Exam List is chosen, a table, (Figure 17), with the entire patient's exams, is shown. The user gets an overview of the entire patient's examinations and can set the

Patient/Physician fields in multiple exams (useful if several exams need to have the Patient's or Physician's fields manually inputted).

| Save | Saved | Date | Images | Doctor's Name | Valid Doctor | |
|-------------------------------------|-------|-----------------------|--------|-------------------|--------------|----------------------|
| <input checked="" type="checkbox"/> | ✘ | 10/23/2008 7:38:16 AM | 4 | John Thompson, MD | ✔ | View |
| <input checked="" type="checkbox"/> | ✘ | 10/23/2008 7:36:49 AM | 5 | John Thompson, MD | ✔ | View |
| <input checked="" type="checkbox"/> | ✘ | 10/23/2008 6:41:03 AM | 12 | John Thompson, MD | ✔ | View |
| <input checked="" type="checkbox"/> | ✘ | 10/23/2008 6:40:41 AM | 9 | John Thompson, MD | ✔ | View |

[Click here to validate selected exams](#) Validate

Figure 17 - RetCam II Module Grid with all the patient's exams

Examination details containing some pertinent fields that compose the XML are also shown in the table below the Exam List.

Each view mode has its own advantages. Although examination view is where the user is presented with the module's advanced functionalities it only allows to save one examination at once. On the other hand, the Patient view is more oriented to bulk-saving but does not have any additional tools.

It is also possible to discard examinations or patients from the Exam list. By discarding examinations, they will no longer be loaded with the module's startup (they must be loaded manually).

DETAILS

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EXAMINATION SAVING

As explained before, there are two kinds of saving procedures. The user can save single or multiple examinations depending on the selected node. In Examination view, since only one examination is selected, the user can save that unique examination, assuming that the Patient/Physician fields are correctly selected. Following this same assumption, in Patient view, the user can save all the examinations from the selected Patient.

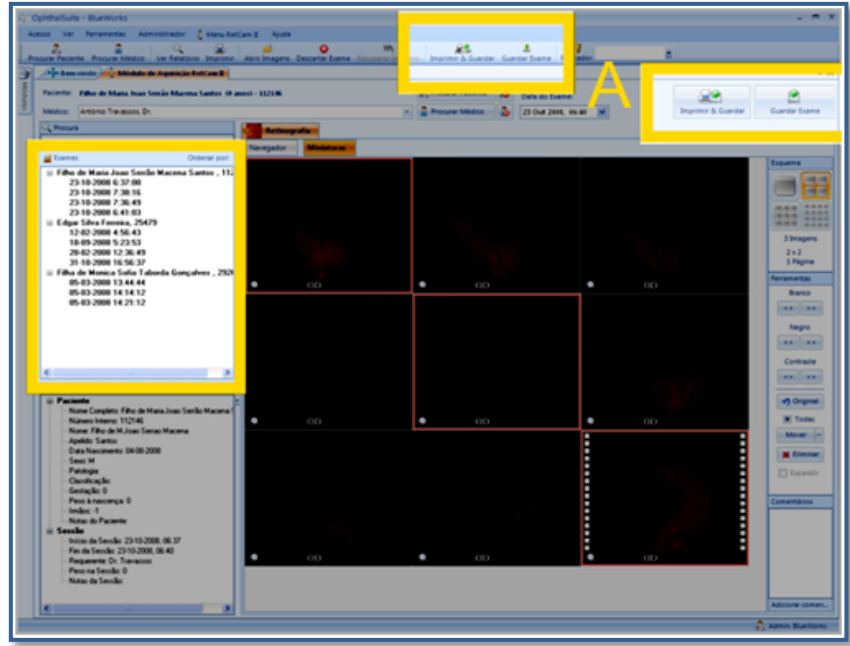


Figure 18 - RetCam II Module saving tools

The save action is accomplished by clicking the *Save* button or *Print & Save* (only available for a single examination), (Figure 18-A), in case report printing is desired; or by selecting either one of the previous possibilities from the context menu associated to the selected node.

It is important to note that for each saved examination, besides the images that compose the full exam, a summary report (PDF), containing the images that the physician chooses as more important, is also created. When accessing that information with other software tools, it is usual to have a look at the summarized report first and, if additional information is necessary, analyze the individual exam images. This task is completely hidden from the user.

At the end of every save a user-configurable behavior is applied: Remove current exam from tree; Leave current exam in tree; Display a pop-up window forcing the user to choose one of the previous options.

DETAILS

Confidential Section

EXAMINATION BACKUPS

Before any examination saving starts, a local backup file is created.

While the saving is being performed, the module can lose its connections with the DB leading to unsuccessful saves in the DB. By providing recoverable exams, the save action can be resumed later. The user can try to save the examination again by using the Exam Recovery Tool which is automatically launched in every module's startup.

The exams are displayed in a list. After selecting an item from the list, exam details are shown and it is possible to view that exam's report. The user can either delete or save any number of exams by selecting them with the *CheckBox* control.

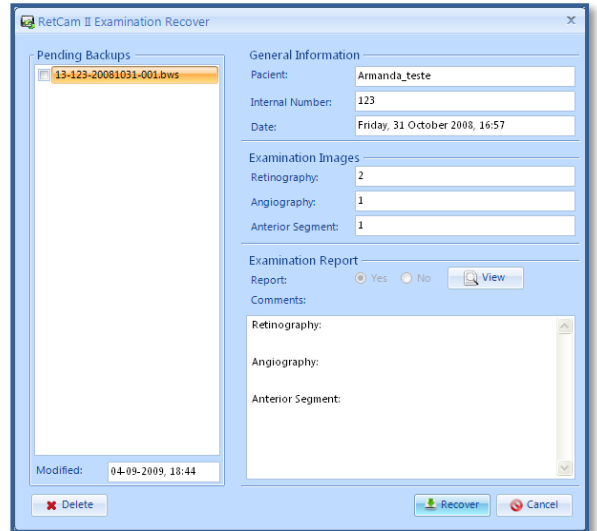


Figure 19 - RetCam II Module Exam Recovery Tool Window

DETAILS

Confidential Section

IMAGE PROCESSING AND ADVANCED VISUALIZATION

In Examination view, choosing either one of the Navigator or Thumbnail modes, the user has the tool menu, (Figure 20), where he/she has the possibility to:

- Adjust image properties such as brightness, contrast or gamma levels;
- Delete/move images;
- Add comments to that specific examination type;
- Choose the report image layout (1x1, 2x2, 3x3 and 4x4).

While in Navigator mode, only the current image has the image processing applied, however, in Thumbnail mode all the selected thumbnails change. These actions are reversible by clicking the *Original* button.

Below the Report configuration buttons it is possible to view the number of selected images and, by considering the layout chosen, the number of pages that will compose the report.

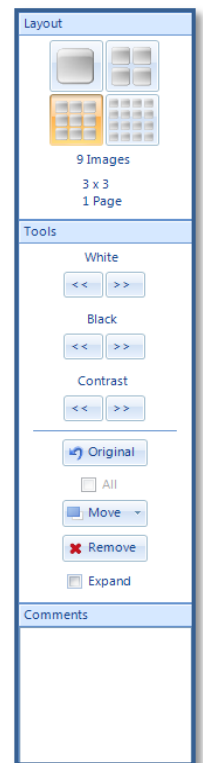


Figure 20 - RetCam II Module Toolbar for report layout control, image manipulation and comment adding

DETAILS

Confidential Section

ADVANCED VIEW MODE

The user can also access the advanced view mode by clicking the *Preview* button found in the Slideshow control panel of the Navigator mode or the magnifying glass present in every thumbnail.

This mode pops-up a new maximized window where the user has gamma, brightness and contrast modifiers; image zooming;

The user can also save the image to a chosen location or save the current modifications that are propagated to the Examination view.

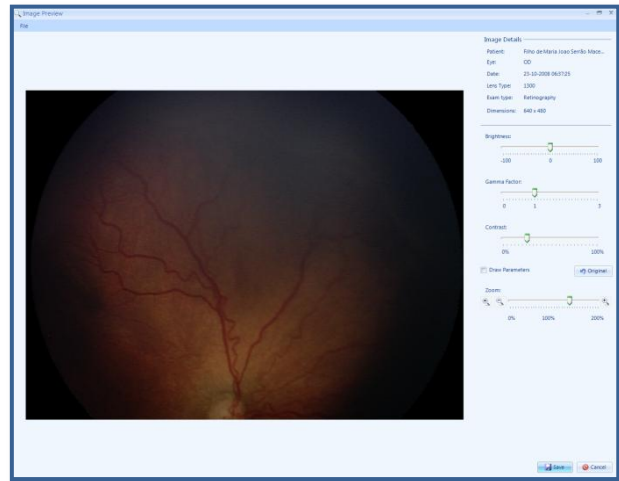


Figure 21 - RetCam II Module Advanced View Mode Window

DETAILS

Confidential Section

EXAMINATION LIST FEATURES

In order to aid the user in finding a specific patient, a dynamic filter is available. The list is constantly filtered whenever the filter field is modified. The list is filtered either by Name or Internal Number. It is also possible to sort the list, in an ascending or descending fashion, by Name, Internal Number or Session Date.

Additionally, unsaved examinations are marked in a bold font and, at the list's bottom, it is possible to view the number of total and unsaved exams.

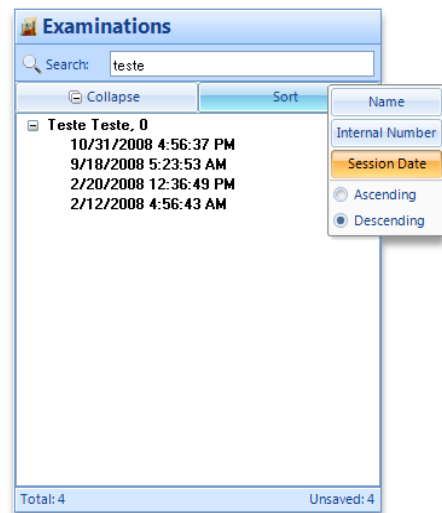


Figure 22 - RetCam II Module Examination List

Confidential Section

4.2.3.4 DEPENDENCIES

Confidential Section

4.2.4 SOFTWARE TESTS

Several tests were conducted in order to validate the module's proper functioning and compliance with the defined requirements. The tests not only try to confirm the features validity but also verify other factors such as memory consumption or how the software deals with unexpected situations such as network disconnections.

The conducted tests can be found in attachment "3. RetCam II Module Tests".

4.2.5 FURTHER IMPROVEMENTS

Even though the software testing has fulfilled the initial requirements, several modifications can be made in order to improve the module's functioning:

- Use the BWMedia class, developed for the GenericVideo Module, for all the video playing. The developed class allows video parameter configuration (brightness, contrast, etc...), zooming and frame capturing that could be useful in this module.
- Add drawing tools that allow the user to add visual annotations on the image.

4.3 RODENSTOCK SLO ACQUISITION MODULE

4.3.1 EQUIPMENT OVERVIEW

The Rodenstock Scanning Laser Ophthalmoscope (SLO) allows one to map the retinal function and assess visual rehabilitation methods for affected individuals (7). It provides an unbiased way to examine the visual function of eyes suffering from lens opacifications or vitreous floaters.



Figure 23 - Rodenstock SLO

In order to provide paper-free functionality to this equipment, the Rodenstock SLO module was developed as a sub-component of the parent application, *OphthalmSuite*.

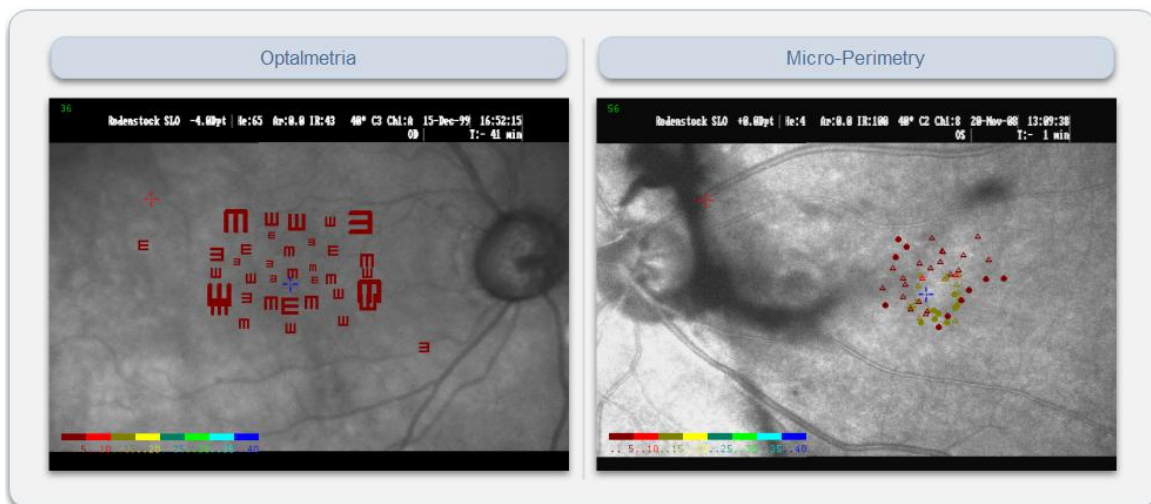


Figure 24 - Rodenstock SLO Exam types

The equipment allows two types of examinations. The first is an opticalmetria exam that allows the physician to access the patient's visual acuity by displaying optotypes with several dimensions. The other consists in a micro-perimetry exam that allows the physician to assess the patient's peripheral vision.

4.3.1.2 EXAM ANALYSIS & EXPORT

Being connected to a legacy computer without network capabilities, a network adapter had to be added. Similarly to the RetCam II Module, it would be best to install the Module in the proprietary PC but its OS is Windows 95 and the computer characteristics do not meet the ideal requirements for running *OphthalSuite*. The best approach is to manually export the image to a network folder.

The equipment allows the user to manually export a fundus image along with a metadata file that contains the exam’s data consisting on the patient response to various visual stimuli. Unfortunately, since patients aren’t registered in the equipment’s software, no Patient info is contained within the metadata file or the image itself. There is no way for the module to automatically select the patient unless the user, when exporting the exam, sets the filename with an identifying string, e.g. the patient’s internal number. Additionally, eye information (i.e. “OS” or “OD”) is only contained within the image.

4.3.2 REQUISITES ANALYSIS

Table 4 - Rodentstock SLO Acquisition Module Requisites

| # | Requisite |
|-----|--|
| R1 | Modular integration with the main application (Plug-in) |
| R2 | Simple, appealing and easy-to-use environment |
| R3 | Permanent lookout for newly created files in a specific folder – Watch folder. |
| R4 | Automatically import newly created files in the watch folder |
| R5 | Automatically select patient by analyzing the imported exam’s filename |
| R6 | Simple/Advanced Patient/Physician Choice |
| R7 | Automatically draw the visual stimuli, that are contained within the data file, on the image |
| R8 | Thumbnail user control for each image |
| R9 | Discarding/Recover an image |
| R10 | Discard/Recover an exam |
| R11 | Image pre-viewing with zoom capability |
| R12 | Report layout configuration |
| R13 | Add/Remove any image from the report |
| R14 | Multiple report pages |
| R15 | Automatic and complete report info |
| R16 | Report is saved in the DB and a server folder as a PDF |

| | |
|-----|---|
| R17 | Report preview |
| R18 | Images and report are saved in pre-defined server folder; image thumbnails and additional information is stored in the DB |
| R19 | Module settings window |
| R20 | New images tooltip notification |
| R21 | Exam recovery for unsuccessful saves |
| R22 | Save Exam Contents only |

4.3.4 IMPLEMENTATION

4.3.4.1 OVERVIEW

Similar to every other module, the Rodenstock SLO Acquisition Module was developed coherently with *OphthalSuite*.

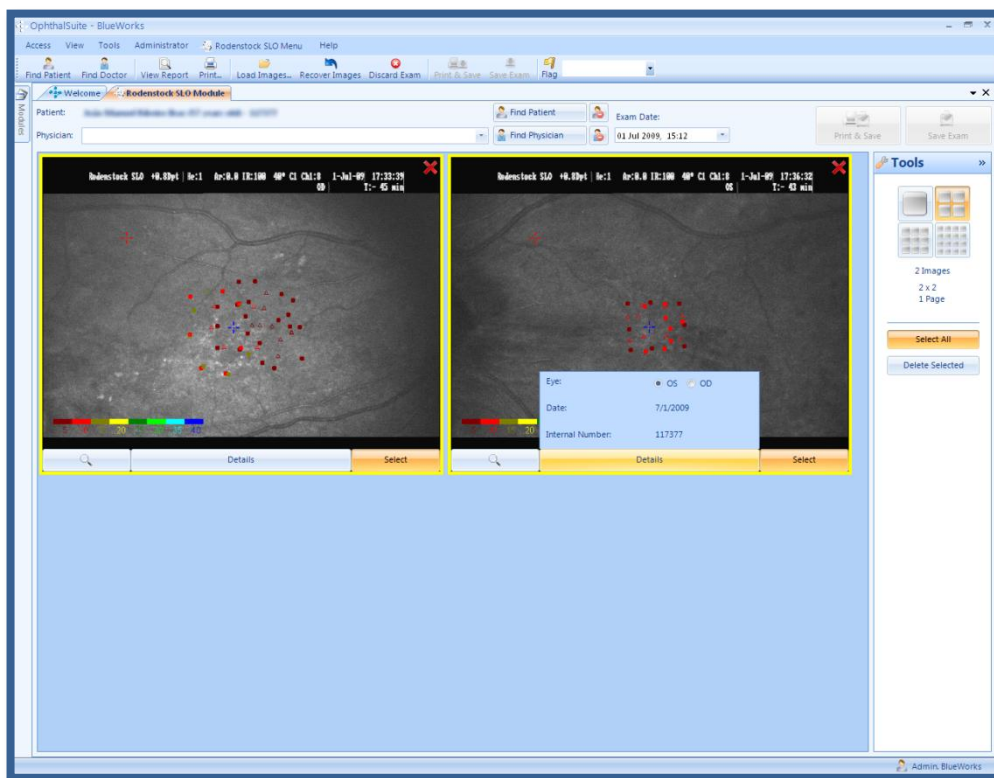


Figure 25 - Rodenstock SLO Acquisition Module Overview

Figure 25 is the module's main window. Unlike the RetCam II Module, there is no need to create specific or advanced functionalities. The module is only required to replicate the drawing in the equipment software and display the images to the user in order to save them. It needs to be as simple and intuitive as possible.

This section will describe those functionalities in a common user and developer point of view.

4.3.4.2 FEATURES

EXAM IMPORT

Importing exams, similarly to the previous module, can be done automatically or manually. However, it only loads images that are newly added to the list (it doesn't load all the images from the watch folder at startup like the RetCamII Module). When images are imported, they are processed in order to replicate the equipment's software visual stimuli drawing. Afterwards, each image is properly arranged in the main window.

DETAILS

Confidential Section

EXAMINATION VISUALIZATION& MANAGEMENT

Each imported image is represented by a selectable Thumbnail. This Thumbnail displays the interpreted image and additional info (interpreted eye, date and internal number) by clicking the Details button. The Thumbnails are displayed in a user-configurable arrangement, i.e. the user selects the number of thumbnails per row. Finally, each Thumbnail can be individually discarded by clicking in the red "X" in the upper-right corner.

The selected Thumbnails compose the report. In addition, the report layout can be chosen in the Tool panel on the right. (1x1, 2x2, 3x3 and 4x4 images/page). The Tool panel also allows the user to select all the Thumbnails and to delete the selected Thumbnails.

For patient selection, if all the existing thumbnails were identified with the same patient, this is automatically selected in the Patient/Physician Control Figure 27-1. Otherwise the user must select it manually.

By clicking in the magnifier glass button the image is opened in a window for advanced viewing.

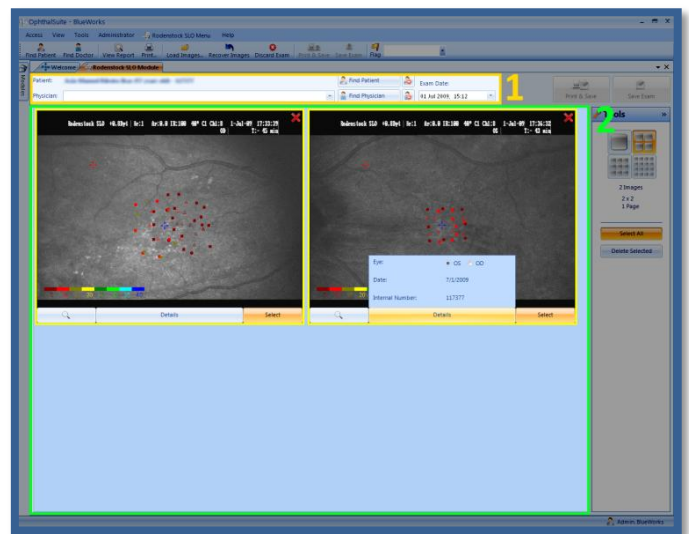


Figure 26 - Rodenstock SLO Module management tools

DETAILS

Confidential Section

EXAMINATION SAVING & REPORT

If both the Patient and Physician fields in the control previously explained (Figure 13) are defined, the Save and Print & Save buttons are made available to the user. At this stage, the user can save the exam and optionally print the generated report composed by all the thumbnails that are selected.

After every examination save, the user can have the exam removed from the workspace, since it is already stored in the DB. This action is definable in the module settings windows. The same behavior from the RetCam II module is found here. Three choices are available: automatically discard the exam; ask the user for confirmation; do nothing.

EXAMINATION BACKING UP

Similar to the RetCam II module, a backup is created before any DB save. If the save procedure is unsuccessful, the user can retry to save it by using the Recover Exams tool. This tool will display all the created backups in a list. By selecting one of the items it is possible to view basic info about the exam as well as the generated report.

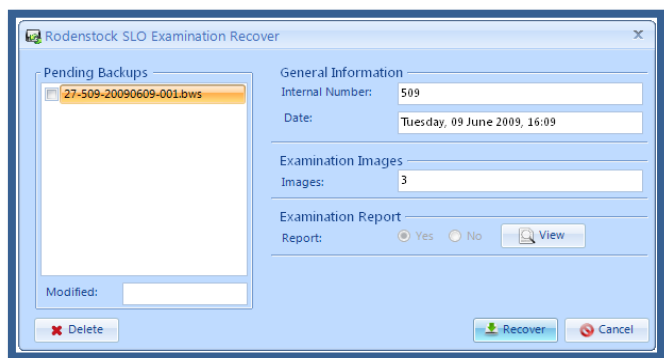


Figure 27 - Rodenstock SLO Module Exam Recovery Tools window

This tool is automatically launched in every module's instance. If any pending backups are found, it will try to resave them.

DETAILS

Confidential Section

PREVIEW MODE

This mode pops-up a new maximized window where the user has image zooming. The user can also save the image to a chosen location.

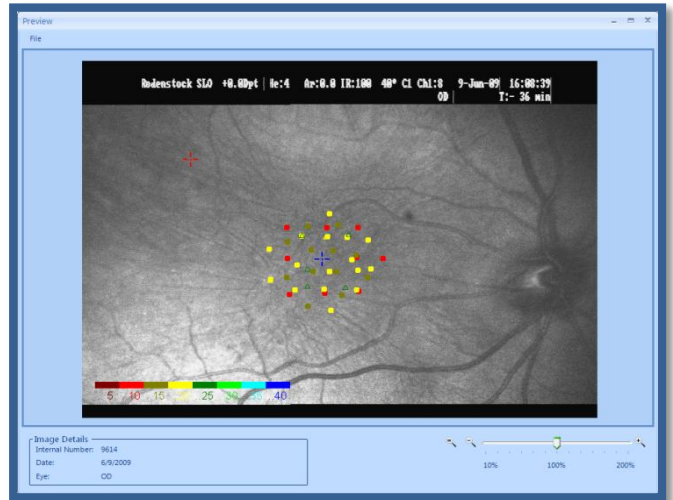


Figure 28 - Rodenstock SLO Module Preview Mode window

DETAILS

Confidential Section

4.3.4.3 DEPENDENCIES

Confidential Section

4.2.5 SOFTWARE TESTS

The tests try to validate the module just like the RetCam II Module.

The conducted tests can be found in attachment “4. Rodenstock SLO Module Tests”.

4.2.6 FURTHER IMPROVEMENTS

Confidential Section

4.4 GENERIC VIDEO ACQUISITION MODULE

4.4.1 EQUIPMENT OVERVIEW



Figure 29 - UltraScan

Initially, it was proposed that a module was developed for the Alcon® UltraScan®, an ecograph targeted for B-Scan and Biometry ecographic needs. Unfortunately, this equipment does not provide any network, export or save capabilities. It only lets the user print the current examination using a video printer.

The only way to extract the information from the equipment is by using the video-out connectors. It has three video-out connectors: one for the monitor display, other for the printer and an s-video female connector.

Acquiring the said video signal would solve the problem. Therefore, the need to create a generic module that would acquire and record the video feed using a video-input arose.

For the video acquisition a Pinnacle Dazzle DCV-100 was used. This hardware's specifications are:

- Video inputs: Composite video (RCA), S-Video (mini-DIN)
- Audio inputs: Stereo audio (RCA x2)
- PC connection: Hi-Speed Universal Serial Bus (USB) 2.0



Figure 30 - Dazzle DCV-100

4.4.1.1 EXAM ANALYSIS

Even though this module is meant to be generic (i.e. it isn't oriented for a specific examination type), there are several general features that would be useful.

The action of just recording the video might not be enough. For instance in the UltraScan case, in order to replicate the equipments behavior, the module should be able to retrieve frames from a video. By capturing several frames from the video it could be possible to create a report for that specific video, granting the same principle from the other modules.

The fact that other modules allow the user to manipulate image properties or to zoom in the image could also be applicable to videos. It is true that in an ophthalmologic environment the work is primarily made with images but, by providing such tools, videos manipulation would become as common and useful as image manipulation.

Moreover, it is possible that a single person is operating both the equipment and the module. As explained before, the module shouldn't hinder the user's workflow, so the module should be as automated as possible. By implementing automatic recording would relieve the user from the additional tasks of operating the module.

Since several equipments can be connected to the module or that specific equipment could have several examination types, e.g. UltraScan, it should be possible to define the type of examinations and media. This way, if a specific equipment does not need more advanced features, the module is sufficient for the record and save actions. If not, it's just a matter of adapting this module to the equipment's needs.

4.4.2 REQUISITES ANALYSIS

Table 5 - Generic Video Module Requisites analysis

| # | Requisite |
|----|--|
| 1 | Modular integration with the main application (Plug-in) |
| 2 | Simple, appealing and easy-to-use environment |
| 3 | Record videos from an input device |
| 4 | Open recorded videos |
| 5 | Capture frame from videos |
| 6 | Play video frame-by-frame |
| 7 | Choose Eye (OS/OD) for each video and image |
| 8 | Thumbnail user control for each video/image |
| 9 | Discarding/Recover a video/image |
| 10 | Discard/Recover an exam |
| 11 | Image/Video pre-viewing with zoom capability and properties manipulation |
| 12 | Report layout configuration |
| 13 | Add/Remove any image from the report |
| 14 | Multiple report pages |
| 15 | Automatic and complete report info |
| 16 | Report is saved in the DB and a server folder as a PDF |
| 17 | Report preview |
| 18 | Add comments to report |
| 19 | Module settings window |
| 20 | Simple/Advanced Patient/Physician Choice |
| 21 | Exam recovery for unsuccessful saves |
| 22 | Automatic recording and stopping |
| 23 | Video, images and report are saved in pre-defined server folder; image thumbnails and additional information is stored in the DB |
| 24 | Save exam contents |

4.4.3 IMPLEMENTATION

4.4.3.1 OVERVIEW

Following the same rule as the previous modules, the coherence is maintained. For this module, some emphasis was given to visual details as it will be explained further ahead.

The module can be divided into three main layouts:

VIDEO VISUALIZATION & RECORDING

This is the primarily used view. It is here that the user will record or play videos and capture frames. It is also where the video and image management is done.

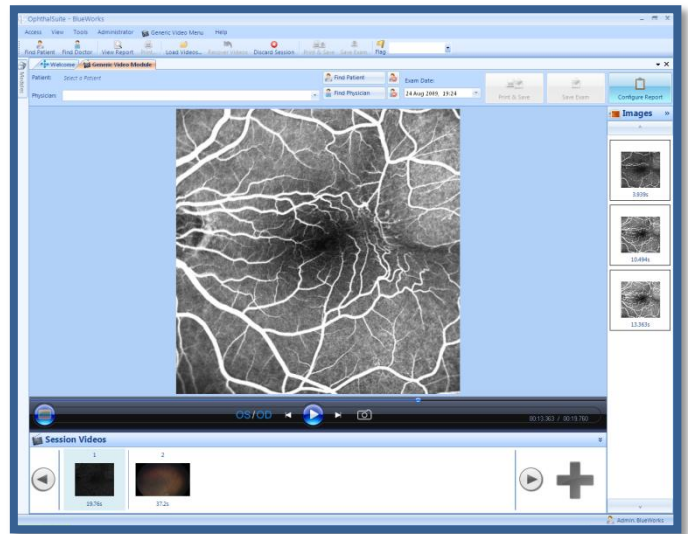


Figure 31- Generic Video Module recording view

REPORT CONFIGURATION

In this view the user can configure a report with the images that were captured.

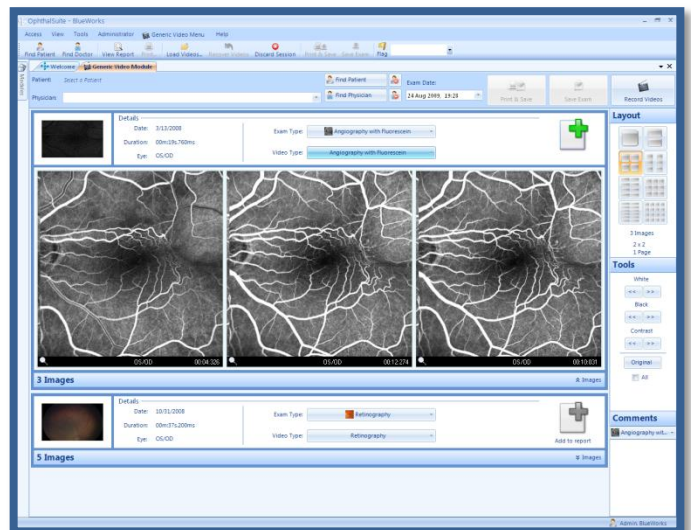


Figure 32 - Generic Video Module report view

Since this module is more complex than the Rodenstock SLO Module, it is necessary to explain the underlying engine of this module first in order to understand the module's features.

4.4.3.2 ENGINE

The module's main workflow is conducted by using three major objects. At any given time, the module contains a unique Session object that holds every loaded video. Whenever a video is loaded, a new video object is added to that session and several operations are performed: extraction of the date of the file by finding its last write time; using the FrameGrabber library (8), the class obtains the video frame size and the video's first frame; by creating a simple DirectShow Filter Graph (9) and querying the *IMediaSeeking* interface the video duration is extracted.

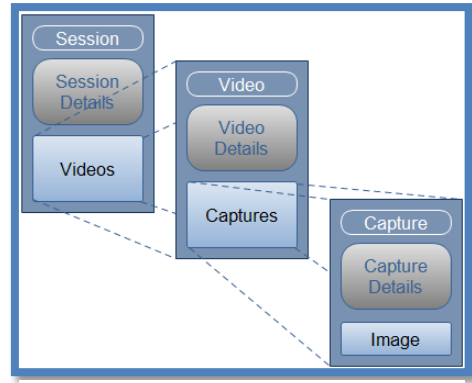


Figure 33 - Generic Video Module main classes

The DirectShow is an API and multimedia framework developed by Microsoft for Windows platforms (10) that allows video reproduction and recording. It is based on the Component Object Model (COM) (11) and was originally developed to be used with C++ programming language. Since we are working with C#, we used a managed DirectShow library for the .NET Framework, the DirectShow.NET (12).

Since it is based on COM, this engine can be viewed as several software modules - Filters (13) - with specific functions, connected together. The conjunction of connected modules is called a Filter Graph. Filters can have different types: Source (e.g. video input channel); Video Overlay, Conversion & Mixing (e.g. *VMR9* renderer used for video manipulation and displaying); Codec (e.g. MP4 used to encode or decode a video stream); Sink (e.g. *FileSink* used to save a stream to a file); ... It is just a matter of choosing the combination of Filters that fits our objectives and connect them.

The library provides an interface oriented for Filter Graph building – the *IGraphBuilder* (14). Usually, this interface is able to create the complete Filter Graph by itself using the Intelligent Connect feature (15); we just need to specify the Source Filter and the Sink/Renderer Filter and it will add and connect the intermediate Filters needed for video playback. Unfortunately, for some input devices the interface does not succeed and the intermediate Filters need to be manually added and connected. By manually creating the Filter Graph, not only we ensure that it will work properly but also we can customize the Filter Graph itself to meet our needs by adding specific Filters.

The Filters (16) are manually connected by using virtual input and output Pins found by via the *DsFindPin* Interface and connecting them using the *ConnectDirect* method that the *IGraphBuilder* provides. If Intelligent Connect is required, we just need to find the output Pin from the device and the input Pin from the renderer, call the Connect method provided by *IGraphBuilder*, and all the intermediary Filters required (such as codec, splitter, etc...) are added and connected.

Having the DirectShow elements explained, it will now be demonstrated how this API can be used to successfully implement the module.

It is obvious that video recording and video playing have different purposes that need specific features. Thence the creation of two distinct classes with distinct Filter Graphs .These two classes were assembled into a library, the BWMedia, which provides the corresponding interfaces to the user.

VIDEO CAPTURE

Confidential Section

VIDEO PLAYBACK

Confidential Section

COMMON FEATURES

Confidential Section

MEDIA PLAYER

At the module's start up, an instance of each class is created. In order to control those classes a Media Player like control was created. This is the control that holds the two BWMedia classes and controls both video playing and recording.

The Media Player assumes different control bars depending on the action required:

PLAY VIDEO



Figure 34- Generic Video Module Video Playback Control

RECORD VIDEO



Figure 35 - Generic Video Module Video Record Control

Above the control interface is the main Panel used for displaying the VMR9 rendering.

Resembling the Windows Media Player interface, both controls are very intuitive. The leftmost button displays the Advanced Video Vie Mode, the *OS/OD* button allows the user to change eye for

the current video and the usual *Play, Pause, Stop* buttons. Additionally, the Video Playback Control (Figure 37) has specific buttons for viewing the video frame-by-frame or to take a snapshot of the video at that exact moment. The *AUTO* button in Video Record Control (Figure 38) activates or deactivates the automatic recording feature.

By now we have pointed all the most important features and we are in order to present the module's features.

VISUAL DETAILS

Some of the buttons of this module as well as the Media Player interface are custom made using the (meter ref pa lib). They have the same features as the original control but, its graphical presentation is different. The buttons are created using a set of pictures and by setting the correct mouse events gives the impression of animation. In addition, the Exam and Image *FlowLayoutPanel* controls where the thumbnails are displayed have special properties. If the Thumbnails do not fit the panel, scroll bars won't be visible. Instead, for scrolling through the various Thumbnails, the user presses the Arrow buttons that are associated to Win32 API message sending (17).

Also, custom controls that use Double Buffering, Notification Overrides or Transparency were developed. (E.g. the video display *Panel* would flicker if resized while the video was playing and disappear if the video was paused. For this specific case, a double buffered *Panel* that overrides the `WM_ERASEBKGD` notification, preventing the background from being erased, was developed.)

All these visual tweaks aim to improve the user experience.

4.4.3.3 FEATURES

EXAM IMPORT

Unlike the other modules, this module also acts as an exam generator. Not only it is used to import previously recorded videos but also allows to record new ones.

Video loading can happen in two different ways:

- Manually load the videos using the Load Video button in the toolbar
- Whenever a recording session ends, the newly created video is automatically loaded.

Each loaded video is displayed as a thumbnail in the Session Videos list.

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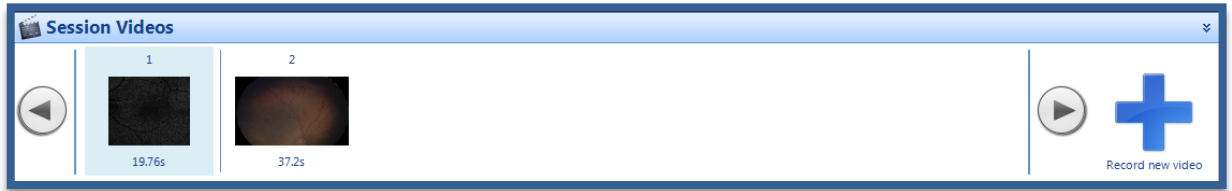


Figure 36 - Generic Video Module Video list

EXAMINATION VISUALIZATION & MANAGEMENT

In order to view a video, the user simply needs to click on the Thumbnail control and the video will be loaded onto the main panel, Figure 40-2, alongside the video playing controls. For recording new videos, the user simply clicks the "+" button in Figure 40-1 and the main panel will display the input feed and the video recording controls. The video's captures are also loaded onto the Image list on the right.

Capturing frames is only available while viewing a video and is accomplished by clicking the Camera button on the Media Player bar. Each capture is added to the Image list on the right Figure 39.

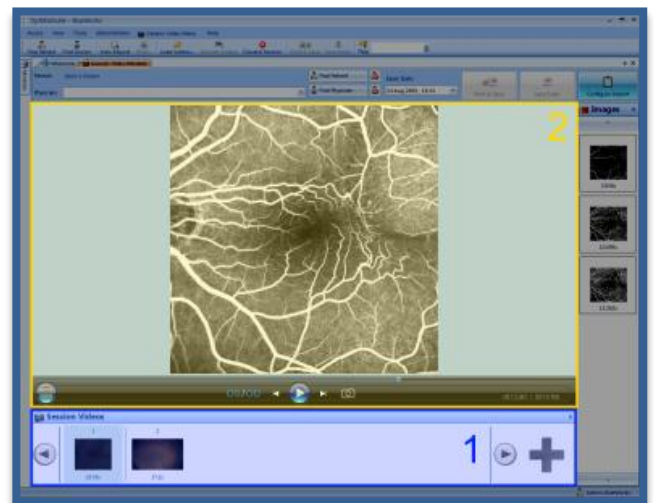


Figure 37 - Generic Video Module video playback and management

It is also possible to discard the current session by clicking the Discard Session button in the toolbar. Similarly, it is possible to discard any loaded video or capture by clicking in the "X" button that appears every time the user has the mouse pointer over the corresponding thumbnail.

DETAILS

Confidential Section

EXAMINATION SAVING

The *Save* button becomes enabled when at least one video exists and the Patient/Physician fields are defined. This module does not interpret any patient or physician data from the videos and, therefore, those fields have to be selected manually.

After ensuring that all requirements are met, the user can save the videos and corresponding captures.

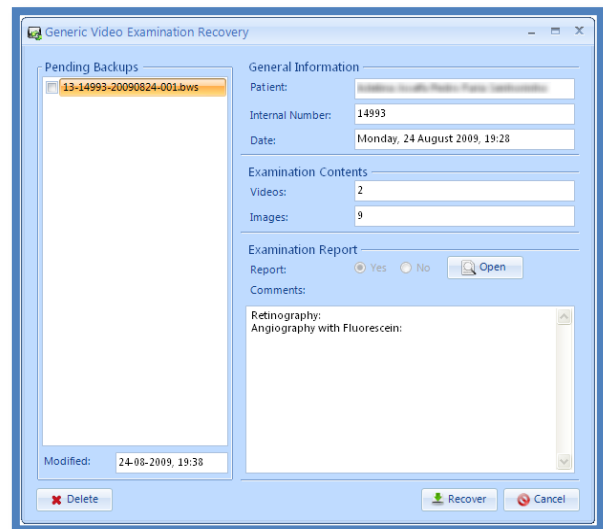
After the save, the same feature from other modules is conducted. The user selects which is the module's behavior after each save: Discard the exam, ask the user or do nothing.

DETAILS

Confidential Section

EXAMINATION BACKING UP

Examination backing up is also available here. It has the same behavior from the previous modules and, as always, it displays exam info as it can be seen in the image on the right.



DETAILS

Confidential Section

REPORT CONFIGURATION

The report configuration section (Figure 33) displays an overview of the elements that compose the current Session.

Each video is represented by a special block (Figure 42) that displays the video's first frame, some video details and the number of captures for that given video. Moreover, in this control, the user can select the Exam and Video types and Add/Remove the captures from the report.

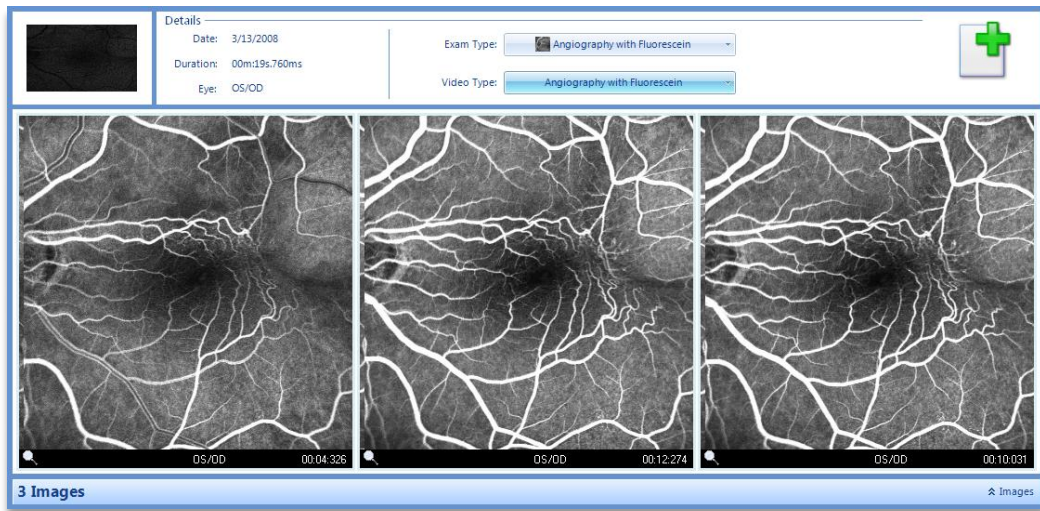


Figure 39 - Generic Video Module Report Video Block

The video block control also holds thumbnails for all the captures. By clicking on the Images button, the thumbnails section is either expanded or collapsed. Note that if a video does not contain any captures, this feature is disabled.

The image thumbnails behave the same way the RetCamII Module Thumbnails do. It displays the image, the instant, a selectable OS/OD eye field and the magnifier glass button for Advanced Image Viewing. Additionally, these Thumbnails are selectable in order to define which ones compose the report and have the image processing applied.

The number of Thumbnails per row inside a video block control is user-definable.

Layout configuration, image processing and comments are once again made available in the Toolbar on the right. The functioning principles are the same as the previous modules: image processing is applied to all selected images, and comments are added only to the chosen Exam type. For further explanation in this Toolbar see chapter 4.2.3.2.

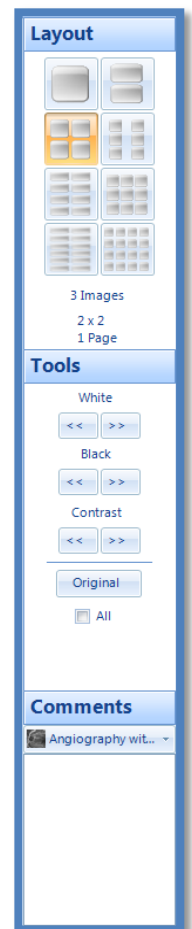


Figure 40 - Generic Video Module Toolbar

DETAILS

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ADVANCED IMAGE VIEW MODE

This mode is identical to the one in the RetCam II Module. For further details see chapter 4.2.3.2.

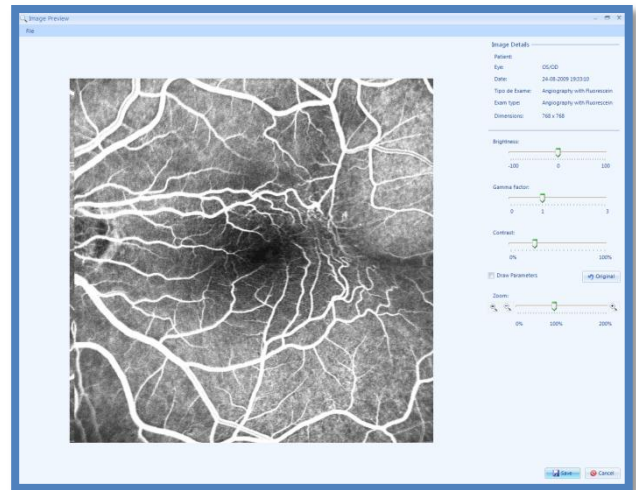


Figure 41 - Advanced Image View Mode window

ADVANCED VIDEO VIEW MODE

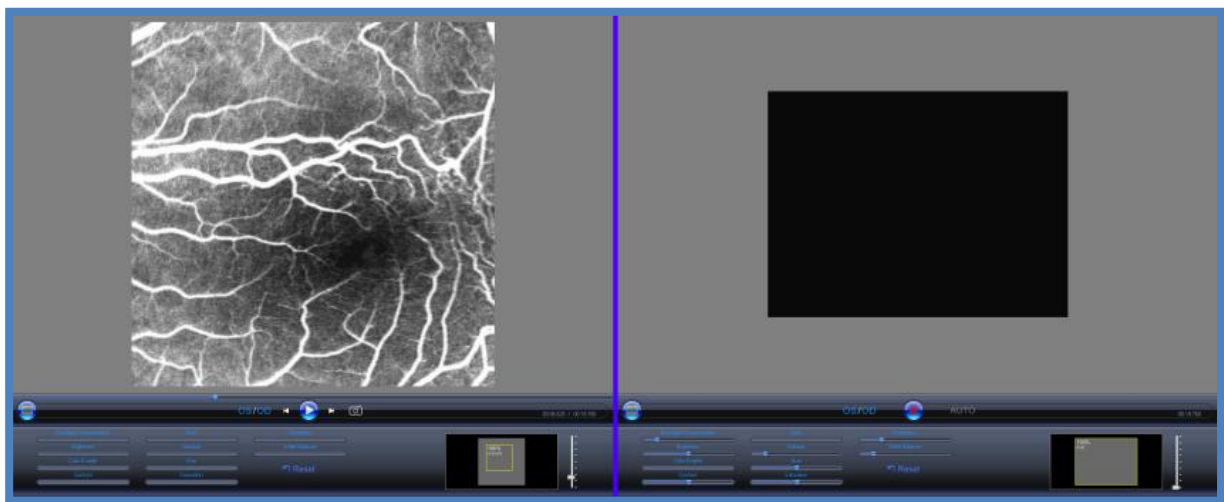


Figure 42 - Advanced Video View Mode window

This view mode, accessible by clicking the TV button on the Media Player interface, displays the Media Player control in full screen. It's where the user can manipulate the available video properties and access video zoom. Depending on the action being performed, recording or playing, the Media Player always assumes the corresponding interface.

Modifying the video properties, as explained before is dependent on the hardware or the codec used for encoding the playing video. Nevertheless, if any video property – Brightness, Contrast ... - is unavailable, it will be hidden from the user.

Video zoom can be applied in two different ways. By using the mouse wheel or by moving the track bar on the right. Changing the position of the current area being viewed is also possible by moving the mouse over the video display window or by using the zoom control.

The Zoom Control was created in order to assist the user in perceiving the current area of the video being viewed. The gray area corresponds to the area of the video while the yellow frame to the area being viewed. The zoom percentage and coordinates is also displayed. In addition, the user can move the yellow frame in order to change the video position.

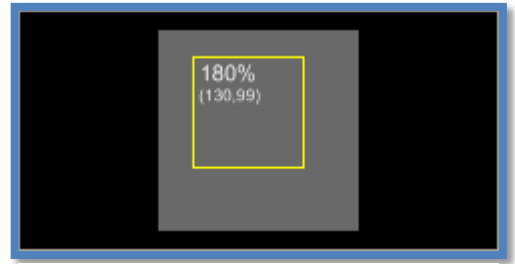


Figure 43 - Video Zoom control

DETAILS

Confidential Section

AUTOMATIC VIDEO RECORDING

Automatic video recording can assist a user that is single-operating both the equipment and the module. By clicking on the Media Player interface *AUTO* button, the module starts recording when the video feed is not blank and stops recording when it is. Blank doesn't mean a black video but rather an image with no distinctive elements independently of the color.

To stop the recording a user-configurable interval is used, i.e. if the feed is blank for that given amount of time, the recording stops.

DETAILS

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4.4.3.4 DEPENDENCIES

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4.4.4 SOFTWARE TESTS

Following the same testing philosophy from the previous modules, several tests were conducted. The tests can be viewed in attachment "5. Generic Video Module Tests"

5. ALGORITHMS

Integrated in the previous chapter, this section will describe, in greater detail, complex algorithms that were used for the software development, particularly an Optical Character Recognition (OCR) algorithm.

5.1 SCOPE

As previously explained, the need to obtain the greatest amount of clinically relevant data is of great importance in this project's context. Unfortunately, data gathering tasks can be greatly hindered if the equipment to be integrated is some kind of legacy system with obsolete technology, if the equipment manufacturer seeks to hide the data in an unreadable proprietary format or if alphanumeric data is made available in an image format rather than in its raw format. Although legacy systems and proprietary formats can lead to situations almost impossible to deal with, the ability to interpret alphanumeric information contained within an image is an already developed field with great success.

“Optical character recognition, usually abbreviated to OCR, is the mechanical or electronic translation of images of handwritten, typewritten or printed text (usually captured by a scanner) into machine-editable text” (18).

Nowadays innumerable OCR engines are developed to be as generalist as possible while maintaining a good accuracy rate and speed. These engines need to comprise recognition for large amounts of fonts, hand or machine typed letters or different oriented text, therefore they lack specificity; the possibility of data misinterpretation exists and in a clinical scenario, where accuracy is of extreme importance, is considered unacceptable.

Given this situation the need to develop a 100% accurate OCR engine, that could return all the useful information contained in a medical examination image aroused. (In order to create an accurate engine, speed and generality would suffer major drawbacks but, given the current scenario, these limitations were acceptable.

It is obvious that having the conversion from image to alphanumeric data done manually is time-consuming, and might have human-induced errors as it consists in non-technical and repetitive copying tasks. Our replications of this process for the HFA Perimeter examinations yielded an average of 6 minutes per exam. Considering the 8101 examinations of this kind that were made in CCC, having a person manually converting the data 8 hours/day would take approximately 100 days.

5.2 REQUISITES

Summing up all the requisites in a very simple and short table, it is easy to see that the system would be made of two parts: The engine, responsible for creating an outputting text given an image, and a User Interface (UI) that would bring simplicity to the Developer/End User in creating the necessary elements for configuring the engine.

Table 6- OCR Engine requisites

| # | Requisite |
|---|---|
| 1 | Perfect classification of vital data. |
| 2 | Reasonable speed. 3-5s per exam. |
| 3 | Class ease-of-use. Enter image, obtain alphanumeric data. |
| 4 | Engine configuration generator interface. |

The engine not only should be accurate but it would also be advantageous that it had a good speed performance. Having a slow engine would seriously hinder the physician's workflow; its implementation should have as little impact as possible in the integrating application and, even though speed isn't a priority, it's necessary that the speed factor meets, somehow, a reasonable value.

Having all the requisites outlined, the first step was to do some research in what would be the best path to take for the creation of the OCR classification engine.

5.3 STATE-OF-THE-ART

OCR is a branch of the pattern recognition field and, therefore, its aim is very much alike: "the act of taking in raw data and taking an action based on the category of the pattern. This includes both supervised learning (e.g., discriminant analysis) and unsupervised learning (e.g., clustering)" (19).

The OCR classification engines can be divided in three main techniques: Template Matching, Structural Analysis and Neural Networks. Initial engines were based either on Template Matching or in Structural Analysis but with the recent developments in Neural Network research this technique has gained a lot of attention.

TEMPLATE MATCHING

Template matching is obtained by comparing a test element with all the elements from a template set. After superimposing each and every template, the sum of differences is computed (usually the Hamming distance) and the element that provided the smallest amount of error is the match. Taking this principle into account, several approaches can be followed:

- **Basic Template Matching:** The most basic approach for this method is the peephole method. Initially, the image is binarized thus obtaining a two-level density image that is computed into a $m \times n$ matrix (being m the width and n the height of the image in pixels) in which white pixels are accounted as 0's and black pixels as 1's. The creation of the peephole set requires the number of peepholes (ideally $\log_2 n$, where N is the number of characters to be classified) and the position within the matrix's space. The following step is simply the computation of the already explained sum of differences.
- Although being a very simple and straightforward method, it's easily perceivable that since this method involves computing all the elements of the template set it is a time-consuming task. Furthermore, this method doesn't take into account variations in shift or rotation. In order to surpass these limitations two methods were developed: Moment-based methods and autocorrelation. Autocorrelation came out to be an ineffective method and therefore won't be explained here (see (20)).
- **Moment-Based template matching**
- **Fourier-Series template matching**

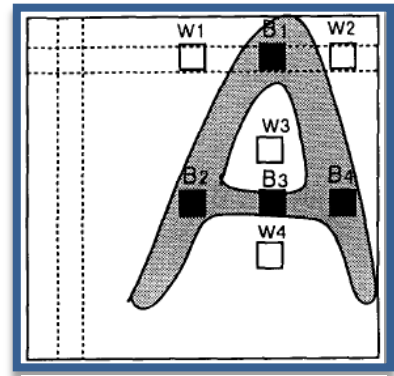


Figure 44 - Peephole representation

Due to the nature of this method, its applicability is somewhat limited to machine-printed characters. It would be very difficult to cover different handwritten shapes, strokes, etc...

STRUCTURE ANALYSIS

Structure analysis doesn't contain any underlying mathematical principle. Rather uses feature extraction by breaking down a character structure into parts and obtain the relations between the features of each part. The main problem is the choice of which parts and relations will be sufficient to correctly identify the set of characters. Usual choices are:

- **Slit/Stroke Analysis:** is an extension of peephole method. Instead of using a unique pixel, a slit or a window, without a specific position in the plane, is considered. The slit featuring is defined by the number of black pixels inside the region where the logical relationship between two pixels is extended to the general relationship between them.
- **Thinning-Line Analysis:** tries to simulate the human brain processing by defining a pixel-width line that represents the character and use its characteristics for classification. This is accomplished by eroding the sides of the line and keeping constraints in order to avoid shortening or breaking of the line. After obtaining the thinned character two kinds of analysis are made, detecting nodes/singular points and describing edges/arcs. For further explanation on this method see [\(21\)](#).
- **Bulk Decomposition:** proposed by Grimsdale et al [\(22\)](#), consists in a very simple principle in which a character is regarded as intuitive components, i.e. the letter L is composed by a vertical and a horizontal line. After obtaining each segment of the character the final description is made by attributing a describing feature for each segment (such as length, slope and curvature) and describing relations between individual segments.

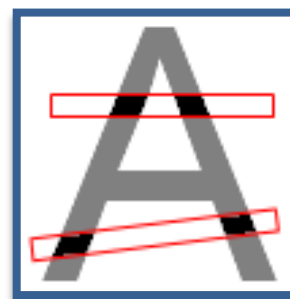


Figure 45 - Slit/Stroke Analysis representation

NEURAL NETWORKS (NN)

This technique will be explained in detail further ahead in chapter 5.5.4.

5.4 FIRST APPROACH

Considering the available solutions in the OCR field, the simplest solution was to implement an existing open-source OCR engine since the development of robust OCR engine would be lengthy.

Given that *OphthalSuite* runs in Windows environment the first approach was to use Microsoft document imaging OCR capabilities that provided good results but presented a major drawback as it depended on the existence of Microsoft Office. This approach was abandoned.

After thorough experimentation of free OCR engines the results weren't satisfactory. The results were never 100% and the process was also very slow.

A very famous engine is Google's Tesseract OCR Engine (23). It is an open-source engine with very good results when comparing with other commercial OCR engines. In some cases it can even outperform expensive OCR engines such as OmniPage (24).

This engine contains advanced algorithms for line and character extraction but wasn't built to deal with special cases.

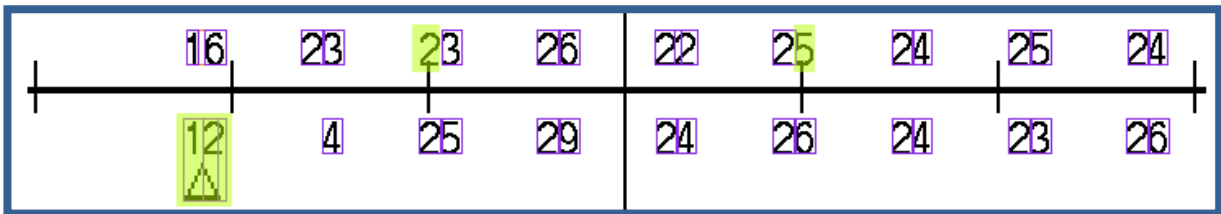


Figure 46 - Tesseract character detection

The regions highlighted in yellow are either undetected or misclassified.

The need to develop an OCR engine arose. After detailing the problem at hand, it was obvious that for a 100% classification accuracy the most obvious and correct choice for the engine model would be by using a template matching method but, due its low performance, the Neural Network (NN) solution, combined with a few pre-processing ideas from template matching methods, such as binarization and resizing, was the path chosen.

Using existing NN .NET libraries that provided a quick way to create and train NN didn't deliver the expected results. The engine turned out to be slow, and the training/testing processes too complicated and with little NN customization. The library that delivered the best results was Neuro.NET by XPIdea (see attachment 6).

An article proved to be the optimal solution to the problem as it presented all the functionalities we needed (25). It was just a matter of developing the engine.

Confidential Section

5.5.4 ARTIFICIAL NEURAL NETWORK (ANN)

5.5.4.1 OVERVIEW

Artificial intelligence aims to simulate brain processing features in a machine. John McCarthy defines it as “... the science and engineering of making intelligent machines, especially intelligent computer programs. It is related to the similar task of using computers to understand human intelligence, but AI does not have to confine itself to methods that are biologically observable” (26). Although being a subject of recent development, its applications of this science are becoming increasingly appealing.

Artificial Neural Networks (ANN) is a mathematical model representation of the mechanisms in a biological neural network derived from how the neurons function and interact with each other. The ANN model can be defined as follows:

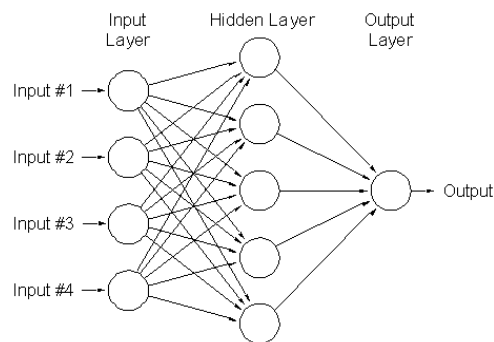


Figure 47 - ANN model representation

Each neuron-representing node receives an input affected by a certain weight, simulating the synaptic efficiency in a biological neuron, and outputs a value. The node is also affected by a threshold factor. The neuron activation, or, in biological systems, the post-synaptic potential, is defined by the sum of the weighted inputs subtracted by the threshold value (bias). The neuron output is then defined by applying an activation function (transfer function) to the activation signal. Several transfer functions can be used depending on the ANN application.

Having the ANN’s main element described, these must have some kind of connection/relation between them much like the biological NN. A typical approach is the feed-forward model usually defined by a multi-layered neuron topology that comprises an input, an output and, optionally, several intermediate hidden layers. The information flow has only one direction, from the input, through the several hidden neuron layers, to the output neurons. Each neuron from the input and hidden layers are connected to each and every neuron from the subsequent layer.

Taking this model into account, executing the ANN involves feeding the input nodes with the input values. Consequently, each layer feeds the following layer until the output layer is reached. Finally, the output is obtained by the output values of each neuron on the output layer (27).

This simple explanation is oriented to the Multi-Layer Perceptron, the chosen OCR classification engine for this project.

MULTI-LAYER PERCEPTRON NEURAL NETWORK (MLP)

Confidential Section

5.6 BW-EYE.OCR WIZARD

Confidential Section

5.6.5 DEPENDENCIES

Confidential Section

5.6.6 FURTHER IMPROVEMENTS

Confidential Section

5.7 BW-EYE.PDFTOIMAGE

5.7.1 OVERVIEW

During the development of the OCR Engine, we came across a very possible situation: equipment exports the examination in PDF format. The alphanumeric data can only be retrieved if its creation was meant that way. However, this doesn't always happen. The PDF simply holds an image with no alphanumeric data whatsoever. Nevertheless, we can apply the OCR Engine to the image from the PDF file. It's just a matter of extracting it from the PDF that holds it.

Unfortunately, there isn't any open-source library that provides this functionality and, therefore, it was necessary to develop one.

5.7.2 ENGINE

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5.8 IMPLEMENTATION

5.8.1 HUMPHREY FIELD ANALYZER (HFA)

5.8.1.1 ANALYSIS

Confidential Section

5.8.1.2 TEMPLATE/ANN CREATION

Confidential Section

5.8.1.3 CLASS CREATION

Confidential Section

5.8.1.4 TESTING

This was the first extensive testing in the engine and it needed to cover not only its accuracy but also memory leaks, stack overflows, and so on.

The testing was conducted using all the examinations of the CCC's HFA Perimeter (8101 exams).

Table 7 - HFA OCR implementation test results

Managed

| Type | Exams | Chars | Time per Exam (ms) | | | Test Time without verification | Chars/s | Accuracy |
|------|-------|---------|--------------------|----------------------|--|--------------------------------|---------|----------|
| | | | with verification | without verification | | | | |
| SCR | 1461 | 43580 | 309 | 236 | | 5min 44s | 126 | 100% |
| 3N1 | 1906 | 338003 | 1024 | 902 | | 28min 39s | 196 | 100% |
| SFA | 4734 | 1575013 | 1664 | 1401 | | 110min 33s | 238 | 100% |

Pointers

| Type | Exams | Chars | Time per Exam (ms) | | Improvement from the previous test | Test Time without verification (ms) | Chars/s | Accuracy |
|------|-------|---------|--------------------|----------------------|------------------------------------|-------------------------------------|---------|----------|
| | | | with verification | without verification | | | | |
| SCR | 1461 | 43580 | 246 | 177 | 133% | 4min 18s | 168 | 100% |
| 3N1 | 1906 | 338003 | 629 | 484 | 186,00% | 15min 22s | 366 | 100% |
| SFA | 4734 | 1575013 | 982 | 710 | 197,00% | 58min 5s | 468 | 100% |

The tests were successful. Not only the engine classified approximately 2 million characters perfectly, its memory consumption peak was acceptable (100MB) and the processing speed, ranging from 168-468 characters/s, was very good considering that the speed of some of the most accurate OCR engines is about 400 characters/s (28).

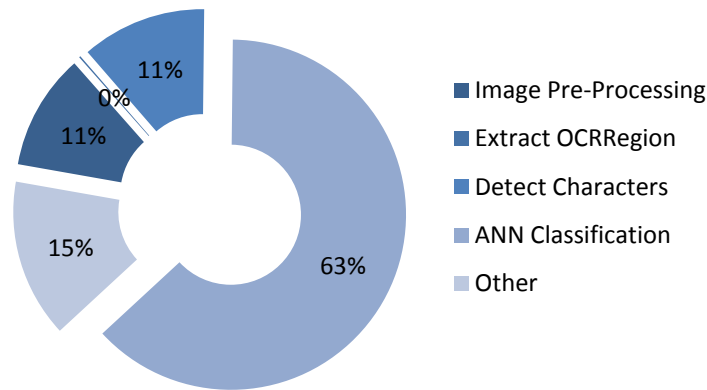


Figure 48 - HFA OCR processing time distribution

Since the regions are so well fitted, the character detection takes very little time. Also the *OCRRegion* objects do not contain any pre-processing hence the 0%. Being the ANN classification task the most time consuming, it should receive special attention in case further speed improvements are required. The tasks that fill the other 15% correspond to memory disposal, image loading and other dataflow operations inherent to the engine.

5.8.2 RETCAM II

5.8.2.1 ANALYSIS

During the RetCam 2 module analysis phase, we discovered that the XML export file doesn't contain information about the instant of the angiography images.

One alternative was to apply the OCR engine to the instant area. It is visible that implementation was very simple: only one region containing numeric and punctuation symbols.

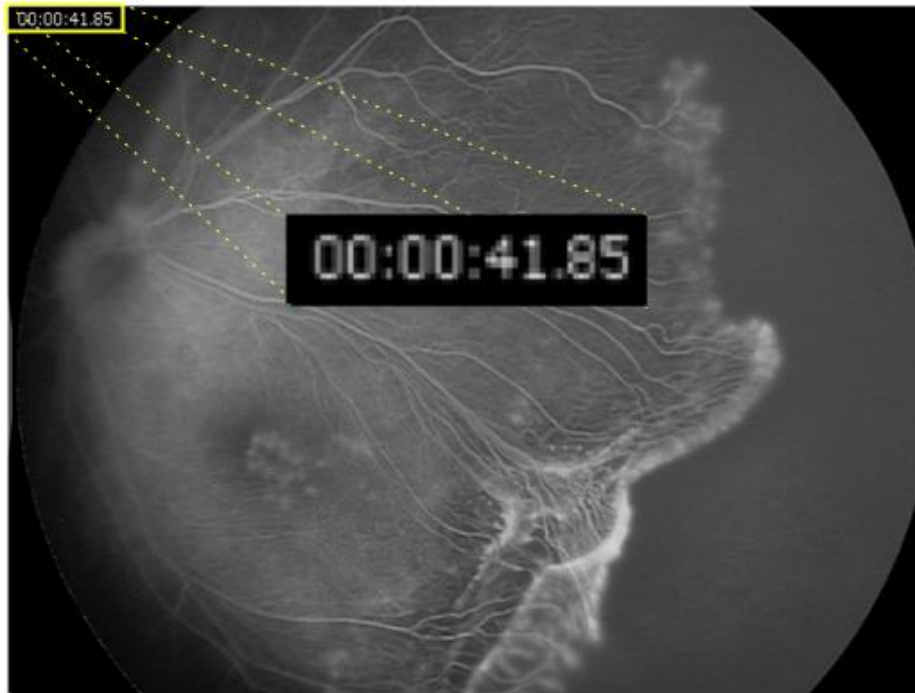


Figure 49 - RetCam II Angiography Instant representation

5.8.2.2 TEMPLATE/ANN CREATION

Confidential Section

5.8.2.3 TESTING

Due to time limitations and the small amount of RetCam II angiographies available, extensive testing similar to the HFA was not carried out. Nevertheless, all the available images were successfully classified (using the template matching verification) and, since the HFA presented very good results, we can conclude that the engine has been successfully implemented.

6. CONCLUSION AND FUTURE WORK

With this work, we have contributed to solve the interoperability issue in Ophthalmology. During this implementation, we have created distinct solutions for the most common types of data that may be exchanged (images, XML metadata, image-like metadata, analog video), and they have been tested and validated in a real medical environment with currently used diagnosis equipments, namely RetCam II, Rodenstock SLO. These and the Generic Video Modules are up and running and the developed OCR engine that retrieves image-like metadata is already used with success in the HFA Perimeter and RetCam II Modules, allowing to increase productivity and reduce errors associated with the manual execution of this “digitalization task”

Regarding the OCR engine, all the goals set in the analysis phase were reached. The engine processes a HFA Perimeter exam well under the 3 seconds threshold defined by the project supervisors based on end-user feedback (177-710 ms) and with an accuracy rate of 100%. When using the engine to create new templates, it is possible to encounter setbacks in unusual exams. In case we do face those problems, several adjustments might need to be implemented in order to maintain the engine’s flexibility and problem solving ability. These changes will merely be applied on the line and character detection routines as the NN classification engine is neutral in this whole process.

The developed modules have been successfully performing their functions but, due to the complexity and dimension of a module, it is possible that minor bugs remain. Considering the constant evolution of computer technology, it is also possible to perceive additional functionalities that could benefit the solution’s added value both for the physician end-user and for the service-provider Blueworks

Considering the initial problem and the work carried out to solve it, it can be concluded that this project was a success.

Further development follows the same line of thought of this project:

- Continue integrating equipments in order to improve the clinical interoperability. There are several equipments that require much more complex routines to interpret its raw data. Creating a tool that could somehow interpret that data would be extremely beneficial since the development of data interpretation routines is one of the most time-consuming phases of a module’s creation.
- It would also be useful to insert data in an equipment. Some equipments maintain an internal database that, by being constantly updated, would retain all the patients’ information relieving the physician from having to manually input the patient’s details.
- Create remote access visualization tools based on internet clients.
- Bring DICOM compatibility to the whole application
- Provide a way for physicians to share exams in order to get a second opinion.
- Add visual annotations on the image that constitute the report.
- ...

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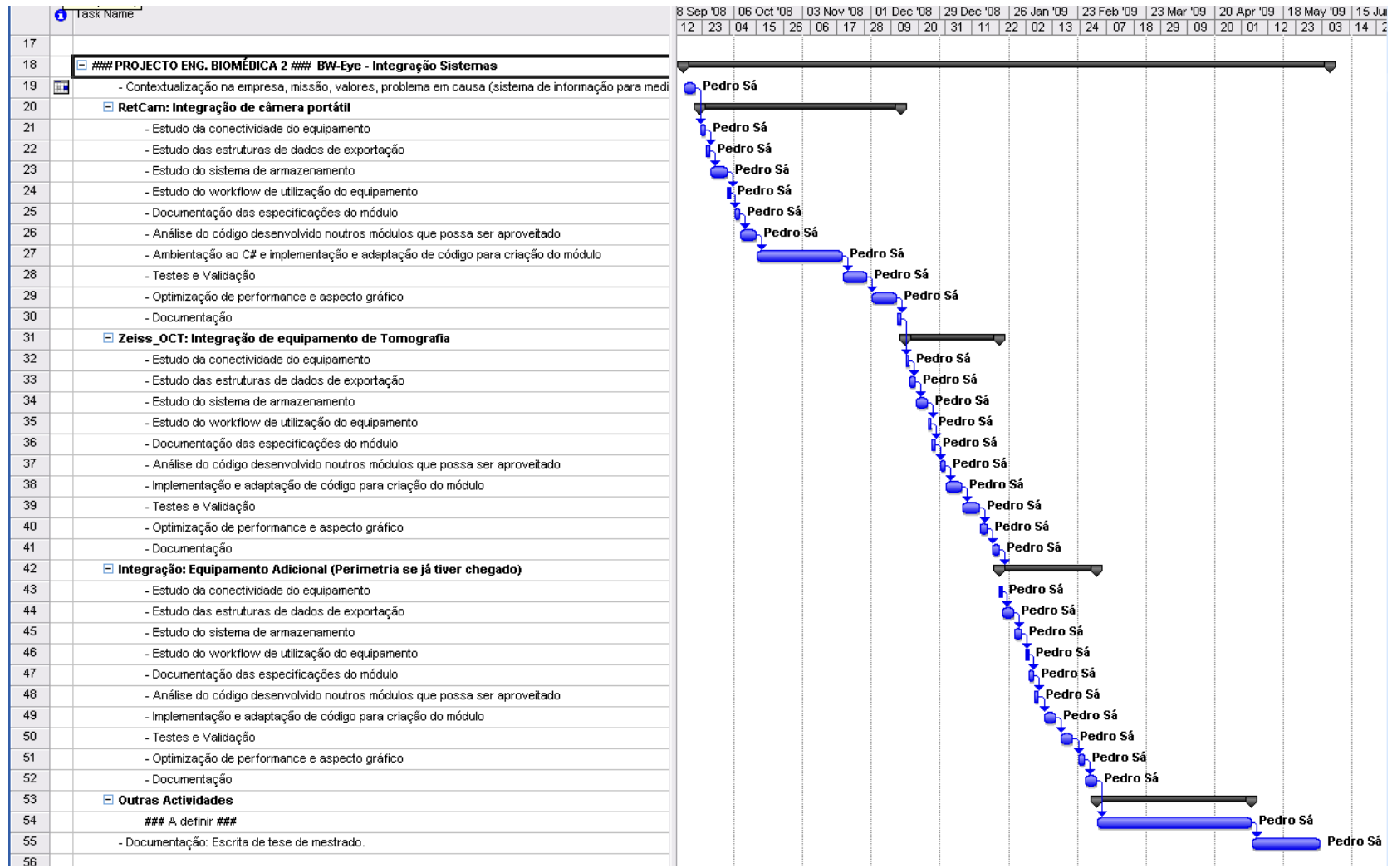
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ATTACHMENTS

1. ORIGINAL GANTT CHART PLAN



2. RETCAMII MODULE SPRINT BACKLOG

| Cod | Task | Duration (h) | Remaining (h) | |
|--------------|--|--------------|---------------|---|
| A | Exam Backup | | | |
| a | • Serialize exam to be saved | 4 | 0 | ✓ |
| B | Report Creation: | | | |
| b | • Add Margins to PDF report | 4 | 0 | ✓ |
| C | Save Exam: | | | |
| c | • Add unsaved elements to previously saved exams | 4 | 0 | ✓ |
| D | Interface revisions: | 14 | 0 | ✓ |
| E | Test battery creation | 2 | 0 | ✓ |
| F | Tests + Documentation: | | | |
| f1 | • Tests | 35 | 0 | ✓ |
| f2 | • Normalize code | 14 | 0 | ✓ |
| f3 | • Field Tests | 8 | 0 | ✓ |
| f4 | • Fix eventual bugs | 8 | 0 | ✓ |
| f5 | • Create tests report | 8 | 0 | ✓ |
| Total | | 101 | 0 | |

| Prediction | | | | | | Done | Lag |
|------------|---|-----------------|------------|-----------|----|------|-----|
| # Days | | Predicted Hours | Real hours | Remaining | | | |
| seg | 1 | 22-Dez-08 | n | 5 | 91 | 91 | 0 |
| ter | 2 | 23-Dez-08 | 7 | 5,5 | 84 | 86 | 2 |
| qua | 3 | 24-Dez-08 | 4 | 3 | 80 | 83 | 3 |
| qui | | 25-Dez-08 | | | | | |
| sex | | 26-Dez-08 | ? | 0 | | | 0 |
| sáb | | 27-Dez-08 | | | | | 0 |
| dom | | 28-Dez-08 | | | | | 0 |
| seg | 4 | 29-Dez-08 | 7 | 5,5 | 73 | 79 | 6 |

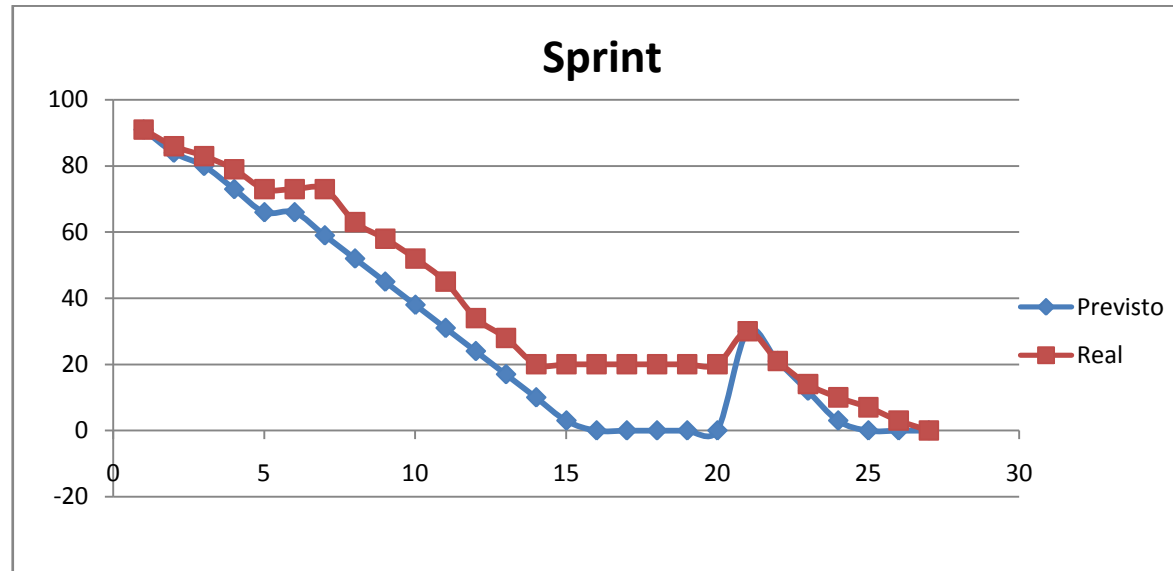
<- Milestone: A & C done

| | | | | | | | |
|-----|----|-----------|---|-----|----|----|----|
| ter | 5 | 30-Dez-08 | 7 | 5,5 | 66 | 73 | 7 |
| qua | 6 | 31-Dez-08 | 0 | 0 | 66 | 73 | 7 |
| qui | | 01-Jan-09 | | | | | |
| sex | | 02-Jan-09 | ? | 0 | | | 0 |
| sáb | | 03-Jan-09 | | | | | |
| dom | | 04-Jan-09 | | | | | |
| seg | 7 | 05-Jan-09 | 7 | 0 | 59 | 73 | 14 |
| ter | 8 | 06-Jan-09 | 7 | 7 | 52 | 63 | 11 |
| qua | 9 | 07-Jan-09 | 7 | 6 | 45 | 58 | 13 |
| qui | 10 | 08-Jan-09 | 7 | 4 | 38 | 52 | 14 |
| sex | 11 | 09-Jan-09 | 7 | 6 | 31 | 45 | 14 |
| sáb | | 10-Jan-09 | | | | | |
| dom | | 11-Jan-09 | | | | | |
| seg | 12 | 12-Jan-09 | 7 | 7 | 24 | 34 | 10 |
| ter | 13 | 13-Jan-09 | 7 | 6 | 17 | 28 | 11 |
| qua | 14 | 14-Jan-09 | 7 | 6 | 10 | 20 | 10 |
| qui | 15 | 15-Jan-09 | 7 | 6 | 3 | 20 | 17 |
| sex | 16 | 16-Jan-09 | 7 | 4 | 0 | 20 | 20 |
| sáb | 17 | 17-Jan-09 | | | 0 | 20 | 20 |
| dom | 18 | 18-Jan-09 | | | 0 | 20 | 20 |
| seg | 19 | 19-Jan-09 | 7 | 0 | 0 | 20 | 20 |
| ter | 20 | 20-Jan-09 | 7 | 0 | 0 | 20 | 20 |
| qua | 21 | 21-Jan-09 | 7 | 0 | 0 | 20 | 20 |
| qui | 22 | 22-Jan-09 | 7 | 0 | 0 | 20 | 20 |
| sex | 23 | 23-Jan-09 | 7 | 4,5 | 30 | 30 | 0 |
| sáb | 24 | 24-Jan-09 | 4 | 4 | 30 | 26 | -4 |
| dom | 25 | 25-Jan-09 | 4 | 0 | 26 | 26 | 0 |
| seg | 26 | 26-Jan-09 | 9 | 7,5 | 21 | 21 | 0 |
| ter | 27 | 27-Jan-09 | 9 | 7,5 | 12 | 14 | 2 |
| qua | 28 | 28-Jan-09 | 9 | 8 | 3 | 10 | 7 |
| qui | 29 | 29-Jan-09 | 9 | 6 | 0 | 7 | 7 |
| sex | 30 | 30-Jan-09 | 9 | 4 | 0 | 3 | 3 |

<- Milestone: B & D
done

Setback

| | | | | | | | |
|-----|----|-----------|---|---|---|---|---|
| sáb | 31 | 31-Jan-09 | 7 | | | | |
| dom | 32 | 01-Fev-09 | 7 | | | | |
| seg | 33 | 02-Fev-09 | 7 | 7 | 0 | 0 | 0 |
| ter | 34 | 03-Fev-09 | 7 | | | | |
| qua | 35 | 04-Fev-09 | 7 | | | | |



3. RETCAM II MODULE TESTS

| # | Application | Section | Functionality/Control | Test Conditions | Message | Option | Expected Result | Approval | Fixed | Notes |
|----|-------------------------|--------------------|--|---|---|-------------------------------|---|----------|-------|---|
| 1 | FormMain | Module Closed | Activate the watch folder while the module is closed | | | | Nothing | ✓ | | |
| 2 | | | Click on the module's icon with the mouse's left button | First Usage | Confirmation Dialog: It is necessary to configure the module options first. Do you wish to continue? | Yes | Opens FormPreview | ✓ | | |
| 3 | | | | | | No | Nothing | ✓ | | |
| 4 | | | | Saved Settings | Yes | Opens FormAcquisitionRetCamII | ✓ | | | |
| 5 | | | Click on the module's icon with the mouse's right button | First Usage / Saved Settings | | | | Nothing | ✓ | |
| 6 | FormOptions | Configure Settings | Cancel button | Defined Settings / Undefined Settings | | | Keeps old Settings / Closes FormSettings | ✓ | | |
| 7 | | | | Undefined Settings (First Usage) | toolTip: Please fill all required fields with valid values before continuing. | | Displays toolTip with warning | ✓ | | |
| 8 | | | Save button | Undefined Settings | toolTip: Please fill all required fields with valid values before continuing. | | Displays toolTip with warning | ✓ | | |
| 9 | | | | Defined Settings | | Saves the Settings correctly | ✓ | | | |
| 10 | | | Browse buttons | Defined Settings / Undefined Settings | | | Opens path selection dialog | ✓ | | Displays the chosen path in the textbox |
| 11 | | | Clear button | Undefined Report folder | | | Nothing | ✓ | | |
| 12 | | | | Defined Report folder | Confirmation Dialog: Do you want to permanently remove the reports from the original folder? | Yes | Deletes Reports from folder | ✓ | | |
| 13 | | | | | | No | Nothing | ✓ | | |
| 14 | | | Default Settings button | Defined Settings / Undefined Settings | Confirmation Dialog: Are you sure you want to revert to the default values? | Yes | Loads the default Settings | ✓ | | |
| 15 | | | | | | No | Nothing | ✓ | | |
| 16 | FormAcquisitionRetCamII | Visual Features | Splitter between the Exam list and the Exam viewing window | With/Without exams in the treeView and in the Exam viewing window | | Click on the splitter | Hides both Exam and Exam Details Lists | ✓ | | |
| 17 | | | | | | Splitter dragging | Resizes the Exam viewing window and the List horizontally | ✓ | | |
| 18 | | | Exam Details contextBar button | With/Without exams in the treeView and in the Exam viewing window | | | Collapses/Expands the Exam Details List | ✓ | | |
| 19 | | Access | Logout / Ctrl + L | | Confirmation Dialog: Do you want to end your | Yes | Returns to login | ✓ | | |

| | | | | | | | | | |
|----|-----------|--|--|--|------------------------|---|---|--|--|
| 20 | toolstrip | | session? Every unsaved work will be lost. | No | Nothing | ✓ | | | |
| 21 | | Sair / Ctrl + E | Confirmation Dialog: Do you want to close the application? | Yes | Closes the application | ✓ | | | |
| 22 | | | | No | Nothing | ✓ | | | |
| 23 | | Search Patient button | With an exam selected | | | Displays the search patient window where the detected name in the exam is viewed in the textBox | ✓ | | |
| 24 | | | Without an exam selected | | | Displays the search patient window with na empty textBox | ✓ | | |
| 25 | | Search Physician button | With an exam selected | | | Displays the search physician window where the detected name in the exam is viewed in the textBox | ✓ | | |
| 26 | | | Without an exam selected | | | Displays the search physician window with na empty textBox | ✓ | | |
| 27 | | View Report button | PDF report in settings | | | Displays the report in PDF format | ✓ | | |
| 28 | | | RTF report in settings | | | Displays the report in RTF format | ✓ | | |
| 29 | | Print button | PDF report in settings | | | Prints the report through PDF viewer | ✓ | | |
| 30 | | | RTF report in settings | | | Prints the report through RTF viewer | ✓ | | |
| 31 | | Open Images button | RetCamII XML | Open XML search dialog | Click OK | Option 1: If exam already exists, adds image Option 2: If exam does not exist, creates new exam and adds it to the Exam list | ✓ | | |
| 32 | | | | | Click Cancel | Nothing | ✓ | | |
| 33 | | | Any XML | | Click OK/Cancel | Nothing | ✓ | | |
| 34 | | Discard Exam button | | Confirmation Dialog: Are you sure you want to discard the current exam? | Yes | Deletes exam from the Exam list and clears the exam viewing area | ✓ | | |
| 35 | | | | | No | Nothing | ✓ | | |
| 36 | | Save Exam button | Successful exam saving | Patient/physician are undefined display confirmation dialog | Yes | Continues saving | ✓ | | |
| 37 | | | | | No | Ends saving | ✓ | | |
| 38 | | | | Option 1: Create new exam in DB Confirmation Dialog: Exame guardado. Deseja apagar? | Yes | Deletes exam from the Exam list and clears the exam viewing area | ✓ | | |
| 39 | | | | | No | Nothing | ✓ | | |
| 40 | | Option 2: If exam was previously saved, only new images are saved. (Confirmation Dialog: Exam previously saved. | Yes | Deletes exam from the Exam list and clears the exam viewing area | ✓ | | | | |

| | | | | | | | | | |
|----|---|-------------------------|---|--------------|--|---|---|--|--|
| 41 | | | Do you wish to update? Confirmation Dialog: X new images added. Do you wish to discard the current exam?) | No | Nothing | ✓ | | | |
| 42 | | Failed exam saving | Adds exam to the Backup Exam list. Confirmation Dialog: Exam not saved. Do you wish to discard the current exam? | Yes | Deletes exam from the Exam list and clears the exam viewing area | ✓ | | | |
| 43 | | | | No | Nothing | ✓ | | | |
| 44 | | Print & Save button | | | Tests 29,30,36-43 | ✓ | | | |
| 45 | | Flag comboBox | Define the exam flag type | | Exam is saved with the correct flag type | ✓ | | | |
| 46 | Patient/Doctor Control | Search Patient button | | | Tests 23 e 24 | ✓ | | | |
| 47 | | Search Physician button | | | Tests 25 e 26 | ✓ | | | |
| 48 | | Delete Patient button | | | Deletes the patient for the current exam | ✓ | | | |
| 49 | | Delete Physician button | | | Deletes the physician for the current exam | ✓ | | | |
| 50 | | Exam Date | | | Displays exam date | ✓ | | | |
| 51 | | | | | Changes exam date | ✓ | | | |
| 52 | | Save Exam button | | | Tests 36-43 | ✓ | | | |
| 53 | | Print & Save button | | | Tests 29,30,36-43 | ✓ | | | |
| 54 | | Trees | Filter | | | Filters exam by name and internal number | ✓ | | |
| 55 | treeExams | | New exam | | Displays exams in bold | ✓ | | | |
| 56 | | | | | Displays the Patient node in bold | ✓ | | | |
| 57 | | | Saved Exam | | Displays exam in normal font | ✓ | | | |
| 58 | | | | Both | If at least one unsaved exam, display the patient node in bold | ✓ | | | |
| 59 | treeDetails | | | | Displays selected exam details | ✓ | | | |
| 60 | Click with the left mouse button on a Patient node | | | | | Displays all the Patient's exams in a Data Grid control | ✓ | | |
| 61 | Click with the right mouse button on a Patient node | | With/without a selected exam | Context menu | Option 1: Delete Patient | Deletes patient nodes and all exams from the tree | ✓ | | |
| 62 | | | | | Option 2: Save Exams | Saves Exams if validated | ✓ | | |
| 63 | | Option 2: Save Exams | | | Displays warning window and does Nothing | ✓ | | | |

| | | | | | | | | | | |
|----|-----------------------------|--|-----------------------------------|-------------------------|--|---|--------------|---|--|--|
| 64 | | Click with the left mouse button on a Exam node | | | Option 1: The same exam that is being viewed | Nothing | ✓ | | | |
| 65 | | | | | Option 2: Different from the exam being viewed | Displays the selected exam in the exam viewing window | ✓ | | | |
| 66 | | Click with the right mouse button on a Exam node | | Context menu | Option 1: Save Exam | Tests 36-43 | ✓ | | | |
| 67 | | | | | Option 2: Discard Exam | Tests 34 e 35 | ✓ | | | |
| 68 | | | | | Option 3: Delete Patient | Igual a teste 61 | ✓ | | | |
| 69 | | Click with the right mouse button on a Exam Details node | | | | Nothing | ✓ | | | |
| 70 | | Click with the left mouse button on a Exam Details node | | | | Nothing | ✓ | | | |
| 71 | | Menu | Clicar Envios completos | Without pending backups | | Nothing | ✓ | | | |
| 72 | | | | With pending backups | | Opens FormBackup | ✓ | | | |
| 73 | | | Click Settings | | | Opens FormSettings | ✓ | | | |
| 74 | Click About RetCamII Module | | | | Opens About window | ✓ | | | | |
| 75 | ExaminationSeriesTab | Tabs | Select na exam from the Exam list | | | Opens exam and sorts each image into the corresponding tabs | ✓ | | | |
| 76 | | | Select a tab | | | Displays the ExaminationSeries control for each exam type | ✓ | | | |
| 77 | | | Select Navigator/Thumbnails tab | | | Displays the chosen view mode | ✓ | | | |
| 78 | Navigator Tab | Image | | | | Displays the image centered in the viewing area | ✓ | | | |
| 79 | | Video | | | | Displays video and vidoe controls | ✓ | | | |
| 80 | | Video Controls | | | | Play | Plays video | ✓ | | |
| 81 | | | | | | Pause | Pauses video | ✓ | | |

| | | | | | | | | |
|-----|----------------|-----------------------------------|----------------|----------|--|---|---|--|
| 82 | | | | Stop | Stops video | ✓ | | |
| 83 | | | | trackBar | Selects video position | ✓ | | |
| 84 | | | | Label | Displays duration and video current position | ✓ | | |
| 85 | | Image info | | | Displays eye, lens and instant correctly | ✓ | | |
| 86 | | Slideshow Controls | | Play | Plays slide show | ✓ | | |
| 87 | | | | Pause | Pauses slide show | ✓ | | |
| 88 | | | | Next | Displays next image | ✓ | | |
| 89 | | | | Previous | Displays previous image | ✓ | | |
| 90 | | | | First | Displays first image | ✓ | | |
| 91 | | | | Last | Displays last image | ✓ | | |
| 92 | | | | | Trackbar scrolling | Displays the image accordingly with the trackBar position | ✓ | |
| 93 | | Preview button | | | Opens current image in a FormPreview | ✓ | | |
| 94 | Thumbnails tab | Thumbnails tab chosen | | | Displays the exam images as thumbnails | ✓ | | |
| 95 | | Click on na image | | | Selects image | ✓ | | |
| 96 | | Double-Click on an image | | | Opens selected image in a FormPreview | ✓ | | |
| 97 | | Click on the magnifier glass icon | | | Opens selected image in a FormPreview | ✓ | | |
| 98 | | Icon ✓ | | | Displays ✓ in saved images | ✓ | | |
| 99 | | Eye | | | Displays image eye in thumbnial | ✓ | | |
| 100 | Layout Menu | Choose report image layout | | Button 1 | One image per page | ✓ | | |
| 101 | | | | Button 2 | 2x2 image per page | ✓ | | |
| 102 | | | | Button 3 | 3x3 images per page | ✓ | | |
| 103 | | | | Button 4 | 4x4 image per page | ✓ | | |
| 104 | Tools Menu | Change image's black levels | tab Miniaturas | | Change levels on the selected images | ✓ | | |
| 105 | | | tab Navegador | | Change levels on the selected image | ✓ | | |
| 106 | | Change image's white levels | tab Miniaturas | | Change levels on the selected images | ✓ | | |
| 107 | | | tab Navegador | | Change levels on the selected image | ✓ | | |
| 108 | | Change image's contrast levels | tab Miniaturas | | Change levels on the selected images | ✓ | | |
| 109 | | | tab Navegador | | Change level on the selected image | ✓ | | |

| | | | | | | | | | | |
|-----|----------------------------|----------------------------|------------------|----------------|---|-------------------------------------|---|---|-------------------------------|---|
| 110 | | | Original button | tab Miniaturas | | | Restores original images on the selected images | ✓ | | |
| 111 | | | | tab Navegador | | | Restores original images on the selected image | ✓ | | |
| 112 | | | All checkBox | tab Miniaturas | | | Selects all images | ✓ | | |
| 113 | | | | tab Navegador | | | Disabled | ✓ | | |
| 114 | | | Move button | tab Miniaturas | | | Move selected images to the selected tab | ✓ | | |
| 115 | | | | tab Navegador | | | Move current image to the selected tab | ✓ | | |
| 116 | | | Delete button | tab Miniaturas | | | Deletes selected images | ✓ | | |
| 117 | | | | tab Navegador | | | Deletes current image | ✓ | | |
| 118 | | | Fill checkBox | tab Miniaturas | | | Disabled | ✓ | | |
| 119 | | | | tab Navegador | | | Enlarges image to fit window | ✓ | | |
| 120 | | | Comments textBox | | | | Adds comments to the current exam type | ✓ | | |
| 121 | | | FormPreview | Menu | Save button | with modification | Open Save File dialog with the following formats: PNG, JPEG, BMP, GIF, TIFF | | Saves image with manipulation | ✓ |
| 122 | without modifications | | | | | Saves original image | | ✓ | | |
| 123 | Close button | with modification | | | Confirmation Dialog: Do you wish to save the modifications? | Yes | Closes FormPreview and saves the manipulation | ✓ | | |
| 124 | | | | | | No | Closes FormPreview | ✓ | | |
| 125 | | without modifications | | | | Closes FormPreview | ✓ | | | |
| 126 | Main Window | Image | | | | | Displays current image | ✓ | | |
| 127 | | | | | | Scroll | Image Zoom in/out | ✓ | | |
| 128 | | | | | | Drag | Change image position if bigger than the display area | ✓ | | |
| 129 | | Image Details | | | | | Display correct image info | ✓ | | |
| 130 | | Brightness trackBar | | | | | Change image brightness levels | ✓ | | |
| 131 | | Gamma trackBar | | | | | Change image gamma levels | ✓ | | |
| 132 | | Contrast trackBar | | | | | Change image contrast levels | ✓ | | |
| 133 | | Zoom trackBar | | | | image Zoom in/out | ✓ | | | |
| 134 | | Draw Parameters checkBox | | | | Draw the image parameters correctly | ✓ | | | |
| 135 | | Original button | | | | Restores image to original values | ✓ | | | |
| 136 | | Magnifier Glass "=" button | | | | Original Zoom | ✓ | | | |
| 137 | | Magnifier Glass "-" button | | | | Zoom out | ✓ | | | |
| 138 | Magnifier Glass "+" button | | | | Zoom in | ✓ | | | | |
| 139 | Save button | | | | Tests 119 e 120 | ✓ | | | | |

| | | | | | | | | | | | |
|-----|----------------|-------------|-------------------------|---------------------|--|-----|---|---|---|--|--|
| 140 | | | Cancel button | | | | Closes FormPreview | ✓ | | | |
| | | | | | | | | | | | |
| 141 | FormBackupData | Main Window | Exam List | | | | Displays list with unsaved exas | ✓ | | | |
| 142 | | | Exam Details | | | | Displays info about the selected unsaved exam | ✓ | | | |
| 143 | | | Exam images | | | | Displays the number of images for each type of the selected exam | ✓ | | | |
| 144 | | | Exam Report | | | | Displays if the report exists or not | ✓ | | | |
| 145 | | | Comments | | | | Displays the exam comments | ✓ | | | |
| 146 | | | Save button | 1+ exam(s) selected | | | | Saves seleted exams to the db and closes FormBackupData | ✓ | | |
| 147 | | | | No exam selected | | | | Closes FormBackupData | ✓ | | |
| 148 | | | Cancel button | 1+ exam(s) selected | | | | Closes FormBackupData | ✓ | | |
| 149 | | | | No exam selected | | | | Closes FormBackupData | ✓ | | |
| 150 | | | Delete button | | | | | Deletes unsaved exams | ✓ | | |
| | | | | | | | | | | | |
| 151 | Global tasks | Save Exams | Without selected images | | Confirmation Dialog: The following series do not have any selected image. Do you wish to continue? | Yes | If the exam hasn't een previously saved a new exam entry is created | ✓ | | | |
| 152 | | | | | | No | Nothing | ✓ | | | |
| 153 | | | Backup with error: | | | | At report saving | Backup DB saving is accomplished | ✓ | | |
| 154 | | | | | | | At image saving | | ✓ | | |
| 155 | | | | | | | at Session creation | | ✓ | | |
| 156 | | | | | | | at EAV creation | | ✓ | | |
| 157 | | | | | | | at Exam creation | | ✓ | | |
| 158 | | | | | | | at Image entry creation | | ✓ | | |

4. RODENSTOCK SLO ACQUISITION MODULE TESTS

| # | Application | Section | Functionality/Control | Test Conditions | Message | Option | Expected Result | Approval | Fixed | Notes | | |
|----|------------------------------|--------------------|--|---------------------------------------|---|------------------------------|---|----------|------------------------|---|--|--|
| 1 | FormMain | Module Closed | Activate the watch folder while the module is closed | | | | Nothing | ✓ | | | | |
| 2 | | | Click on the module's icon with the mouse's left button | First Usage | Confirmation Dialog: Antes de prosseguir é necessário configurar as opções obrigatórias do módulo 'RetCam II'. Pretende continuar? | Yes | Opens FormPreview | ✓ | | | | |
| 3 | | | | | | No | Nothing | ✓ | | | | |
| 4 | | | | Saved Settings | | Yes | Opens FormAcquisitionRetCamII | ✓ | | | | |
| 5 | | | Click on the module's icon with the mouse's right button | First Usage / Saved Settings | | | | Nothing | ✓ | | | |
| 6 | FormOptions | Configure Settings | Cancel button | Defined Settings / Undefined Settings | | | Keeps old Settings / Closes FormSettings | ✓ | | | | |
| 7 | | | | Undefined Settings (First Usage) | toolTip: Por favor preencha todos os campos de pasta com valores válidos antes de guardar as definições | | Displays toolTip with warning | ✓ | | | | |
| 8 | | | Save button | Undefined Settings | toolTip: Por favor preencha todos os campos de pasta com valores válidos antes de guardar as definições | | Displays toolTip with warning | ✓ | | | | |
| 9 | | | | Defined Settings | | Saves the Settings correctly | ✓ | | | | | |
| 10 | | | Browse buttons | Defined Settings / Undefined Settings | | | Opens path selection dialog | ✓ | | Displays the chosen path in the textbox | | |
| 11 | | | Clear button | Undefined Report folder | | | Nothing | ✓ | | | | |
| 12 | | | | Defined Report folder | Confirmation Dialog: Tem a certeza que pretende eliminar definitivamente os relatórios da pasta local? | Yes | Deletes Reports from folder | ✓ | | | | |
| 13 | | | | | | No | Nothing | ✓ | | | | |
| 14 | | | Default Settings button | Defined Settings / Undefined Settings | Confirmation Dialog: Tem a certeza que pretende reverter as opções para os valores padrão? | Yes | Loads the default Settings | ✓ | | | | |
| 15 | | | | | | No | Nothing | ✓ | | | | |
| 16 | FormAcquisitionRodenstockSLO | Access | Logout / Ctrl + L | | Confirmation Dialog: Tem a certeza de que pretende concluir a sua sessão? Todas as alterações No guardadas serão perdidas. | Yes | Returns to login | ✓ | | | | |
| 17 | | | | | | No | Nothing | ✓ | | | | |
| 18 | | | | | | Sair / Ctrl + E | Confirmation Dialog: Tem a certeza de que pretende sair da aplicação? | Yes | Closes the application | ✓ | | |
| 19 | | | | | | | | No | Nothing | ✓ | | |
| 20 | | toolStrip | Search Patient button | With an exam selected | | | Displays the search patient window where the detected name in the exam is viewed in the textBox | ✓ | | | | |

| | | | | | | | | | | |
|----|------------------------|-------------------------|--------------------------------|---|----------------------|---|--------------------------------------|---|--|--|
| 23 | | | Without an exam selected | | | Displays the search patient window with na empty textBox | ✓ | | | |
| 24 | | Search Physician button | With an exam selected | | | Displays the search physician window where the detected name in the exam is viewed in the textBox | ✓ | | | |
| 25 | | | Without an exam selected | | | Displays the search physician window with na empty textBox | ✓ | | | |
| 26 | | View Report button | PDF report in settings | | | Displays the report in PDF format | ✓ | | | |
| 27 | | | | RTF report in settings | | | Displays the report in RTF format | ✓ | | |
| 28 | | Print button | PDF report in settings | | | Prints the report through PDF viewer | ✓ | | | |
| 29 | | | | RTF report in settings | | | Prints the report through RTF viewer | ✓ | | |
| 30 | | Open Images button | TIFF files | Open TIFF search dialog | Click OK | Draw parameters correctly, create a Thumbnail and adds it to the workspace | ✓ | | | |
| | Click Cancel | | | | Nothing | ✓ | | | | |
| | Click OK/Cancel | | | | Nothing | ✓ | | | | |
| 31 | | Discard Exam button | | Confirmation Dialog: Are you sure you want to discard the current exam? | Yes | Clears the exam viewing area | ✓ | | | |
| | | | | | No | Nothing | ✓ | | | |
| 32 | | Recover Images button | | | | Restores previously deleted thumbnails | ✓ | | | |
| 33 | | Save Exam button | Patient or Physician undefined | | Save button disabled | Nothing | ✓ | | | |
| | | | | Patient & Physician defined | | | Exam is saved correctly | ✓ | | |
| 34 | | Print & Save button | | | | Tests 29,30,36-43 | ✓ | | | |
| 35 | | Flag comboBox | | Define the exam flag type | | Exam is saved with the correct falg type | ✓ | | | |
| 36 | Patient/Doctor Control | Search Patient button | | | | Tests 23 and 24 | ✓ | | | |
| 37 | | Search Physician button | | | | Tests 25 and 26 | ✓ | | | |
| 38 | | Delete Patient button | | | | Deletes the patient for the current exam | ✓ | | | |
| 39 | | Delete Physician button | | | | Deletes the physician for the current exa | ✓ | | | |
| 40 | | Exam Date | | | | | Displays exam date | ✓ | | |
| 41 | | | | | | | Changes exam date | ✓ | | |
| 42 | | Save Exam button | | | | | Tests 36-43 | ✓ | | |
| 43 | | Print & Save button | | | | | Tests 29,30,36-43 | ✓ | | |
| 44 | | Menu | Recover incomplete saves... | Without pending backups | | | Nothing | ✓ | | |
| | With pending backups | | | | | | Opens FormBackup | ✓ | | |
| | Click Settings | | | | | | Opens FormSettings | ✓ | | |

| | | | | | | | | | | |
|----|----------------|--|---------------------------------------|----------------------------|---|------------------------|--|---|---------------------------|--|
| 47 | FormPreview | | Click About Rodenstock SLO Module | | | | Opens About window | ✓ | | |
| 48 | | | Click on an image/click Select button | | | | Selects image | ✓ | | |
| 49 | | | Double-Click on an image | | | | Opens selected image in a FormPreview | ✓ | | |
| 50 | | | Click on the magnifier glass icon | | | | Opens selected image in a FormPreview | ✓ | | |
| 51 | | | Click on Details button | | | | Displays detail panel | ✓ | | |
| 52 | | | Eye in Detail panel | | | | Correctly classified | ✓ | | |
| 53 | | Layout Menu | Choose report image layout | | | Button 1 | One image per page | ✓ | | |
| 54 | | | | | | Button 2 | 2x2 image per page | ✓ | | |
| 55 | | | | | | Button 3 | 3x3 images per page | ✓ | | |
| 56 | | | | | | Button 4 | 4x4 image per page | ✓ | | |
| 57 | | Tools Menu | Select All button | | | | Selects all images | ✓ | | |
| 58 | | | Delete Selected button | | | | Deletes selected images | ✓ | | |
| 59 | | | | | | | | | | |
| 60 | Thumbnail | Click "X" button | | | | Deletes the Thumbnail | ✓ | | | |
| 61 | | Thumbnail redimensioning when workspace size changes | | | | Update Thumbnails size | X | | Event isn't being handled | |
| 62 | | | | | | | | | | |
| 63 | FormPreview | Menu | Save button | | Open Save File dialog with the following formats: PNG, JPEG, BMP, GIF, TIFF | | Saves image | ✓ | | |
| 64 | | | Close button | | | | Closes FormPreview | ✓ | | |
| 65 | | Main Window | Image | | | | Displays current image | ✓ | | |
| 66 | | | | | | Scroll | Image Zoom in/out | ✓ | | |
| 67 | | | | | | Drag | Change image position if bigger than the display area | ✓ | | |
| 68 | | | | Image Details | | | Display correct image info | ✓ | | |
| 69 | | | | Magnifier Glass "=" button | | | Original Zoom | ✓ | | |
| 70 | | | | Magnifier Glass "-" button | | | Zoom out | ✓ | | |
| 71 | | Magnifier Glass "+" button | | | Zoom in | ✓ | | | | |
| 72 | | | | | | | | | | |
| 73 | FormBackupData | Main Window | Exam List | | | | Displays list with unsaved exams | ✓ | | |
| 74 | | | Exam Details | | | | Displays info about the selected unsaved exam | ✓ | | |
| 75 | | | Exam images | | | | Displays the number of images for each type of the selected exam | ✓ | | |
| 76 | | | Exam Report | | | | Displays if the report exists or not | ✓ | | |
| 77 | | | Comments | | | | Displays the exam comments | ✓ | | |
| 78 | | | Save button | 1+ exam(s) selected | | | Saves seleted exams to the db and closes FormBackupData | ✓ | | |

| | | | | | | | | | | |
|----|--------------|-----------------|--------------------|---------------------|--|-------------------------|----------------------------------|---|--|--|
| 81 | | | | No exam selected | | | Closes FormBackupData | ✓ | | |
| 82 | | | Cancel button | 1+ exam(s) selected | | | Closes FormBackupData | ✓ | | |
| 83 | | | | No exam selected | | | Closes FormBackupData | ✓ | | |
| 84 | | | Delete button | | | | Deletes unsaved exams | ✓ | | |
| 85 | Global Tasks | Backup creation | Backup with error: | | | At report saving | Backup DB saving is accomplished | ✓ | | |
| 86 | | | | | | At image saving | | ✓ | | |
| 87 | | | | | | at Session creation | | ✓ | | |
| 88 | | | | | | at Exam creation | | ✓ | | |
| 89 | | | | | | at Image entry creation | | ✓ | | |

5. GENERIC VIDEO ACQUISITION MODULE TESTS

| # | Application | Section | Functionality/Control | Test Conditions | Message | Option | Expected Result | Approval | Fixed | Notes | |
|----|-----------------------------|--------------------|--|--|---|---|--|--|-------|--|---|
| 1 | FormMain | Module Closed | Activate the watch folder while the module is closed | | | | Nothing | ✓ | | | |
| 2 | | | Click on the module's icon with the mouse's left button | First Usage | Confirmation Dialog: It is necessary to configure the module options first. Do you wish to continue? | Yes | Opens FormPreview | ✓ | | | |
| 3 | | | | | | No | Nothing | ✓ | | | |
| 4 | | | | Saved Settings | | Yes | Opens FormAcquisitionRetCamII | ✓ | | | |
| 5 | | | Click on the module's icon with the mouse's right button | First Usage / Saved Settings | | | | Nothing | ✓ | | |
| 6 | FormOptions | Configure Settings | Cancel button | Defined Settings / Undefined Settings | | | Keeps old Settings / Closes FormSettings | ✓ | | | |
| 7 | | | | Undefined Settings (First Usage) | toolTip: Please fill all required fields with valid values before continuing. | | Displays toolTip with warning | ✓ | | | |
| 8 | | | Save button | Undefined Settings | toolTip: Please fill all required fields with valid values before continuing. | | Displays toolTip with warning | ✓ | | | |
| 9 | | | | Defined Settings | | | Saves the Settings correctly | ✓ | | | |
| 10 | | | Browse buttons | Defined Settings / Undefined Settings | | | | Opens path selection dialog | ✓ | | Displays the chosen path in the textbox |
| 11 | | | Clear button | Undefined Report folder | | | | Nothing | ✓ | | |
| 12 | | | | Defined Report folder | Confirmation Dialog: Do you want to permanently remove the reports from the original folder? | Yes | Deletes Reports from folder | ✓ | | | |
| 13 | | | | | | No | Nothing | ✓ | | | |
| 14 | | | Default Settings button | Defined Settings / Undefined Settings | Confirmation Dialog: Are you sure you want to revert to the default values? | Yes | Loads the default Settings | ✓ | | | |
| 15 | | | | | | No | Nothing | ✓ | | | |
| 16 | | | Input Devices | | | | | Shows the conected input devices correctly | ✓ | | |
| 17 | Device channels | | | | | Shows the channels which allow video-in | ✓ | | | | |
| 18 | FormAcquisitionGenericVideo | Visual Features | Click Collapse button in every Header control | With/Without thumbnails in the control | | | Collpases the Header | ✓ | | | |
| 20 | | | Scrollbar-free scrolling | | | | Scrolls correctly | ✓ | | | |
| 21 | | | Animated buttons | | | | Buttons display animation | ✓ | | | |
| 22 | Access | | Logout / Ctrl + L | | Confirmation Dialog: Tem a certeza de que pretende concluir a sua sessão? Todas as alterações No guardadas serão perdidas. | Yes | Returns to login | X | | Note: error if video is playing. COM objects are being incorrectly released. | |
| 23 | | | | | | No | Nothing | X | | | |

| | | | | | | | | | | |
|----|-----------------------|---|---------------------------|--|---|--|--|---|---|--|
| 24 | | | | Confirmation Dialog: Tem a certeza de que pretende sair da aplicação? | Yes | Closes the application | ✓ | | | |
| 25 | | Sair / Ctrl + E | | | No | Nothing | ✓ | | | |
| 26 | toolstrip | Search Patient button | | | | Displays the search patient window with na empty textBox | ✓ | | | |
| 27 | | Search Physician button | | | | Displays the search physician window with na empty textBox | ✓ | | | |
| 28 | | View Report button | PDF report in settings | | | | Displays the report in PDF format | ✓ | | |
| 29 | | | RTF report in settings | | | | Displays the report in RTF format | ✓ | | |
| 30 | | Print button | PDF report in settings | | | | Prints the report through PDF viewer | ✓ | | |
| 31 | | | RTF report in settings | | | | Prints the report through RTF viewer | ✓ | | |
| 32 | | Open Videos button | | Open Video search dialog | Click OK | | Load video, Create thumbnail and add to the list | ✓ | | |
| 33 | | | Click Cancel | | | Nothing | | | ✓ | |
| 34 | | Discard Exam button | | Confirmation Dialog: Do you want do discard the current session? | Yes | | Deletes videos from the Video list and clears the video viewing area and Report configuration area | ✓ | | |
| 35 | | | | | No | | Nothing | ✓ | | |
| 36 | | Save button | Exam correctly saved | Confirmation Dialog: Exam saved. Do you wish to discard it? | Yes | | Deletes videos from the Video list and clears the video viewing area and Report configuration area | ✓ | | |
| 37 | | | | | No | | Nothing | ✓ | | |
| 38 | | | Failed exam saving | Adds exam to the Backup Exam list. Confirmation Dialog: Exam not saved. Do you wish to discard the current exam? | Yes | | Deletes videos from the Video list and clears the video viewing area and Report configuration area | ✓ | | |
| 39 | | | | | No | | Nothing | ✓ | | |
| 40 | Print & Save button | | | | | Tests 29,30,36-43 | ✓ | | | |
| 41 | Flag comboBox | | Define the exam flag type | | | Exam is saved with the correct falg type | ✓ | | | |
| 42 | PatientDoctor Control | Search Patient button | | | | Tests 23 e 24 | ✓ | | | |
| 43 | | Search Physician button | | | | Tests 25 e 26 | ✓ | | | |
| 44 | | Delete Patient button | | | | Deletes the patient for the current exam | ✓ | | | |
| 45 | | Delete Physician button | | | | Deletes the physician for the current exa | ✓ | | | |
| 46 | | Exam Date | | | | | Displays exam date | ✓ | | |
| 47 | | | | | | | Changes exam date | ✓ | | |
| 48 | | Save Exam button | | | | | Tests 36-43 | ✓ | | |
| 49 | | Print & Save button | | | | | Tests 29,30,36-43 | ✓ | | |
| 50 | Record Videos | Click with left mouse button on a video thumbnail | | | Option 1: Video is playing or recording | Loads video to vieweing area | ✓ | | | |

| | | | | | | | | | | |
|----|--------------|---|----------------------------------|--|--------------------------------------|---|---|---|--|--|
| 51 | | | | | Option 2: Video is stopped or paused | Loads video to vieweing area | ✓ | | | |
| 52 | | Click with left mouse button on a video thumbnail | | | | Nothing | ✓ | | | |
| 53 | | Click with left/right mouse button on a image thumbnail | | | | Nothing | ✓ | | | |
| 54 | | Click with left mouse button on a "X" button contained within a video/image thumbnail | | | | Displays all the Patient's exams in a Data Grid control | ✓ | | | |
| 55 | | Click with the right mouse button on a Patient node | | | | Deletes the thumbnail | ✓ | | | |
| 56 | | Click Add New Videos button | | | | Option 1: The input device is available | Loads Media Play control in record mode | ✓ | | |
| 57 | | | | | | Option 2: The input device isn't available | Loads Media Play control in play mode. Warning Message: The input device is unavailable. Check connection or change device using the Module's settings. | ✓ | | |
| 58 | Menu | Clickar Recover Examination Sessions... | Without pending backups | | | Nothing | ✓ | | | |
| 59 | | | With pending backups | | | Opens FormBackup | ✓ | | | |
| 60 | | Click Settings | | | | Opens FormSettings | ✓ | | | |
| 61 | | Click About RetCamII Module | | | | Opens About window | ✓ | | | |
| □ | | | | | | | | | | |
| 62 | ReviewReport | Main Panel | Video Thumbnail Area | | | | Videos are correctly displayed by Video Splitter controls | ✓ | | |
| 63 | | | Exam/Image type in VideoSplitter | | | | Displays the correct exams available for the current equipment | □ | | |
| 64 | | | Image Thumbnails | | | | Images are loaded into each Video Splitter correctly | ✓ | | |
| 65 | | | Video info in Video Splitter | | | | Displays video info correctly | ✓ | | |
| 66 | | | Image info in thumbnail | | | | Displays image info correctly | ✓ | | |

| | | | | | | | | | | |
|----|------------------|-----------------------------------|----------|--|--|---|---|---|--|--|
| | | | | | | | | | | |
| 67 | Tools Menu | Preview button | | | | Opens current image in a FormPreview | ✓ | | | |
| 68 | | Click on na image | | | | Selects image | ✓ | | | |
| 69 | | Double-Click on an image | | | | Opens selected image in a FormPreview | ✓ | | | |
| 70 | | Click on the magnifier glass icon | | | | Opens selected image in a FormPreview | ✓ | | | |
| 71 | | Click Eye button | | | | Changes the eye for that image | ✓ | | | |
| 72 | | Choose report image layout | Button 1 | | | | One image per page | ✓ | | |
| 73 | | | Button 2 | | | | 2x1 image per page | ✓ | | |
| 74 | | | Button 3 | | | | 2x2 images per page | ✓ | | |
| 75 | | | Button 4 | | | | 3x2 images per page | ✓ | | |
| 76 | | | Button 5 | | | | 4x2 images per page | ✓ | | |
| 77 | | | Button 6 | | | | 3x3 images per page | ✓ | | |
| 78 | | | Button 7 | | | | 6x2 image per page | ✓ | | |
| 79 | | | Button 8 | | | | 4x4 image per page | ✓ | | |
| 80 | | Change image's black levels | | | | | Change levels on the selected images | ✓ | | |
| 81 | | Change image's white levels | | | | | Change levels on the selected images | ✓ | | |
| 82 | | Change image's contrast levels | | | | | Change levels on the selected images | ✓ | | |
| 83 | | Original button | | | | | Restores original images on the selected images | ✓ | | |
| 84 | All checkBox | | | | | Selects all images | ✓ | | | |
| 85 | Delete button | | | | | Deletes selected images | ✓ | | | |
| 86 | Comments textBox | | | | | Adds comments to the selected exam type | ✓ | | | |
| | | | | | | | □ | | | |
| 87 | Media Player | Controls | | | | Option 1: If video is paused | plays video | ✓ | | |
| 88 | | | | | | Option 2: If video is playing | nothing | ✓ | | |
| 89 | | | | | | Option 1: If video is paused | Nothing | ✓ | | |

| | | | | | | | | | | |
|-----|-------------|---------------|----------------------|----------------------------|---|-------------------------------|---|---|--|--|
| 90 | | | | | Option 2: If video is playing | Pauses video | ✓ | | | |
| 91 | | | | | Option 1: If video is paused | displays next/previous frame | ✓ | | | |
| 92 | | | | | Option 2: If video is playing | nothing | ✓ | | | |
| 93 | | | click Record button | | | | Starts Recording Video | ✓ | | |
| 94 | | | click Stop button | | | | Stops recording video | ✓ | | |
| 95 | | | click Capture button | | | Option 1: If video is paused | Captures the current frame | ✓ | | |
| 96 | | | | | | Option 2: If video is playing | Captures the current frame | ✓ | | |
| 97 | | Engine | BWPlay | | | | All methods work correctly | ✓ | | |
| 98 | | BWCapture | | | | All methods work correctly | ✓ | | | |
| 99 | FormPreview | Menu | Save button | with modification | Open Save File dialog with the following formats: PNG, JPEG, BMP, GIF, TIFF | | Saves image with manipulation | ✓ | | |
| 100 | | | | without modifications | | | Saves original image | ✓ | | |
| 101 | | | Close button | with modification | Confirmation Dialog: Do you wish to save the modifications? | Yes | Closes FormPreview and saves the manipulation | ✓ | | |
| 102 | | | | without modifications | | No | Closes FormPreview | ✓ | | |
| 103 | | | | | | Closes FormPreview | ✓ | | | |
| 104 | | Main Window | Image | | | | Displays current image | ✓ | | |
| 105 | | | | | | Scroll | Image Zoom in/out | ✓ | | |
| 106 | | | | | | Drag | Change image position if bigger than the display area | ✓ | | |
| 107 | | | | | | | Display correct image info | ✓ | | |
| 108 | | | | Brightness trackBar | | | Change image brightness levels | ✓ | | |
| 109 | | | | Gamma trackBar | | | Change image gamma levels | ✓ | | |
| 110 | | | | Contrast trackBar | | | Change image contrast levels | ✓ | | |
| 111 | | | | Zoom trackBar | | | image Zoom in/out | ✓ | | |
| 112 | | | | Draw Parameters checkBox | | | Draw the image parameters correctly | ✓ | | |
| 113 | | | | Original button | | | Restores image to original values | ✓ | | |
| 114 | | | | Magnifier Glass "=" button | | | Original Zoom | ✓ | | |
| 115 | | | | Magnifier Glass "-" button | | | Zoom out | ✓ | | |
| 116 | | | | Magnifier Glass "+" button | | | Zoom in | ✓ | | |
| 117 | | | Save button | | | Tests 119 e 120 | ✓ | | | |
| 118 | | Cancel button | | | Closes FormPreview | ✓ | | | | |

| | | | | | | | | | | |
|-----|------------------|-------------|--------------------|---------------------|----------------------------|--|---|---|--|--|
| 119 | FormAdvancedView | Controls | Filter controls | | | Display filter controls for capture device or video being played correctly | ✓ | | | |
| 120 | | | | | | When a filter is modified the video feed changes | X | Some videos display configurable filters but no visible change is perceived | | |
| 121 | | | zoom control | | Option 1: move trackBar | Zoom in/out correctly | ✓ | | | |
| 122 | | | | | Option 2: Scroll the mouse | | ✓ | | | |
| 123 | | | | | | When image is zoomed, move the viewing area correctly | ✓ | | | |
| 124 | | | | | | When yellow rectangle is dragged, the viewing area is correctly moved | ✓ | | | |
| 125 | FormBackupData | Main Window | Exam List | | | Displays list with unsaved exas | ✓ | | | |
| 126 | | | Exam Details | | | Displays info about the selected unsaved exam | ✓ | | | |
| 127 | | | Exam videos/images | | | Displays the number of video/images for the selected exam | ✓ | | | |
| 128 | | | Exam Report | | | Displays if the report exists or not | ✓ | | | |
| 129 | | | Comments | | | Displays the exam comments | ✓ | | | |
| 130 | | | Save button | 1+ exam(s) selected | | | Saves seleted exams to the db and closes FormBackupData | ✓ | | |
| 131 | | | | No exam selected | | | Closes FormBackupData | ✓ | | |
| 132 | | | Cancel button | 1+ exam(s) selected | | | Closes FormBackupData | ✓ | | |
| 133 | | | | No exam selected | | | Closes FormBackupData | ✓ | | |
| 134 | Delete button | | | | Deletes unsaved exams | ✓ | | | | |
| 135 | Global Tasks | Save Exams | Backup with error: | | At report saving | Backup DB saving is accomplished | ✓ | | | |
| 136 | | | | | At image saving | | ✓ | | | |
| 137 | | | | | at Session creation | | ✓ | | | |
| 138 | | | | | at EAV creation | | ✓ | | | |

| | | | | | | | | |
|-----|--|--|--|-------------------------|--|---|--|--|
| 139 | | | | at Exam creation | | ✓ | | |
| 140 | | | | at Image entry creation | | ✓ | | |

6. NEURAL.NET OCR TESTS

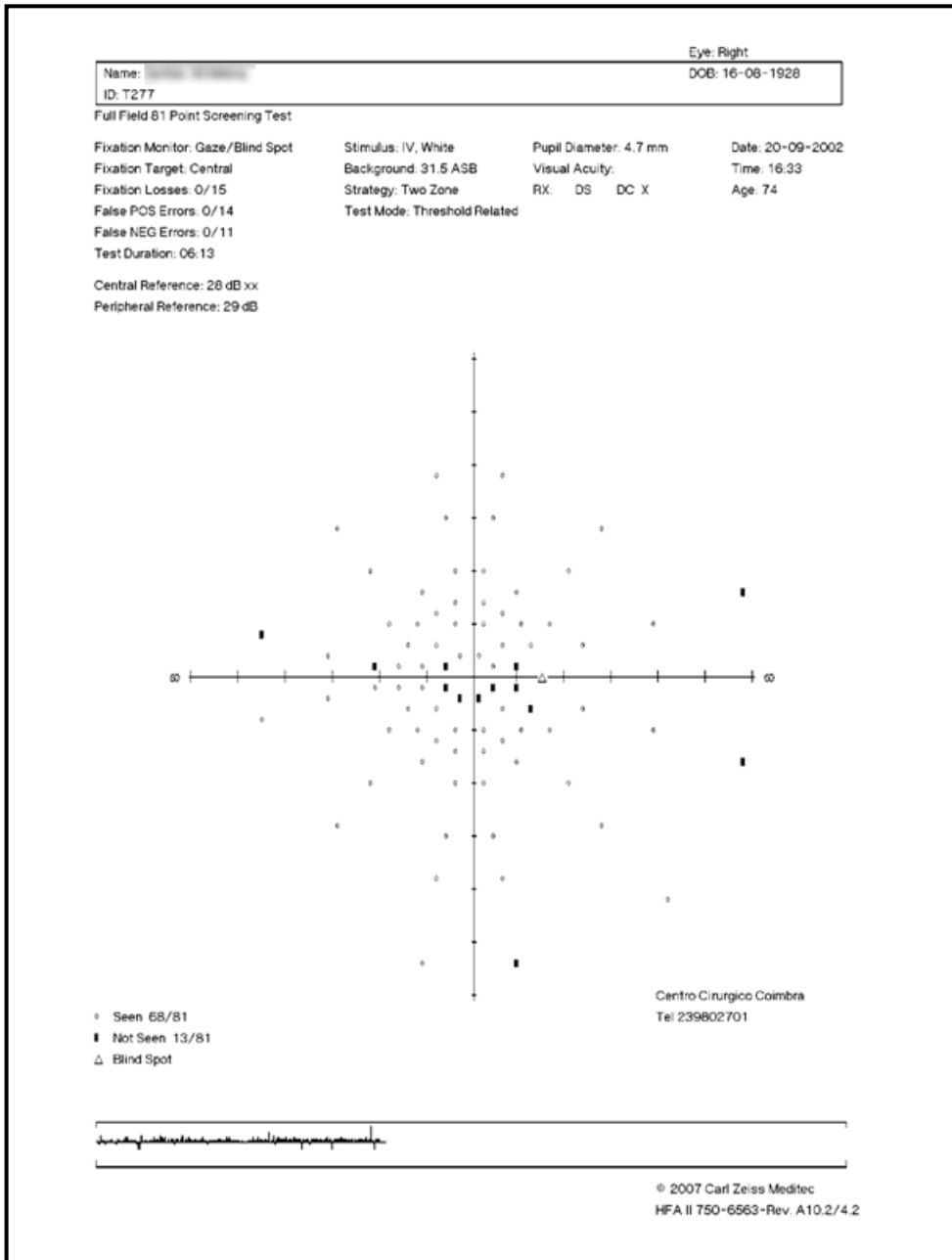
| AForge | | | | | | Normal | | | | | |
|---------------|--------|-----------|---------|---------|---------|---------------|--------|-----------|---------|---------|---------|
| Interpolation | Resize | Threshold | % Chars | % Words | % Ratio | Interpolation | Resize | Threshold | % Chars | % Words | % Ratio |
| 2 | 2 | 220 | 0,8182 | 0,9683 | 0,8932 | 3 | 2 | 0,55 | 0,9091 | 0,9841 | 0,9466 |
| 2 | 2 | 230 | 0,8182 | 0,9683 | 0,8932 | 3 | 3 | 0,65 | 0,9091 | 0,9841 | 0,9466 |
| 3 | 2 | 220 | 0,8182 | 0,9683 | 0,8932 | 4 | 2 | 0,55 | 0,9091 | 0,9841 | 0,9466 |
| 3 | 2 | 230 | 0,8182 | 0,9683 | 0,8932 | 4 | 3 | 0,65 | 0,9091 | 0,9841 | 0,9466 |
| 3 | 3,5 | 220 | 0,8182 | 0,9683 | 0,8932 | 5 | 2 | 0,60 | 0,9091 | 0,9841 | 0,9466 |
| 3 | 3,5 | 230 | 0,8182 | 0,9683 | 0,8932 | 1 | 2 | 0,50 | 0,8182 | 0,9683 | 0,8932 |
| 2 | 3 | 220 | 0,7273 | 0,9524 | 0,8398 | 1 | 2 | 0,55 | 0,8182 | 0,9683 | 0,8932 |
| 3 | 3,5 | 240 | 0,7273 | 0,9524 | 0,8398 | 1 | 2 | 0,60 | 0,8182 | 0,9683 | 0,8932 |
| 2 | 2,5 | 230 | 0,7273 | 0,9365 | 0,8319 | 1 | 2 | 0,65 | 0,8182 | 0,9683 | 0,8932 |
| 2 | 3,5 | 240 | 0,7273 | 0,9365 | 0,8319 | 1 | 2 | 0,70 | 0,8182 | 0,9683 | 0,8932 |
| 2 | 3 | 240 | 0,6364 | 0,9365 | 0,7864 | 1 | 2,5 | 0,80 | 0,8182 | 0,9683 | 0,8932 |
| 2 | 3,5 | 230 | 0,6364 | 0,9365 | 0,7864 | 1 | 3 | 0,80 | 0,8182 | 0,9683 | 0,8932 |
| 3 | 2,5 | 240 | 0,6364 | 0,9365 | 0,7864 | 1 | 3,5 | 0,80 | 0,8182 | 0,9683 | 0,8932 |

7. ASCII TABLES

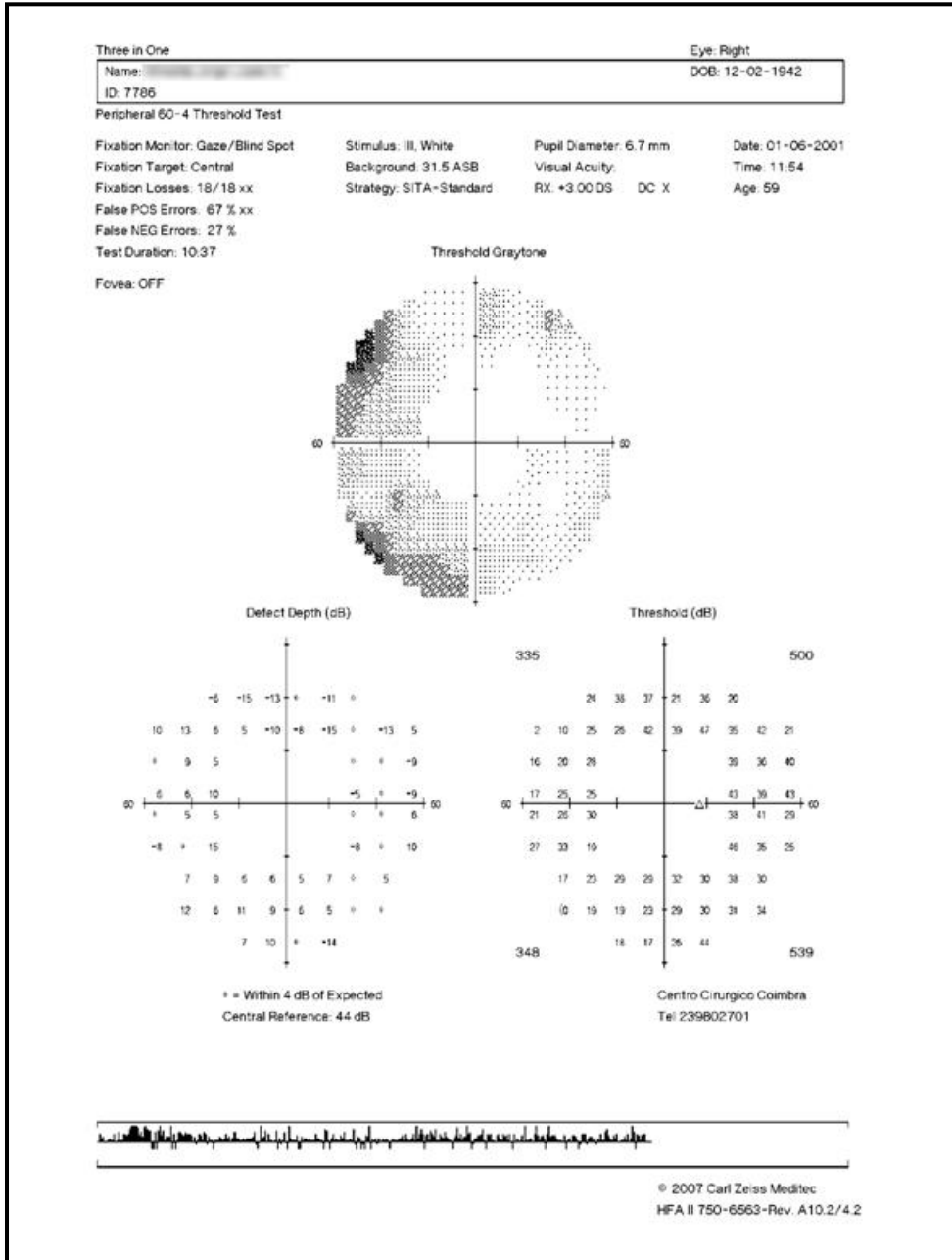
| Ctrl | Dec | Hex | Char | Code | Dec | Hex | Char | Dec | Hex | Char | Dec | Hex | Char | Dec | Hex | Char | Dec | Hex | Char | Dec | Hex | Char | Dec | Hex | Char |
|----------|----------|----------|--------|----------|----------|----------|-------------|----------|----------|-------------|------------|----------|-------------|------------|----------|-------------|------------|----------|--------|------------|----------|--------|------------|----------|------|
| ^@ | 0 | 00 | | NUL | 32 | 20 | ! | 64 | 40 | @ | 96 | 60 | ' | 128 | 80 | Ç | 160 | A0 | à | 192 | C0 | Ł | 224 | E0 | α |
| ^A | 1 | 01 | | SOH | 33 | 21 | ! | 65 | 41 | A | 97 | 61 | a | 129 | 81 | ü | 161 | A1 | á | 193 | C1 | ł | 225 | E1 | β |
| ^B | 2 | 02 | | STX | 34 | 22 | " | 66 | 42 | B | 98 | 62 | b | 130 | 82 | ë | 162 | A2 | â | 194 | C2 | Ł | 226 | E2 | Γ |
| ^C | 3 | 03 | | ETX | 35 | 23 | # | 67 | 43 | C | 99 | 63 | c | 131 | 83 | ä | 163 | A3 | ã | 195 | C3 | ł | 227 | E3 | Π |
| ^D | 4 | 04 | | EOT | 36 | 24 | \$ | 68 | 44 | D | 100 | 64 | d | 132 | 84 | å | 164 | A4 | ä | 196 | C4 | ł | 228 | E4 | Σ |
| ^E | 5 | 05 | | ENQ | 37 | 25 | % | 69 | 45 | E | 101 | 65 | e | 133 | 85 | ä | 165 | A5 | å | 197 | C5 | ł | 229 | E5 | σ |
| ^F | 6 | 06 | | ACK | 38 | 26 | & | 70 | 46 | F | 102 | 66 | f | 134 | 86 | å | 166 | A6 | ä | 198 | C6 | ł | 230 | E6 | μ |
| ^G | 7 | 07 | | BEL | 39 | 27 | ' | 71 | 47 | G | 103 | 67 | g | 135 | 87 | ç | 167 | A7 | ç | 199 | C7 | ł | 231 | E7 | Υ |
| ^H | 8 | 08 | | BS | 40 | 28 | (| 72 | 48 | H | 104 | 68 | h | 136 | 88 | ê | 168 | A8 | è | 200 | C8 | ł | 232 | E8 | ϕ |
| ^I | 9 | 09 | | HT | 41 | 29 |) | 73 | 49 | I | 105 | 69 | i | 137 | 89 | ë | 169 | A9 | é | 201 | C9 | ł | 233 | E9 | Θ |
| ^J | 10 | 0A | | LF | 42 | 2A | * | 74 | 4A | J | 106 | 6A | j | 138 | 8A | è | 170 | AA | è | 202 | CA | ł | 234 | EA | Ω |
| ^K | 11 | 0B | | VT | 43 | 2B | + | 75 | 4B | K | 107 | 6B | k | 139 | 8B | ï | 171 | AB | í | 203 | CB | ł | 235 | EB | δ |
| ^L | 12 | 0C | | FF | 44 | 2C | , | 76 | 4C | L | 108 | 6C | l | 140 | 8C | î | 172 | AC | î | 204 | CC | ł | 236 | EC | ϖ |
| ^M | 13 | 0D | | CR | 45 | 2D | - | 77 | 4D | M | 109 | 6D | m | 141 | 8D | ï | 173 | AD | ï | 205 | CD | ł | 237 | ED | Φ |
| ^N | 14 | 0E | | SO | 46 | 2E | . | 78 | 4E | N | 110 | 6E | n | 142 | 8E | Ï | 174 | AE | Ï | 206 | CE | ł | 238 | EE | € |
| ^O | 15 | 0F | | SI | 47 | 2F | / | 79 | 4F | O | 111 | 6F | o | 143 | 8F | Ā | 175 | AF | Ā | 207 | CF | ł | 239 | EF | ∩ |
| ^P | 16 | 10 | | DLE | 48 | 30 | 0 | 80 | 50 | P | 112 | 70 | p | 144 | 90 | Ă | 176 | B0 | Ă | 208 | D0 | ł | 240 | F0 | ≡ |
| ^Q | 17 | 11 | | DC1 | 49 | 31 | 1 | 81 | 51 | Q | 113 | 71 | q | 145 | 91 | Ĕ | 177 | B1 | Ĕ | 209 | D1 | ł | 241 | F1 | + |
| ^R | 18 | 12 | | DC2 | 50 | 32 | 2 | 82 | 52 | R | 114 | 72 | r | 146 | 92 | Ė | 178 | B2 | Ė | 210 | D2 | ł | 242 | F2 | ∇ |
| ^S | 19 | 13 | | DC3 | 51 | 33 | 3 | 83 | 53 | S | 115 | 73 | s | 147 | 93 | ő | 179 | B3 | ő | 211 | D3 | ł | 243 | F3 | ∫ |
| ^T | 20 | 14 | | DC4 | 52 | 34 | 4 | 84 | 54 | T | 116 | 74 | t | 148 | 94 | ò | 180 | B4 | ò | 212 | D4 | ł | 244 | F4 | ∫ |
| ^U | 21 | 15 | | NAK | 53 | 35 | 5 | 85 | 55 | U | 117 | 75 | u | 149 | 95 | ó | 181 | B5 | ó | 213 | D5 | ł | 245 | F5 | ∫ |
| ^V | 22 | 16 | | SYN | 54 | 36 | 6 | 86 | 56 | V | 118 | 76 | v | 150 | 96 | ù | 182 | B6 | ù | 214 | D6 | ł | 246 | F6 | + |
| ^W | 23 | 17 | | ETB | 55 | 37 | 7 | 87 | 57 | W | 119 | 77 | w | 151 | 97 | ú | 183 | B7 | ú | 215 | D7 | ł | 247 | F7 | ≈ |
| ^X | 24 | 18 | | CAN | 56 | 38 | 8 | 88 | 58 | X | 120 | 78 | x | 152 | 98 | ÿ | 184 | B8 | ÿ | 216 | D8 | ł | 248 | F8 | ◦ |
| ^Y | 25 | 19 | | EM | 57 | 39 | 9 | 89 | 59 | Y | 121 | 79 | y | 153 | 99 | ÿ | 185 | B9 | ÿ | 217 | D9 | ł | 249 | F9 | • |
| ^Z | 26 | 1A | | SUB | 58 | 3A | : | 90 | 5A | Z | 122 | 7A | z | 154 | 9A | ÿ | 186 | BA | ÿ | 218 | DA | ł | 250 | FA | • |
| ^[| 27 | 1B | | ESC | 59 | 3B | ; | 91 | 5B | [| 123 | 7B | { | 155 | 9B | ÿ | 187 | BB | ÿ | 219 | DB | ł | 251 | FB | • |
| ^\ ^] | 28 29 | 1C 1D | | FS GS | 60 61 | 3C 3D | < = > | 92 93 | 5C 5D | \] ^ | 124 125 | 7C 7D | { ~ | 156 157 | 9C 9D | ÿ ÿ ÿ | 188 189 | BC BD | ÿ ÿ | 220 221 | DC DD | ł ł | 252 253 | FC FD | • |
| ^^ ^- | 30 31 | 1E 1F | ▲ ▼ | RS US | 62 63 | 3E 3F | > ? | 94 95 | 5E 5F | ^ _ | 126 127 | 7E 7F | ~ Đ* | 158 159 | 9E 9F | ÿ f | 190 191 | BE BF | ÿ ÿ | 222 223 | DE DF | ł ł | 254 255 | FE FF | • |

* ASCII code 127 has the code DEL. Under MS-DOS, this code has the same effect as ASCII 8 (BS). The DEL code can be generated by the CTRL + BKSP key.

8. HFA SCR EXAMINATION



9. HFA 3N1 EXAMINATION



10. HFA SFA EXAMINATION

