ISA

WIA-DM

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

Sistema de Apoio à Decisão para a especialidade de Oftalmologia baseado em técnicas de Workflow e Data Mining aplicadas em dados obtidos em Ambiente Clínico

Project Report
Version 1.0

Paulo Barbeiro – Nr. 501022543

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Centro Cirúrgico de Coimbra

Departamento de Física
FACULDADE DE CIÊNCIAS E TECNOLOGIAS
UNIVERSIDADE DE COIMBRA

“Ninguém é tão grande que não possa aprender,
nem tão pequeno que não possa ensinar”

Acknowledgments

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Abstract

Medicine practice is a subjective issue, and although there are many known logical rules to understand the human body and its diseases, it is common knowledge that different expert Medical Doctors may have different opinions towards the same clinical case.

This report describes the executed work during the Final Project of Biomedical Engineering, which had as objective to diminish this subjectivity by creating a Decision Support System for the Ophthalmologic medical practice. This initial raw idea was analyzed, discussed with engineers and medical doctors, and a prototype solution was created.

Due to the extent of the ophthalmologic practice, this project focused on the automatic detection of retinal structural changes in OCT (Optical Coherence Tomography) images, such as macular holes, retinal detachments and extracellular edemas, using image processing algorithm for features extraction and neural networks to classification. There was also a parallel creation of software which objective was to optimize systems integration and information access, already aiming to future developments of analysis techniques.

The created integration and management software complies with the defined requisites, and although their development is not yet finished or tested, simulations with them were very satisfy and promising.

As for diagnosis aid, image process algorithms with performances ranging from 80% to 99% in detecting characteristics were developed, as a neural network able to associate correctly 97% of the characteristics with the respective disease.

Keywords

Decision-Support, Ophthalmology, Neural Networks, OCT image processing

Resumo

A prática da medicina é algo subjectivo, e embora se conheçam muitas das regras lógicas que permitem compreender o corpo humano e doenças que o possam afectar, também é do conhecimento comum que diferentes Médicos especialistas podem ter opiniões diferentes acerca de um mesmo caso clínico.

Este relatório descreve o trabalho executado durante o Projecto Final de Engenharia Biomédica, que teve como objectivo a diminuição desta subjectividade através da criação de um sistema de apoio à decisão médica para a área de oftalmologia. Esta ideia inicial foi analisada, discutida com engenheiros e médicos, e foi criada uma solução protótipo.

Devido à abrangência de toda a área de oftalmologia, este projecto focou-se na detecção automática de alterações estruturais da retina visíveis em imagens de OCT (Tomografia de Coerência Óptica), tais como buracos maculares, descolamentos da retina, e edemas. Para tal foram utilizadas técnicas de processamento de imagem para extracção de características, e redes neuronais para a classificação destas. Paralelamente a isto, foi também desenvolvido software cujo objectivo é optimizar a integração de sistemas e consequente acesso à informação, de modo a permitir futuros desenvolvimento em técnicas de análise de informação.

O software criado para integração e gestão satisfaz os requisitos definidos, e embora o seu desenvolvimento não esteja ainda terminado ou testado, as simulações efectuadas são bastante satisfatórias e promissoras.

Quanto ao apoio ao diagnóstico, os algoritmos de processamento de imagem têm performances de detecção de características entre os 80% e 99%, ao passo que a rede neuronal é capaz de associar correctamente 97% destas às respectivas doenças.

Palavras-chave

Apoio à decisão, Oftalmologia, Redes Neuronais, Processamento de imagens de OCT

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Acronyms and Abbreviations

AI	Artificial Intelligence
CCC	Centro Cirúrgico de Coimbra
DB	Data Base
DM	Data Mining
LASER	Light Amplification by Stimulated Emission of Radiation
LED	Light Emitting Diode
MD	Medical Doctor
NN	Neural Network
OCT	Optical Coherence Tomography
PCA	Principal Component Analysis
Pixel	Picture Element
RAL	Retinal Anterior Layer
RNFL	Retinal Nerve Fiber Layer
SLO	Scanning Laser Ophthalmoscope
SOM	Self Organizing Maps

1. Introduction

1.1. Project Vision

This project began with Dr António Travassos vision that engineering concepts and ideas could be used to improve the actual state of work of CCC, and improve the practice of medicine.

His vision for CCC is a vision of excellence, and in an ideal scenario it would exist a single and simple computer application capable of handling all equipments, and making information accessible anytime anywhere.

Also, in his opinion, there is still much subjectivity associated to the analysis of information during the practice of medicine nowadays. Consequences of this are the different opinions and decisions that different doctors may have towards the same exact problem. However, technological evolution may provide the tools and knowledge integration to allow medicine to become a more accurate science, and new technologies of artificial intelligence will certainly play a major role on that evolution.

It was immediately perceivable to all project elements that accomplishing both this tasks would take much more than one year. So, the first difficulty was to understand where to start from.

1.2. Project Team

WIA-DM official project team was composed of five elements: three students, one medical supervisor, one engineering supervisor, and the project Coordinator.

Due to the great interdisciplinary of the project, there was a need to gather more knowledge into it, which was done with the gentle aid of all collaborators.

Table 1 – Project Team

Name	**Designation**	**Contact**
Paulo Barbeiro	Trainee Student	paulobarbeiro@gmail.com
Armanda Santos	Trainee Student	santos.amn@gmail.com
Edgar Ferreira	Trainee Student	edgar.bajouca@gmail.com
Eng. Jorge Saraiva	Project Supervisor	jsaraiva@isa.pt
Dr. António Travassos	Project Supervisor	info@ccci.pt
Eng. Jorge Landeck	Project Coordinator	jlandeck@lei.fis.uc.pt
Eng. José Basílio Simões	Collaborator	jbasilio@isa.pt
Engª Lara Osório	Software Collaborator	losorio@isa.pt
Prof. Carlos Correia	Collaborator	correia@lei.fis.uc.pt
Prof. Requicha Ferreira	Collaborator	requicha@ci.uc.pt
Dr Rui Proença	Medical Collaborator	+351 239 802 705

1.3. Report Overview

This project report is divided in six sections. In the current section (Section 1), an introduction to the theme is made, project team is presented and report overview is made.

On Section Two, basic concepts intended to use on this project are explained, and some application examples are provided.

Section Three is dedicated to problem analysis, and states the current operation mode of the Clinical Unit to improve (CCC). It also contains overviews regarding ocular diseases, machines which can detect them and possible approaches to Decision-Support.

Section Four enounces the defined objectives for each of the areas.

Section Five shows for each of the intervention fields executed work and obtained results.

Finally, Section Six is dedicated to conclusions future work.

2. Background

This project name states upstart several concepts and technologies which are intended to use during the execution of the same. So being, it is vital to explain them before proceeding. Also, an anatomical introduction to the human eye is made.

2.1. Data Mining

Data Mining, also known as Knowledge-Discovery in Databases (KDD), is the process of autonomously extracting useful information or knowledge from large data sets [1]. This is accomplished by using complex algorithms to search large amounts of data attempting to find patterns, correlations, and trends in that data. A data-mining application can create a model that can identify buying habits, shopping trends, credit card purchases as well as perform many non-commercial functions[2].

2.2. Workflow

A Workflow is a collection of steps and data that define element's paths that can be taken to complete a task, where these elements might be goods, persons or information. Workflows may contain activities such as displaying content to users, collecting information from users or computer systems, performing calculations, and sending messages to external computer systems[3].

It may be mathematically modeled through Petri Nets, having matrices to represent content, position, transition of each stage.

2.3. Decision Support Systems

One of the existing definitions for decision support systems is: "*Computer technologies used in healthcare which allow providers to collect and analyze data in more sophisticated and complex ways. Activities supported include case mix, budgeting, cost accounting, clinical protocols and pathways, outcomes, and actuarial analysis*." [4].

In our opinion, there are mainly two ways to support a medical decision. One is to work as an information provider, so MD has the maximum data possible to understand the situation and correctly diagnosis the disease. Main tasks in this area are gathering, organization and display the information to the MD, so he has the maximum amount of it available to allow him to take decisions. Information systems applied in healthcare environments are examples of this support, enabling information integration, information quick access, and dynamic interaction between different structures.

Other approach is to attempt to comprehend the same information, thus creating logical models that allow providing an empiric second opinion, which should help to reduce the subjectivity of present medicine. Examples of this are already existing AI systems that are at the present trying to understand information from several fields of medicine as happens with specific-purpose-created neural networks, which perform diversified tasks such as detecting skin cancer, define the length of ocular muscle cut in strabismus surgery, label retinal hemorrhage, classification of images by comparison, character recognition, industrial processes monitoring and much more natural and artificial systems simulation. Some of these examples are analyzed in section 3.4.

Furthermore, there are some systems which play both this roles, for example by extracting information from images in order to better inform the MD about the observed characteristics.

2.4. Human Eye

Eyes are organs of vision that detect light. Its structure may be divided in several ways, but the most common is into two sections: The anterior and posterior segments.

The anterior segment is the front third of the eye that includes the structures in front of the vitreous humour: the cornea, iris, ciliary body, and lens. Within the anterior segment are two fluid-filled spaces: the anterior chamber and the posterior chamber. The anterior chamber is the space between the posterior surface of the cornea (i.e. the corneal endothelium) and the iris, whereas the posterior chamber is between the iris and the front face of the vitreous.

The iris, between the lens and the first humour, is a pigmented ring of fibro-vascular tissue and muscle fibers. Light must first pass though the centre of the iris, the pupil. The size of the pupil is actively adjusted by the circular and radial muscles to maintain a relatively constant level of light entering the eye. Too much light being let in could damage the retina; too little light makes sight difficult

The lens, behind the iris, is a convex, springy disk which focuses light, through the second humour, onto the retina.

The cornea and lens help light rays to focus onto the retina. It is attached to the ciliary body via a ring of suspensory ligaments known as the Zonule of Zinn. To clearly see an object far away, the ciliary muscle is relaxed, which stretches the fibers connecting it with the lens, flattening the lens. When the ciliary muscle contracts, the tension of the fibers decrease (imagine that the distance between the tip of a triangle to its base, is less than the tip of the triangle to the other two tips.) which lets the lens bounce back a more convex and round shape.

All of the individual components through which light travels within the eye before reaching the retina are transparent, minimizing dimming of the light. Light enters the eye from an external medium such as air or water, passes through the cornea, and into the first of two humours, the aqueous humour. Most of the light refraction occurs at the cornea which has a fixed curvature. The first humour is a clear mass which connects the cornea with the lens of the eye, helps maintain the convex shape of the cornea (necessary to the convergence of light at the lens) and provides the corneal endothelium with nutrients[5][6].

The posterior segment is the back two-thirds of the eye that includes the anterior hyaloid membrane and all structures behind it: the vitreous humor, retina, choroid, and optic nerve.

The hyaloid is the membrane surrounding the vitreous humor, which has a vital role on maintaining the eyeball shape.

The retina is a thin layer of neural cells that lines the back of the eyeball, being the central retina is cone-dominated and the peripheral retina is rod-dominated. At its center is the fovea, a pit that is most sensitive to light and is responsible for our sharp central vision. In section the retina is no more than 0.5 mm thick.

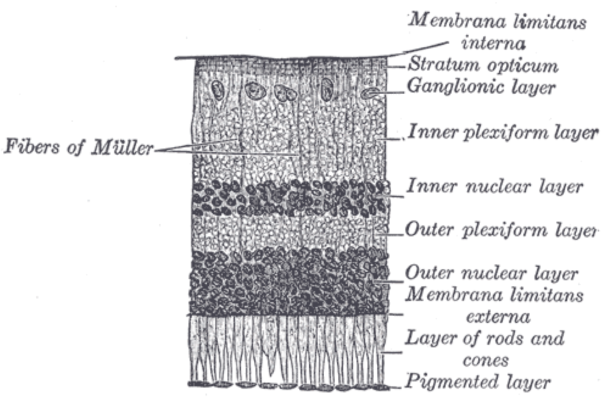


Figure 1 - Retina tomographic section

It has three layers of nerve cells and two of synapses. The optic nerve carries the ganglion cell axons to the brain and the blood vessels that open into the retina. As a byproduct of evolution, the ganglion cells lie innermost in the retina while the photoreceptive cells are located in the external side. Because of this arrangement, light must first pass through the thickness of the retina before reaching the rods and cones, where almost all of it is reflected by the pigmented epithelium (PE).

Between the ganglion cell layer and the rods and cones there are two layers of neuropils where synaptic contacts are made. The neuropil layers are the outer plexiform layer and the inner plexiform layer. In the outer the rod and cones connect to the vertically running bipolar cells and the horizontally oriented horizontal cells connect to ganglion cells[6].

3. Problem Analysis

As said in the project vision, the global concept of improving medical practice by using engineering techniques is a wide one. The first task needed to execute was to understand what was and how worked CCC, and understand the practice of ophthalmology medicine.

Also, since there were numerous ideas and approaches that could be used to address the decision support idea, there was a need to gather and understand some of them, in a global overview similar to *State of the Art*.

3.1. Centro Cirurgico de Coimbra

The *Coimbra Surgical Centre* (CCC) is a private health unit, which can be seen as a complement to the existing institutions within the central region of Portugal. Like them it aims to create conditions of excellence, both for the professionals who work there and for those who use its services, aiming to be recognized for its distinctive and high quality medical services, as well as the care and facilities which it offers its users[33].

3.1.1. CCC Inner Organization

CCC HealthCare Center is administrated by a company named Intercir. Exception made to MDs consultations and surgical interventions, all services and facilities maintenance are provided by Intercir.

One of the provided services is the renting of rooms, either equipped for surgical interventions or for patient regular examination. Regarding the examinations rooms, there are some available on a rotational system, with different MDs on different days of the week (that from now on will be referred as external MDs), as others are permanently occupied by the same doctor (these will be referred as Internal MDs).

Internal or external MDs may use surgical rooms for interventions, and patients subject to these will be interned on Intercir's infirmary. Once there, Intercir is the responsible for the provided nurse assistance, additional accommodation for family members, pharmacy drugs, meals, infirmary expendables, and other provided services.

3.1.2. Administrative Organization

By administrative organization we are referring all management that does not concern clinical aspects, so eventually a better designation would be financial organization.

There are two distinct administrative organization issues. One of them concerns internal MDs and how they manage their patients. The other one concerns Intercir and its management of consultation rooms, surgery rooms, and internment aspects.

Since at the present time, each doctor has its own tool to administrate patients, and keeping in mind that the seek solution would be one where there was only one software responsible for all of this, we will focus on Intercir needs, since all existing patients from internal and external MDs are registered in it.

3.1.2.1. Current State of Functioning

Intercir's administrative tool is HIGIA. This program, created by Cardinal2, allows doing all the regular financial operations which administrative software does. Without exhaustive enunciation of all of them, some examples of those operations are:

- Registry of clients (patients)
- Scheduling of surgeries
- Tables of items to sell
- Some amount of flexibility to allow discounts to patients
- Special prices tables to companies with whom there are commercial agreements
- Existence of composite items

This tool is used to register all CCC patients, meaning Intercir patients and individual clinics patients.

3.1.2.2. Current Administrative Software Advantages

HIGIA software is able to cover most of the existing needs, and providing administrative services with a small amount of flexibility.

It has de secondary advantage of having all staff used to it.

3.1.2.3. Current Administrative Software Disadvantages

The major reported flaw of this system are its inability to perform personalized queries, which for end-of-year reports of performance obliges users to manually compile information into excel files, and prevents the verification of relationships between datasets, thus forcing the investment of human resources into exhaustive repeatable and otherwise unnecessary tasks.

Other pointed flaw is the increasing number of times of system crash within the latter years, with all the advantages that one may imagine to a situation as such. Besides the waiting patients, and the common data loss, there are only two persons on CCC who know how to restart the server, and it has happened that none was on the building and was forced to return for server resetting.

Finally, and being not a software flaw but more of a circumstance one, there is the fact that HIGIA is a closed solution, rendering improvements intended to do undoable without Cardinal2 consent and software details disclosure.

3.1.3. Clinical Organization

Due to it's goal and functional structure, CCC doctors – intern and extern ones – do not use the same software for clinical information management. This occurs because MDs do not all have the same patients, and due to doctor-patient confidentiality there is no interest in sharing information.

These systems are unable to communicate with each other, thus forcing operations between them to use printed information.

This problem also occurs between these systems and the machines used to examine patients, but it will be addressed on section 3.1.5

3.1.3.1. Clinical Software

Existing clinical software tool is CMOC, from SilverInfor.Lda. CMOC allows the user to search and select patients, and for each one of them, create or edit textual data and visualized stored images, which are available organized by date of exam execution and type of exam.

3.1.3.2. Current Clinical Software Advantages

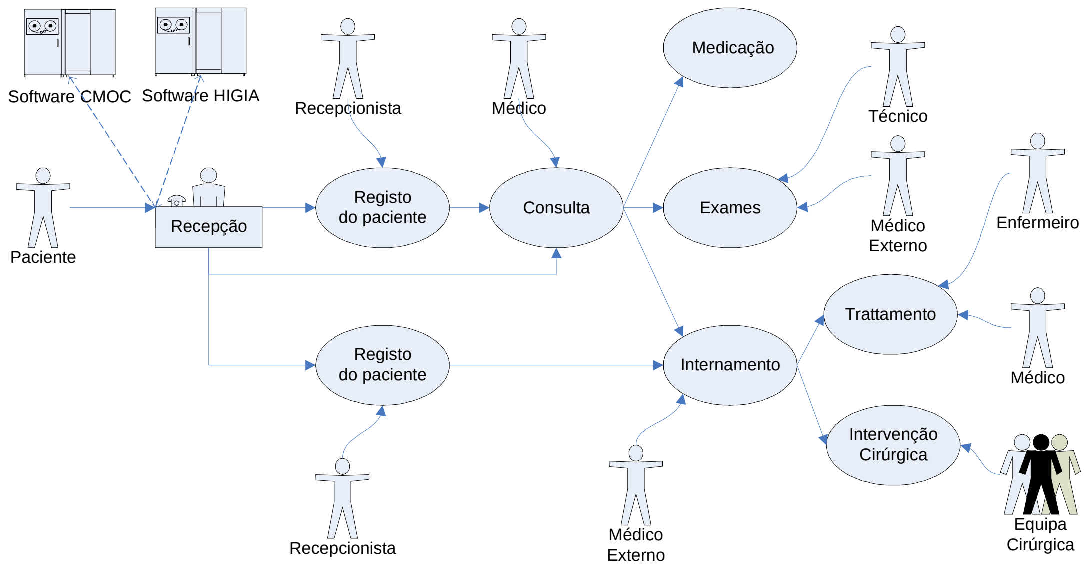
CMOC main advantage is its simple method of working. It partially replaces the need of paper output from some of the machines, and serves as an organized data-store.

3.1.3.3. Current Clinical Software Disadvantages

It does not allow interaction with the examination equipments, for example by scheduling requests. Also, since it is mainly an information repository, it does not structure information in a relational fashion, thus preventing medical data-mining from being made.

3.1.4. Clinical Workflow

Clinical workflow analysis was made by Edgar Ferreira and Armanda Santos, and for a detailed version it is advisable to read their *Project Report*. However, in order to correctly contextualize the systems integration, it is necessary to explain the workflow of a patient, which is depicted in Schematic 1.



Schematic 1 - Patient workflow

The main issue illustrated in there is the double registry of a new patient into two distinct softwares: administrative and clinical ones. This replication of data and data acquisition causes unnecessary human resources and data storage needs, and could be overcome with system integration.

3.1.5. Systems Integration

As said before, CCC's system integration is a field which needs improvements. Most information is still passed around with papers, either between examination equipments and MDs, as between several MDs themselves. Existing equipments were analyzed, and the current state of integration is described:

3.1.5.1. Integration Tool

The software used to help integration between examination equipments and CMOC is *SnagIt*, a screen capture software from TechSmith Corporation©. While the program is running on the background, whenever the user presses a predefined combination of keys, the current image present on the screen will be captured and a User Interface will appear, to allow defining the path, name, and format of the stored file.

3.1.5.2. Integration Method

Current equipments integration method consists on storing print screens from the applications software.

Since CMOC is able to parse specially written names, user must write a special code containing image number, followed by patient identification number, by the machine identification code and by the current date.

As an example, the second image for patient 12345 observed by a machine with code 111 on first of august of the present year would have this code registered:

02-12345-111-01082007

3.1.5.3. Advantages

The obvious advantage of this current state of functioning it's it simplicity ability to deal with numerous machines without being necessary to modify the process of integration for each individual case.

3.1.5.4. Disadvantages

By simply copying the contents of the computer screen, there is a loss of information. Image resolution may be compromised, and data not presented in the screen but available through software navigation becomes inaccessible. Also, data processing operations, such as image enhancement and combination became unavailable (although this is more a CMOC disadvantage that an integration one).

Another disadvantage is due to the fact that during each exam several images may be acquired and the export each one of them individually consumes too much time. The current solution for this is that the examination technician chooses a few of the best images (choice based on his experience and knowledge)

3.1.5.5. Currently integrated equipments

Currently integrated examination equipments are all of those who have a windows 2000 or XP network connection, and whose output is an image, namely:

- Stratus OCT ™ from Karl Zeiss Meditech Inc,
- OCT-SLO from OTI Ophthalmic Technologies Inc.
- Orbscan from Bausch & Lomb
- Angiography and Retinography camera apparatus

The remaining equipments do not allow easy export of data, and to achieve their integration, further analysis must be done. Table 2 shows these machines and respective outputs.

Table 2 - Equipments currently not integrated

Equipment	Operating System	Output
GDx™ Scanning Laser System	Owner Operative System	Printer, Software display
Specular Microscopy	Windows 95	Software display
Perimetry	Owner Operative System	Printer, software display
Micro Perimetry	Windows 95	Printer, Software display
Visumetry	Windows 95	Software display

3.2. Equipments and Examinations

When attempting to create a decision support system related with a diagnosis process, it is of vital importance to understand how this diagnosis is done, and what is diagnosed.

Before addressing the existing pathologies description, it is important to know which examinations are used detected them, and how they work. To achieve that, all CCC's existing examination equipments were analyzed.

Examination Name: Retinography

Structure Analyses: Retina – Posterior Segment

Operating Principles: Retinography consist in simply take a picture of the ocular fundus, which may be done with or without pupil dilation.

Machine Output: PDF or printed colored picture

Examination Name: Retinal Angiography

Structure Analyses: Retinal and choroidal blood vessels – Posterior Segment

Operating Principles: In retinal angiography, vessels are brought into high contrast by intravenous injection of a fluorescent dye, which emits light in a different wavelength of the received excitatory one. The retina is then illuminated with an excitation color, and by filtering to exclude the excitation color and pass the fluorescent color, a very high-contrast image of the vessels is produced. Shooting a timed sequence of photographs of the progression of the dye into the vessels reveals the flow dynamics and related pathologies. Specific methods include sodium fluorescein angiography and indocyanine green angiography[7].

Machine Output: PDF or printed sequence of grayscale images

Examination Name: Specular Microscopy

Structure Analyses: Corneal cells – Anterior Segment

Operating Principles: When illuminating eye's anterior segment with a slit lamp, as light strikes the posterior corneal surface, almost all of it is transmitted into the aqueous humor. However, because there is a change in index of refraction at the endothelium-aqueous humor interface, about 0.022 per cent of the total incident light is reflected; this reflected light is captured by the clinical specular microscope and forms the endothelial image[8].

Machine Output: Display on system software of statistical data regarding cell count and shapes.

Examination Name: Corneal Topography

Structure Analyses: Cornea

Operating Principles: A corneal topographer projects a series of illuminated concentric rings onto the corneal surface, which are reflected back into the instrument. Existing corneal distortions will affect rings shape when they reach the instrument. These are analyzed by the computer and a topographical map of the cornea is generated[9].

Executing Machine: Orbscan.(Bausch & Lomb's)

Machine Output: Corneal thickness and optic power maps, which may be printed or saved as bitmap.

Examination Name: Perimetry

Structure Analyses: Not applicable, since it's a functional evaluation of the whole visual system.

Operating Principles: Light dots are projected on different points of a concave semispherical surface, which occupies patient whole visual field, and he must indicate which one he is able to visualize.

Machine Output: Printed paper of decibel coded visual sensibility in each point of the visual field.

Examination Name: Micro Perimetry

Structure Analyses: Not applicable, since it's a functional evaluation of a portion of the visual system – anterior segment troubles are overridden due to the use of a laser beam.

Operating Principles: Laser dots are projected on different retinal areas, and patient must indicate which one he is able to visualize.

Machine Output: Printed paper of decibel coded visual sensibility in each point of the tested retinal visual field.

Examination Name: Visumetry

Structure Analyses: Not applicable, since it's a functional evaluation of a portion of the visual system – anterior segment troubles are overridden due to the use of a laser beam.

Operating Principles: A laser is used to project several symbols with several orientations and sizes in the macular area. As in an optotype, patient visual function is evaluated considering the smallest symbols correctly identified.

Machine Output: Non-dimensional number proportional to the size of the smallest symbols correctly perceived.

Examination Name: Coherence Tomography (OCT)

Structure Analyses: Retina, PE and choroid.

Operating Principles: OCT is based on low-coherence interferometry. In conventional interferometry with long coherence length (laser interferometry), interference of light occurs over a distance of meters. In OCT, this interference is shortened to a distance of micrometers, thanks to the use of broadband light sources (sources that can emit light over a broad range of frequencies). Light with broad bandwidths can be generated by using super luminescent diodes or lasers with extremely short pulses. White light is also a broadband source with lower powers.

Light in an OCT system is broken into two arms -- a sample arm (containing the item of interest) and a reference arm (usually a mirror). The combination of reflected light from the sample arm and reference light from the reference arm gives rise to an interference pattern, but only if light from both arms have travelled the "same" optical distance ("same" meaning a difference of less than a coherence length). By scanning the mirror in the reference arm, a reflectivity profile of the sample can be obtained (this is time domain OCT). Areas of the sample that reflect back a lot of light will create greater interference than areas that don't. Any light that is outside the short coherence length will not interfere. This reflectivity profile, called an A-scan contains information about the spatial dimensions and location of structures within the item of interest. A cross-sectional tomograph (B-scan) may be achieved by laterally combining a series of these axial depth scans (A-scan), as happens on the Stratus OCT, or may by vertically combining a sequence of transversal scans (T-scans), which is the operating method of the OCT-SLO[10].

Executing Machine: OCT-SLO (OTI) and Stratus OCT (Carl Zeiss Meditec)

Machine Output: RBG Image of retinal cross-section, which may be printed or exported to common format image file, paired with a representation of eye fundus and scanning line.

OTI's OCT-SLO provides images composed of 500 8mm length T-scans, separated from each other 4µm, thus resulting in 8mm x 2mm pictures. Also, it may provide DICOM output[11].

Examination Name: Scanning Laser Ophthalmoscope (SLO)

Structure Analyses: Retina, PE and choroid.

Operating Principles: A highly collimated narrow beam of light from a laser is swept over the retina, delivering all its energy to a very small spot for a very short time. Light returned from that spot is detected and synchronously decoded to form an image on a monitor. When combined with OCT technology, has happens in OTI's machine, this allows en face imaging (C-scan) at an acquired depth[10][12].

Executing Machine: OCT-SLO (OTI)

Machine Output: RBG Image of retinal cross-section, which may be printed or exported both to a common format image file, or a DICOM one.

Examination Name: Scanning Laser Polarimetry

Structure Analyses: Retinal Nerve Fiber Layer (RNFL)

Operating The principles of SLP utilize birefringence and retardation. Briefly,

Principles: the RNFL is birefringent due to the parallel arrangement of microtubules within NFL axons. Birefringence changes the polarization of the incident light into orthogonal planes. The time delay between the return of these fast and slow axes is called retardation. Polarized light passing through a birefringent medium (NFL) is split into two rays. Rays of laser light that travel perpendicular to fibers passes through at a speed different from those rays passing through in parallel. The phase shift results in retardation and provides the basis for which to measure the thickness of the NFL[13].

Executing Machine: GDX™ (Carl Zeiss's Meditec)

Machine Output: Color coded image showing physiological changes probability in the optic disk and adjacent areas.

3.3. Retinopathies Study

Finished the comprehension of the diagnosis equipments principles and information that they may retrieve, the next step is to understand existing eye diseases, and how they may be detected using the equipments described above.

Since there are too many eye diseases to be analyzed in only one study, it was defined by our Medical Supervisor that we would focus on the posterior segment area, mainly some of the most common retinal diseases, which may be diagnosed by just using OCT, Retinography and Angiography.

Name: Cotton-Wool Exudates

Cause: Local hypoxia (diminished presence of oxygen) forces cells mitochondria to group together in axons central body, in order to save energy. This increase in cellular structures concentration is changes the optical properties of the cells.

Observation Characteristics:

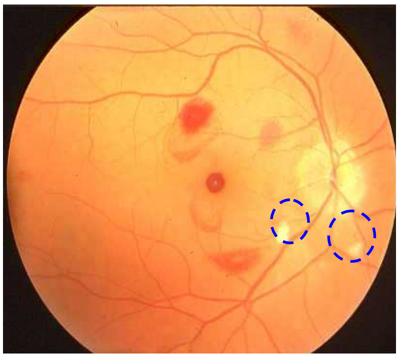
Retinography	- White clouds with middling undefined contours - Located above blood-vessels	
OCT	- Retinal thickening, showed as hyper-reflective spots	

Table 3 – Cotton-wool exudates images

Name: Hard Exudates

Cause: When ischemia (total absence of oxygen) causes cellular death, glial cells have the task to clear the area by absorbing and digesting the remainders. However, their ability to digest great amounts of lipids (which are the main element of cells membranes) is limited, which results in absorption with no digestion, thus retaining lipidic material inside of them.

Observed Characteristics:

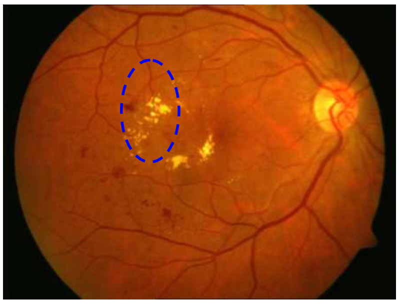
Retinography	- Yellow spots with well-defined contours.. - Generally located around the fovea, in a radial disposition. - Located below blood vessels	
OCT		

Table 4 – Hard Exudates images

Name: Extra-cellular Edemas

Cause: Blood-vessels wall are composed of adjacent cells, attached to each other through sealed connections named tight-junctions, who prevent physiological fluids from leaking out. When these tight-junctions suffer a rupture, but there is no red-globules leakage (only smaller blood elements), extra-cellular edemas appear.

Observed Characteristics:

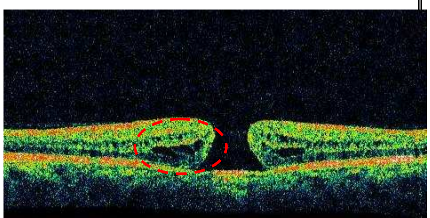
Angiography	- Diffuse fluorescence area, , visible in the mid-time of the angiography test.	
OCT	- Dark petal-shaped spots, with well-defined contours, in the retina.	

Table 5 - Extra-cellular edemas images

Name: Hemorrhage

Cause: Blood-vessels wall are composed of adjacent cells, attached to each other through sealed connections named tight-junctions, who prevent physiological fluids from leaking out. Hemorrhages occur when these tight-junctions suffer severe rupture, with red-globules leakage

Observed Characteristics:

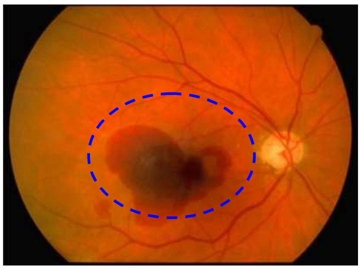
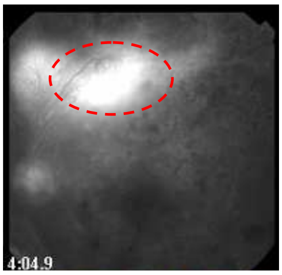
Retinography	- Red or dark red areas - Superficial hemorrhages commonly present a round shape	
Angiography	- Hyper-fluorescent regions	

Table 6 – Hemorrhage images

Name: Micro-aneurisms

Cause: Micro-aneurisms occur when small blood vessels became obstructed, and there is a swelling as a reaction.

Observed Characteristics:

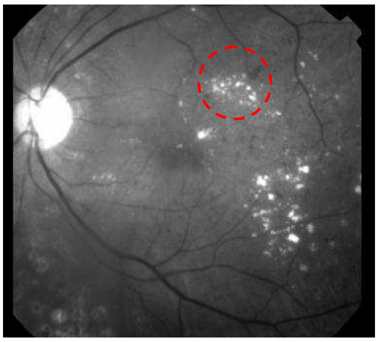
Angiography	- Small hyper-fluorescent (white) dots, coincident with retinal small blood vessels	

Table 7 – Micro-aneurisms images

Name: Retinal Neo-vascularization

Cause: This occurs when there is a release of VEGF (vascular endothelium growth factor) into the retinal medium, mostly as a consequence of hypoxia. VEGF creates new blood-vessels to irrigate the retinal tissue, but when there is an excess of VEGF this new blood-vessels do not have tight-junctions, causing severe leakage throughout the retina. Leaking fluids also increase ocular tension.

Observed Characteristics:

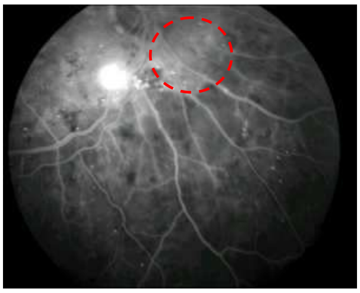
Angiography	- Diffuse areas of hyper-fluorescence (white regions)	
Ocular Tensiometer	- Increased Intra-Ocular Tension	

Table 8 – Retinal neo-vascularization images

Name: Choroidal Neo-vascularization

Cause: This occurs when there is a release of VEGF (vascular endothelium growth factor) into the choroidal medium, mostly as a consequence of hypoxia. VEGF creates new blood-vessels to irrigate the choroid tissue, but when there is an excess of VEGF this new blood-vessels do not have tight-junctions, causing severe leakage throughout the choroid. Leaking fluids push the PE and may even tear it, causing increase in ocular tension and retinal neo-vascularization due to VEGF migration.

Observed Characteristics:

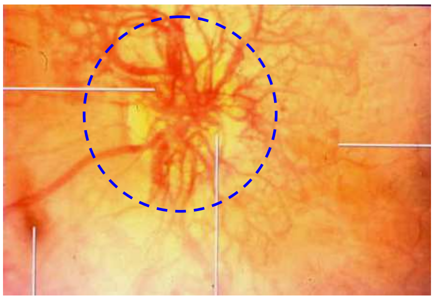
Retinography	- Abnormal reflectance area, due to PE distortion - Hidden sub-retinal membrane	
Angiography	- Hyper-fluorescent areas with green-indocyanine imaging	

Table 9 – Choroidal Neo-vascularization images

Name: Serous Detachment

Observed Characteristics:

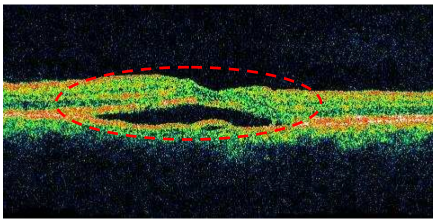
Angiography	- Gray region with well-defined contours during the final stage of angiography.	
OCT	- Empty area above EP.	

Table 10 – Serous detachment images

Name: Macular Hole

Cause: As the vitreous humor ages, it becomes less liquid, and loses volume. The hyaloid membrane, which surrounds the vitreous, accompanies this shrinkage, and as a result of this there is a traction force applied to the retina. This force may be strong enough to cause a small retinal tissue break, and generally this break occurs in the slimmer retinal region – the macula.

Macular holes may also be cause by external ocular trauma.

Observed Characteristics:

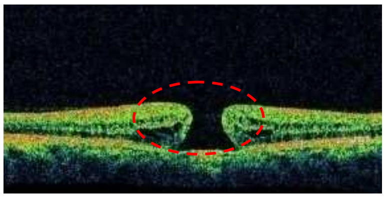
OCT	Full-height retinal horizontal discontinuity	

Table 11 – Macular hole images

Name: Detached Macular Hole

Cause: When a macular hole appears, there is a natural tendency to detach the retina from the EP.

Observed Characteristics:

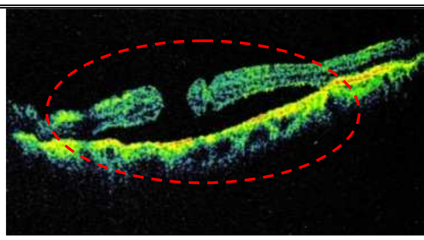
OCT	- Empty area between retina and EP, with a horizontal discontinuity in the first.	

Table 12 – Detached macular hole images

Name: Lamellar Hole

Cause: The same as Macular Holes.

Observed Characteristics:

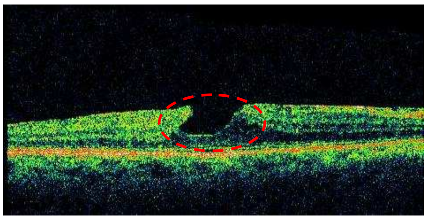
OCT	- Partial horizontal discontinuity in the retina	

Table 13 – Lamellar hole images

Name: Retinal Cyst

Cause:

Observed Characteristics:

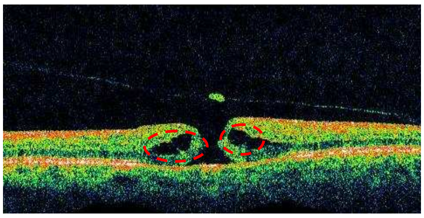
OCT	Dark round spots inside the retina	

Table 14 – Retinal Cysts images

Name: Macular Pucker, Epiretinal membrane

Cause: A macular pucker is a thin, transparent scar tissue which grows over the macula. This thin sheet can contract and form wrinkles in the retina, therefore causing visual distortion.

Observed Characteristics:

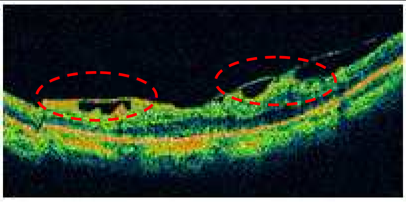
OCT	Dense membrane above the retina, often with retinal structure distortion	

Table 15 – Epiretinal membrane images

Name: Pigmented Epithelium Detachment

Cause: Sub-retinal neovascularization

Observed Characteristics:

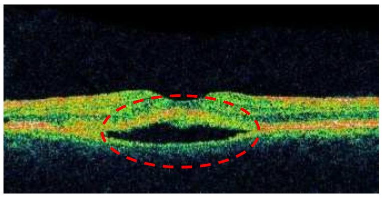
Angiography	- Well-defined oval gray areas in the final stage of angiography	
OCT	- Empty space below PE	

Table 16 – Pigmented epithelium detachment images

Name: Central Retinal Artery Obstruction (CRAO)

Cause: Embolisms occur when there is an abrupt obstruction of an artery, mainly cause by clots.

Due to ischemia during twenty or more minutes, death of all retina photo receivers occurs, which results in permanent blindness.

Observed Characteristics:

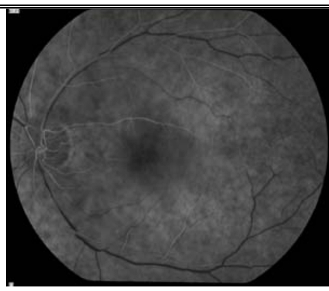
Angiography	-Absence of highlighted blood vessels during the first minute after dye injection	
Retinography	- Regular aspect of a healthy retina - Blood vessels emerging from the optic nerve with a thinner initial section.	

Table 17 – Central Retinal Artery Obstruction images

Name: Cataracts

Cause: Alteration in the optical properties of the crystalline, causing less light to cross into the retina.

Observed Characteristics:

Bio-microscope	- Direct observation of crystalline opacity	
Retinography	- Low contrast image	

Table 18 – Cataracts images

Name: Laser Scars

Cause: Caused by retinal laser photocoagulation treatment.

Observed Characteristics:

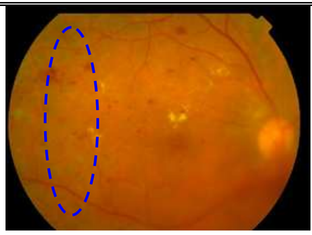
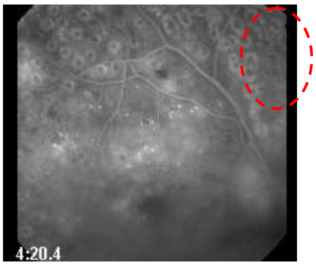
Retinography	- Green-grayish rings	
Angiography	- Light-grey rings with dark-gray center.	

Table 19 – Laser scars images

3.4. Decision Support Systems

Diagnosis aid is a complex problem, and it has numerous ways to approach it. While researching and executing this project, several methods with potential to prove useful were found. We have grouped them together regarding their field of action as follows:

3.4.1 Database Organization

3.4.2 Images Comparison

3.4.3 Patient Comparison

3.4.4 Image Processing Techniques

3.4.5 Medical Classification

There is a partial section overlap, since majority of classification techniques are more or less based on comparisons. Formulas and concepts are not exhaustive exposed and analyzed, since this in mostly an overview.

3.4.1. Database Organization

OLAP

OLAP is the acronym for *OnLine Analytical Processing*, and is a subsection of the broader category Business Intelligence, which also includes data warehouse, ETL (Extraction, Transformation and Load) and Data Mining. OLAP typical applications are mainly management reports, business performance management (BPM), budgeting, forecasting and prediction, financial reports and similar ones.

OLAP basic work concept is the re-organization of copies of the database in different *star-schemes*. In these *star-schemes*, the center table contains the *fact table*, the main table where the query will start. Spreading from the center are the remaining tables of the relational data-base, where all the relationships are preserved, but with different hierarchical organization for each of the *star-scheme*. The sum of all this *star-schemes* is designated as *OLAP Cube*, and it have been reported queries taking only 0.1% of the regular time due to this technology [14].

3.4.2. Images Comparison

Wavelets and Codebooks

A wavelet is a kind of mathematical function used to divide a given function into different frequency components and study each component with a resolution that matches its scale. A wavelet transform is the representation of a function by wavelets, in a similar manner has sinusoids are used in fourier representations [15].

By using different wavelets analysis windows size, high frequency bands may be distinguished from low ones. In the particular case of images, the resulting of applying a wavelet to one of them is a low frequency half-sized image, and three residual images for the high frequencies according to different sweeping directions. This is illustrated in Schematic 2.

Schematic 2 - Wavelet decomposition [16]

In similar images, the low-frequency signals are much alike, being the differences stored in the high-frequency residues. Being so, it is possible to code common components into a reference book, which results in a memory save. Also, since similar images will share the same code (will have the same low-frequency image), search for identical images will be greatly eased.

These codebooks training may be achieved by overlapping images, and using Euclidean distance as a distortion measure between each one of them.

For a particular application (e.g. brain tomography), images will probably be similar, so they will share the same code, but will have different residual trees. This will achieve two important things – reduction of the needed space to store and transmit images, and ease the searches for similar images, since similar images share the same code[17].

Neural Networks for image comparison

NN traditionally are used to process low-dimensional signals. Their typical ability to compare images consisted on first rearranging image pixels so they became a one-dimensional array, and then make pixel-by-pixel comparisons. However, this pixels rearranging creates context losses, and neural networks direct application to image is not broadly used.

A way to overcome this limitation is to mimic the mammalian visual process, as is described by Magnus Borga in his Learning Multidimensional Signal Processing dissertation. In a very brief summary of it, adopted approach was to divide the image in sections, in an analogy to horizontal cells processing, and for each section extract two values to describe local feature: a phase representation of existing feature, and its angle – also similar to what happens in the first steps of visual cortex processing.

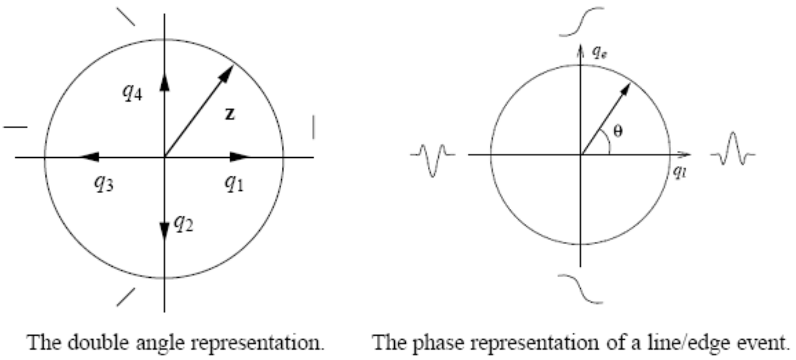


Figure 2 - Angle and phase feature representation from Magnus Borga dissertation.

Afterwards, dimension reduction techniques are used to model extracted features in a lower-dimensional space, which are in turn feed to a NN that learns how to compare images[18].

3.4.3. Patient Comparison

Dimensions Reduction and Clustering – VISRED

Dimensions reduction techniques consist into transform a set of *m* observations of an *n* dimensional numerical variables into a new set of again *m* observations, but with only *k* dimensions, where $k<n$. The interesting feat accomplishing this is that this new dataset retains almost the same amount of information as the previous one.

To perform this dimension reduction, there are several existing methods, such as

Principal Component Analysis (PCA), Correlation Component Analysis (CorCA), Mutual (MIA) Information Analysis, Canonical Correlation Analysis (CanCA), Cosine Correlation Analysis (CCA), and multi-dimensional scaling (MDS). All of these, relying in different mathematical or logical processes, are able to 'compact' information. They are not exhaustive explained since that is not the goal of this survey.

Clustering consists on joining similar observations based on the distance between them. Adjacent points became part of same cluster, and there are numerous methods and algorithms to perform it, being some of them K-means, subtractive clustering, Self-Organized Maps (SOM)

VISRED was a BIC (Bolsa de iniciação à Investigação Científica – Science research grant) in whom Paulo Barbeiro and Edgar Ferreira where involved during the year. The goal was to monitor industrial processes, by reduction information to a three dimensions space. Doing such allowed controller to see a point for each minute of the process. The position of this point would indicate the stage and situation of the global process[19][20].

If instead of analyzing industrial process, the goal of the analysis was a set of *m* patients whom had been subjected to *n* examinations, it would be expected that points plotted on a 3D space would separate themselves accordingly to pathologies presented. This would allow patients comparison and classification, since newly arrived patients would be plotted into this space and associated pathology would depend of their correspondent dot position.

Also, since a black and white image is a bi-dimensional array of numbers where each of the lines (or columns) may be seen as a one-dimensional signal, it is possible to apply regular signal processing methods and tools.

Bi-dimensional signal processing may be applied by consecutively applying a method to each row, and them to each column, as it happens for example on bi-dimensional Fourier Transforms[21].

A possible approach with VISRED to this would be to transform each image into a line (or a cloud of dots, depending on the characteristics of the reduction methods) on a 3D space. Images would then be compared to each other depending on the differences and similarities of their correspondent line (or dot's cloud).

The disadvantage of this process is its dependency of statistical coincidences. If they do not exist, or are not totally attuned, the results will not be satisfactory, and there are few ways to improve them.

The advantage of it, if results are optimum, is its speed to classify an image or a patient, since reducing dimensions and clustering using most common methods takes only a few seconds.

3.4.4. Image Processing Techniques

There are several techniques described in the literature to process ophthalmologic images. An interesting one found was a Retinography spot detection, which used complex mathematical techniques for image analysis, but was able to identify dark and light lesions with great accuracy.

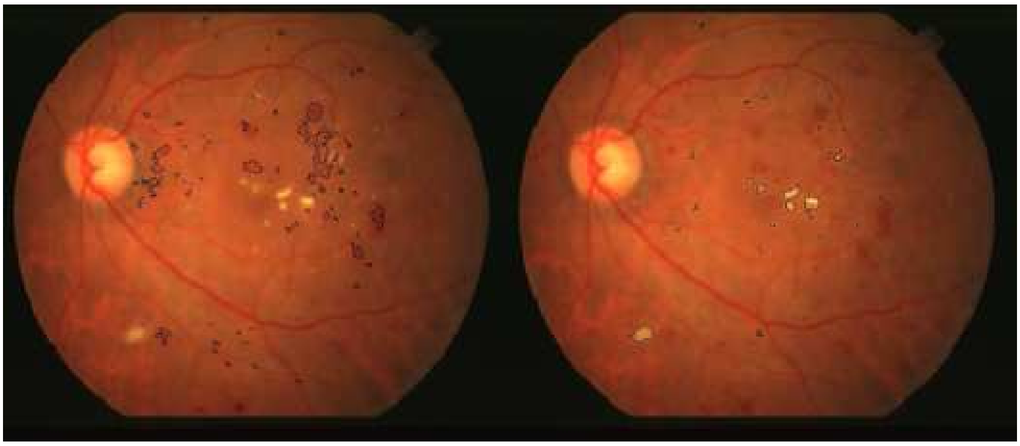


Figure 3 - Morphological algorithm results

One withdrawn picture of this article is elucidative of its capabilities. In the left image are the detected dark spots, an in the right are the light-spots. Due to the great complexity of procedures involved, it is unlikely that this algorithm will be implemented during this project, although is certainly an interesting subject for future developments[22].

Other interesting article found was related to fundus angiography reconstruction based on vessels detection to correctly overlap acquired images. This overlap is done by individually calculating regional entropy throughout the image, and uses it to extract the vascular tree. Vascular ramification points are than extracted from all the images, and compared to each other in order to find perfect overlapping. A result of this algorithm is depicted in the below images[23]:

Figure 4 - Hybrid retinal image registration

One more relevant image processing algorithm found was related to OCT images processing. In this, noise was calculated from the first 50 rows, and then removed from the image. An additional technique named Complex Nonlinear filtering was applied to further image enhancement, and then image was processed. Each column was individually analyzed, and knowing the anatomical features of a regular retina, intensity variation peaks were associated with retinal layers. This method also takes in account the different architecture of the foveal area, and uses horizontal interpolation to guarantee the layers continuity. It is able to detect 7 distinct edges within the retina for images acquired with Stratus OCT machine.

However, this algorithm greatly fails on processing images presenting pathologies that induce changes in the retinal structure, especially if the foveal pit is not shown. An obtained result with this algorithm is depicted below[24]:

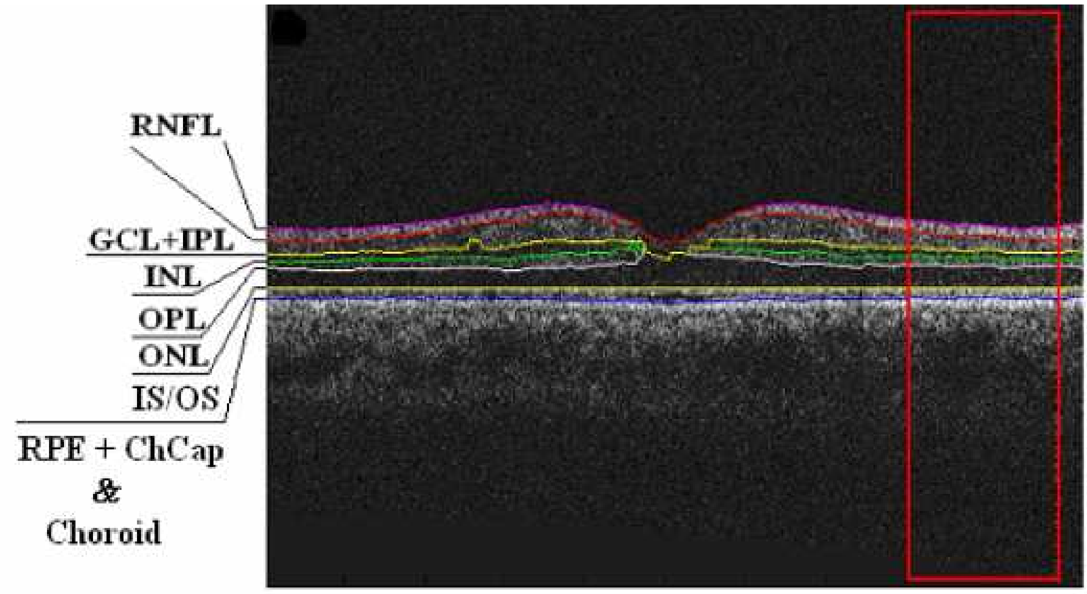


Figure 5 - Automated detection of Retinal Structures on OCT image

3.4.5. Medical Classification

Classification methods studied are all very similar. Features are extracted from the original data, there may be a data dimension reduction by using PCA or similar techniques, and finally information is sent to an AI structure, commonly a neural network, in order to be classified. Just to state some examples, this method is used for determination the degree of retinal hemorrhages[25], measurement of refractive defects[26], planning surgical correction of strabismus[27] and a melanoma diagnosis system[28].

4. Project Objectives

After analyzing the entire problem and understanding how could we improve CCC state of work and ophthalmologic diagnosis, it was necessary to outline our goals. So, consistently with the problem analysis, there would be three areas of intervention during the remaining time for this project:

4.1. Administrative Management

Due to the fact that it was impossible to correct and adapt HIGIA, it was decided by our project supervisor Eng. Jorge Saraiva that the solution would be to replace the existing software by one named 2SoftClinic, made by 2Soft.Lda.

This choice was made due to his previous work experience with 2soft, and the assurance that they would adapt the software to CCC needs, and provide the means to integrate the administrative software with the Clinical Software that would eventually be developed.

Without disclosing business details, our objective was to supervise the installation of 2SoftClinic in CCC.

4.2. Clinical Management and Systems Integration

Being CMOC quite a rudimentary tool, our goal was to create a better one, with an easier process to import data from the machines. That tool would also have corresponding software to visualize information, in an intuitive and organized fashion. Additionally, and already aiming a better way to interact between machines and a global management tool, an interactive scheduling of examinations was to be implemented, allowing MD to quickly depict on a picture which area of the eye is to analyze.

One very important issue to consider and implement is the confidentiality of data. Due to existing discussions regarding this subject, it was one goal of the project to allow examinations to be available to all MDs, patient clinical history also available to all MDs, but personal notes only available for the MD who wrote it.

Also, since this solution should not be restricted to CCC, scalability and servers overload were to be considered while developing this solution.

Other important reasons for this replacement of CMOC are the future goals of creating DM procedures and be able to easily compile information to train the AI systems, which is much easier done in a well-organized application

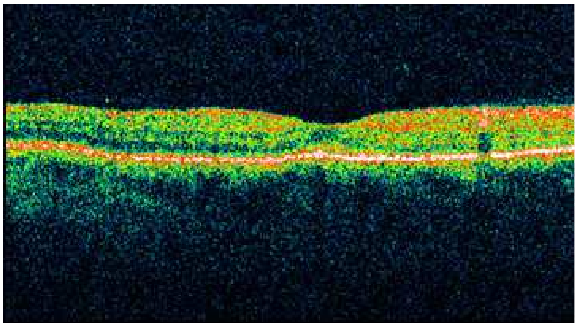
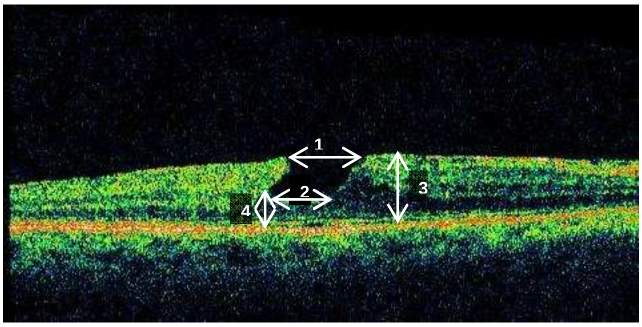
4.3. Decision Support

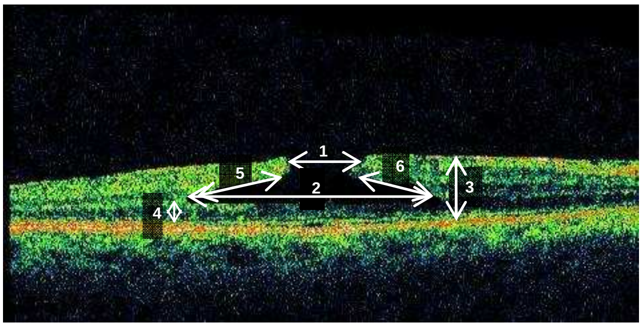
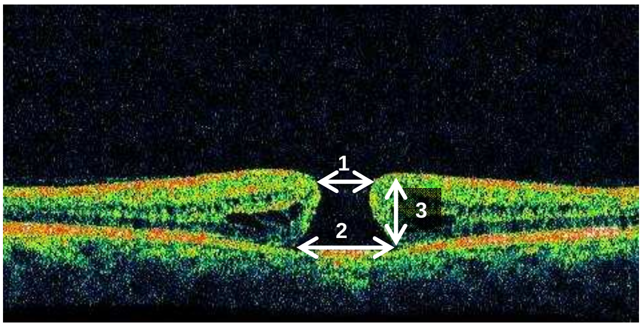
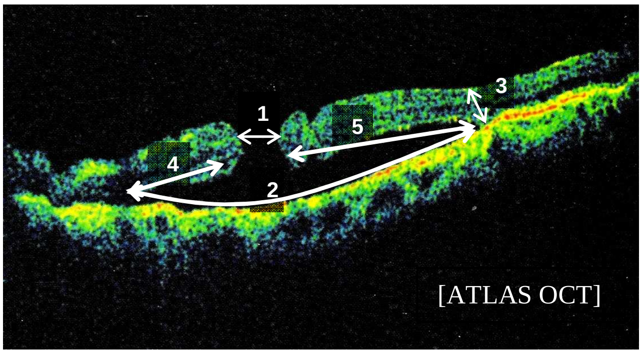
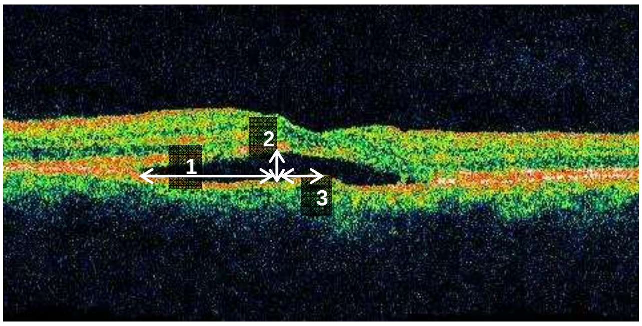
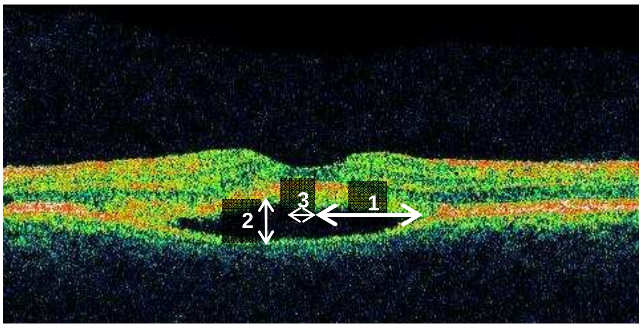
In order to provide MDs with a bigger amount and more accurate information, it was defined that this project would intervene on two distinct fields of action:

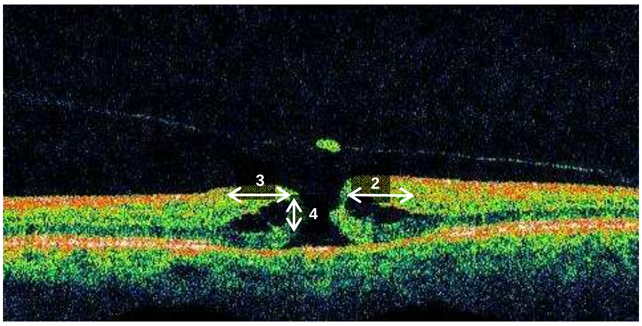
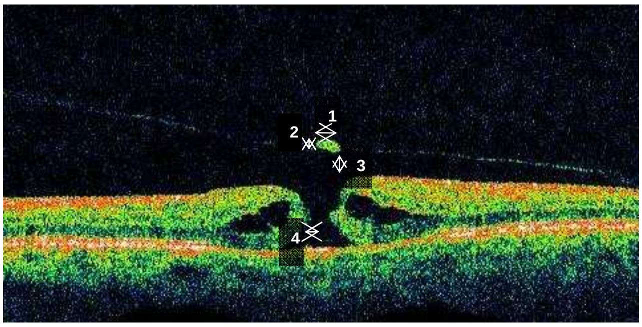
4.3.1. Automatic Analysis of OCT-SLO images

Having a general knowledge of existing retinopathies, and since the path to achieve diagnosis is through the observation of examinations, in order to initialize a diagnosis improvement process it was necessary to select one examination that would allow to distinguish a defined set of pathologies. Discussing this with our Medical Supervisor Dr. António Travassos, the selected examination was the OCT, and our goal was to determined the characteristics and retinopathies depicted in Table 20

Table 20 – OCT images characteristics

Physiological State	Characteristics	OCT Image
Healthy Retina		
Lamellar Hole	1 – Hole aperture diameter 2 – Hole base diameter 3 – Retinal Thickness 4 –Minimum Retinal Thickness	

Physiological State	Characteristics	OCT Image
Detached Lamellar Hole	1 – Hole aperture diameter 2 – Hole base diameter 3 – Retinal Thickness 4 – Minimum Retinal Thickness 5 – Left arm length 6 – Right arm length	
Macular Hole	1 – Hole aperture diameter 2 – Hole base diameter 3 – Retinal Thickness	
Detached Macular Hole	1 – Hole aperture diameter 2 – Hole base diameter 3 – Retinal Thickness 4 – Left arm length 5 – Right arm length	
Retinal Serous Detachment	1 – Detachment Radius 2 – Detachment maximum height 3 – Detachment center distance to fovea.	
Pigmented Epithelium Serous Detachment	1 – Detachment Radius 2 – Detachment maximum height 3 – Detachment center distance to fovea.	

Physiological State	Characteristics	OCT Image
Edemas	1 – Fovea-relative Position - *Adjacent* - *Scattered* 2 – Right extension 3 – Left extension 4 – Retina-relative thickness	
Operculum	1 – Width 2 – Height 3 – Distance to retina 4 –Distance to fovea	

4.3.2. Image pathologies labeling using Neural Networks

In order to have a system with learning ability, which in the future could adapt itself to understand new pathologies set and information from different kinds of examinations, it was defined that a artificial intelligence structure would be created to solve a classification problem, where features determined in the image processing would be used as inputs and desired output was the existing pathology.

The selected AI structure was the NN, whose ability to solve such problems was studied and tested during the current scholar year.

5. Developed Work and Results

This section describes the executed work to achieve the defined objectives. There were three distinct fields of action, being the diagnosis aid composed of image processing, image classification and examination classification.

5.1. Administrative Management

Objective was to coordinate installation of 2SoftClinic. This was not a simple task, due to the fact that we were not acquainted with 2SoftClinic software, and therefore could not make accurate predictions of installation tasks and their lengths. For a successful coordination, collaboration was needed from both CCC and 2Soft staff.

5.1.1. Data Gathering

Whenever software changes occur, it is vital to preserve the existing information. To do so, it was necessary to understand how information was kept on HIGEA and it could be accessed and exported. The selected method for achieving this was to use HIGEA ability to export a full table to an Excel file, and then migrating information to an Access DB.
Higea's option for exportation allows exportation in the following formats: *Xls*, *Wks*, *FoxPlus*, *Sylk*, *Dif*, *Mod*, *Sdf*, and this option may be accessed through:

Menu gestão > Estatística > Genéricos > Exportação

Existing tables on HIGEA are listed on Figures 6, 7 and 8.

Oftalmologia-Contactologia	Gravidezes	Percentis
Oftalmologia-Lentes de Contacto	Ecografia Ginecológica	Consulta de Pneumologia
Oftalmologia-Ensaios com Lentes de Contacto	Ecografia Obstrétricia	Ficha de Epilepsia
Oftalmologia-Motivos de Consulta	Contracepção	Consulta de Epilepsia
Oftalmologia-Acuid.Vis.Perto	Terapêuticas-menopausa	Neurologia
Ficha Geral-Ortopedia	Ficha Geral-Reumatologia	Neurologia-Hérnia
Ortopedia-tratamentos	Reumatologia-articulações	Neurocirurgia
Cirurgias	Pediatria	Urologia
Ginecologia/Obstetrícia	Pediatria sup.	

Figure 6 - Print screen of HIGEA tables list (1)

Utentes	Fact.Risco para a doença Cerebro-	Feriados
Problemas de Saúde	Notas de Crédito	Processos-Arquivo
Terapêuticas	Notas de Crédito-Linhas	Consultas-Arquivo
Consultas	Ficha - Clinica Geral	Processos-Famílias
Grupos de Risco-Utentes	Histórico de Terapêuticas	Imagiologia
Tabela Grupos e Exames	Actos Compostos	Recibos
Alergias	Prescrições	Tipos Consulta
Memorandos	Prescrições-Linhas	Directórios de Ficheiros
Tabela Vacinas	Relatório Anual	Tabela de facturação
Vacinas-Utentes	Tipos de exames	Profissões
Tabela Hábitos	Horários Prof. Saúde (Actos)	Variaveis
Antecedentes Cirúrgicos	Nomes de Protocolos de Actos Médicos	Admissões
Grupos Risco Crianças	Protocolos de Actos Médicos	Tabela Actos Médicos
G.R Crianças-Consultas	Mnemónicas	Actos Médicos
Tab. Gr.Risco Crianças	Serviços de Hospital	Unidades de Saúde
Grupos Mul. Fértil (PF)	Fornecedores	Internamentos
Mul. Férteis (PF)- Consultas	Controlo fich.	Internamentos-Diária
Tab.Gr.Rsc.Plan.Familiar	Códigos Postais	Factura
Gr.Rsc.Grávidas	Histórico Prob. saúde	Factura - Linhas
Grávidas-Consultas	Receitas	Regimes Especiais/Escalões
Grávidas-Tabela Cons.	Incompatibilidades	Causas de Morte
Gr.Rsc.Adulto	Apres. medicamentos	Gráfico
Adultos-Consultas	Especialidades	Terapêuticas - Intern.
Adultos-Tabela Cons.	Médicos	Análises - Tipo
Gr.Rsc.Idoso	Sist. Saúde	Exames Complementares Diagnósti
Idosos-Consultas	Parentescos	Análises - itens
Idosos-Tabela Cons.	Tabela Elementos Diagnóstico	Agenda Pessoal Médico
Gr.Rsc.Diabético	Memorandos do utilizador	Tabela facturação - Honorários

Figure 7 - Print screen of HIGEA tables list (2)

Operadores	Tipos de Quartos	Tipo de Sócio
Mensagens do sistema	Quartos/Ocupação	Avisos Quotas
Protocolos de análises	Notas de Débito	Motivos de Inactivação
Esp.Card.	Motivos Isenção	Instalações
Esp.Cardiovascular-Consultas	Centros Custo	Limpeza, Inst.Sanitárias, Vestiários
Esp.Cardiovascular-Tabela Cons.	GDH	Equip.Mobiliário, Eq.dotados de Visores
Relat.C.V.Prova Esf.	Lotes	Riscos
Relat.C.V.Eco.	Movimentos de Caixa	Cond.Trabalho (Iluminação, Cond.Atmosféricas, Espaciosidad
Electrocard.	Bloco	Cozinhas
Exame Holter	Telefonemas	Sin.Segurança, Prevenção, 1ºSocorros
Exame Hemodin.	Agenda de Recursos	Incêndios
Eco.Transesofágica	Recursos/Equipamento	Check-Up
insuficiência respiratória	Seguradoras	Unidade de cuidados intensivos
Ecocardiogram de Stress	Incapacidades por Acidente	Anestesia
Cons. de Dislipidémias	MT-Acidentes Trab.	Indices de Gravidade (UCI)
Cons. de Hipertensão Arterial	Empresas	Controle dos Utilizadores
Cons. de Hipertensão Arterial	MT-Incapacidades	Genética
Actos - Arquivo	Profissões	Ficha Geral-Otorrinolaringologia
Admissões - Artigo	Categoria Profissional	Otorr.-Alergia
Histórico do Utente	Tipos de acidente	M. Dentária
Admissões - Estrangeiros	Locais - Acidente	Tratamentos efectuados a utentes
Consultas por Especialidade	Actividades	Tipos de Tratamentos
Situações	Causas dos acidentes de trabalho	Modelo de participação de acidente
Documentos	Agentes materiais de acidentes	Ficha Geral-Oftalmologia
Tipos de Dieta	Acções correctivas de acidentes	Oftalmologia-tratamentos
Requisições Dietas - Linhas	Região do corpo atingida	Oftalmologia-lesões
Requisições - Dietas	Sócios	Oftalmologia-Exame objectivo
Quartos	Quotas	Oftalmologia-Acuid.Vis.Longe

Figure 8 - Print screen of HIGEA tables list (3)

Since most of this tables contained little or none relevant information, with the help of Mr. Nuno Videira only the most important ones were selected for importation. These selected tables and fields are below depicted in Table 21.

Table 21 – Identified important HIGEA tables and respective fields

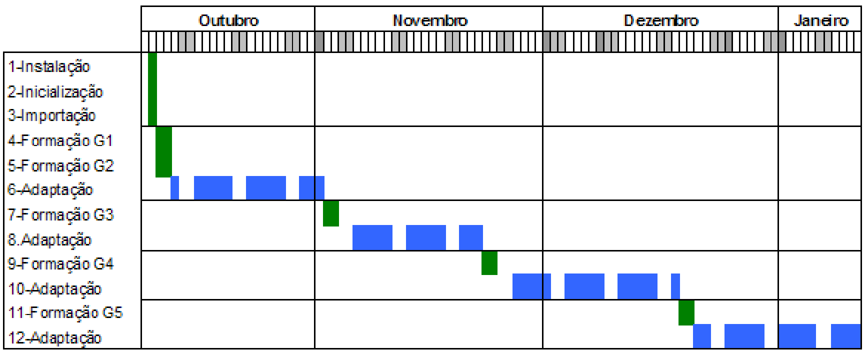
Table	Fields		
Utentes	Id	Nome	Apelido
	Sexo	Data_Nascimento	Nr_Contribuinte
	Estado_Civil	SSN	Morada
	Localidade	Cod_Posta	CodPostal_Numerico
	Telefone	Credito	Debito
	Id_Medico	Credito_Anterior	Debito_Anterior
	Cod_Cliente	Credito_Maximo	Debito_Maximo
	Nr_Bilhete_Identidade	Data_emissao_BI	Arquivo_BI
	ID_Utente	ID_familia	Data_Inscricao
	Id_Operadora_Tlm	Nr_tlm	e_mail
Medicos	Id	Nome	Cod_Especialidade
	Tipo	Nivel	Sexo
	Titulo		
Sistema de Saúde	Nome	Comparticipação	C
	K2	K3	Id_Cliente
	C2	C3	

These data was migrated to Access and sent to 2Soft in the first week of September 2006, where they would create an algorithm to adjust it to their application.

5.1.2. Planning

The initial planning for installing 2softClinic into CCC is depicted in Table 22.

Table 22 - Initial planning for 2softClinic installation



Grupo 1	Administração de Stocks
Grupo 2	Administração de Médicos
Grupo 3	Gestão de Marcações
Grupo 4	Pesquisas e Consultas
Grupo 5	Facturação

This planning was sent on the 4th of October to 2Soft, requiring for feedback on defined activities and times and e-mail receiving confirmation. Their reply contained only e-mail confirmation, so it was assumed that this was a viable planning.

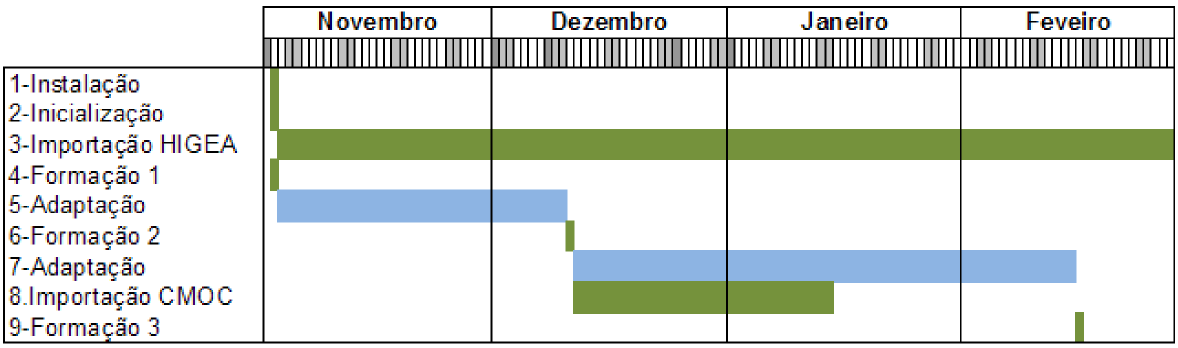
A document containing a layout of formation classes was sent to both 2Soft and CCC on the 9th of October. Contents of this document may be seen on *Attachment 2*. Again, it was request for document completion by 2Soft, request which was unanswered.

All changed e-mail with 2Soft and CCC regarding this installation are available on *Attachment 1*.

5.1.3. Formation Classes

There were three formation classes. On the first session, software was installed on computer terminals, and staff was taught how to manage Doctors, Items and Suppliers, and how to classify articles. Migration of HIGEA data was not addressed. On the second session, nurses, meals, intern patient and payments management were addressed. In this session it was also defined that it would be necessary to insert several items into the 2SoftClinic in order to allow further Stock Management formation. It was also initialized the issue of migrating information from CMOC.

Table 23 - Installation real chronogram



Further discussion with CCC MDs caused CMOC replacement to be abandoned, so eliminating the need to import data from it, although some work was done in that area with the valuable aid of Engª Lara Osório from ISA.

The third formation class addressed the consultations scheduling management, and continued some of the previously taught subjects.

5.1.4. Current State

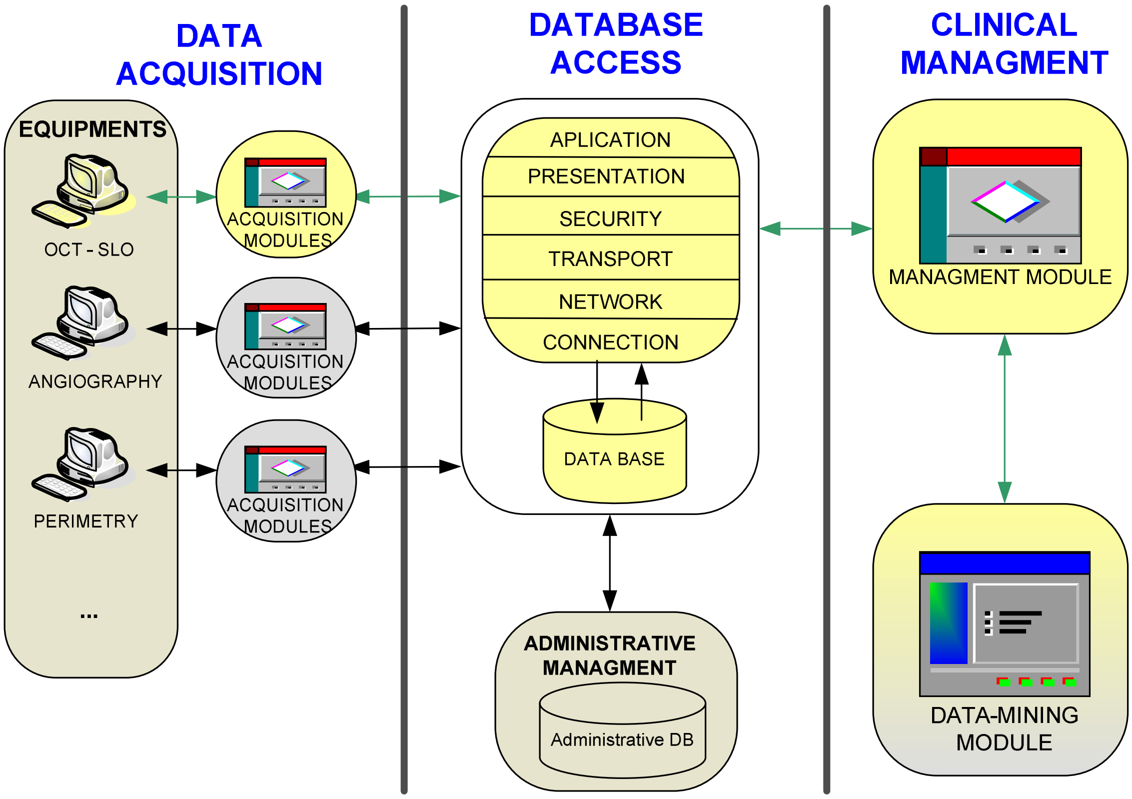
Currently, 2SoftClinic hypothesis for administrative software has been abandoned due to the delay of installation and the absence of communication. Milestones such as information import, which data was provided during the month of September, are said to be still in execution, without prevision to be concluded.

5.2. Clinical Management and Systems Integration

This sub-section describes the created prototype application for clinical data management.

5.2.1. Global Architecture

Software architecture was proposed by our senior Software Collaborator, and was based on his experience in development of similar applications. This architecture contains three important elements – Database, Database access layer, and Applications – divided in three areas: Data Acquisition and Clinical Management for applications and Data Base Access for DB access layer and DBs.



Schematic 3 - Software Architecture (Yellow components are already created)

Starting with the DB Access area, there are three items represented: DB, External DB *Administrative Management* and DB Access Layer, the last composed of seven sections from *Connection* to *Application*. DB is the logical structure that will store in a relational and organized fashion all information sent to it. Since developed DB will only contain clinical data, it will be necessary (in a near future) to connect to the Administrative DB to retrieve additional information and so allowing the implementation of DM techniques. Connecting both DBs to each other and to the applications is the DB Access Layer, which provides the queries for interaction between them.

The advantages of this structure set, are allowing updating DB structure without changing the applications, since the as long as DB access layer is coherent with the new structure, no problems will occur with them; and the possibility of accessing DB through remote connections, either closed networks or by internet. This was developed by Armanda Santos.

As for the applications, and starting in the Data Acquisition area, it shows several modules connecting each machine to the DB. For each machine, acquisition module role is to replace the current paper flow with electronic communication, namely by receiving data from the equipment software and router it to the DB (eventually after processing it); and by sending examinations schedule and requests to machine operator. Also, creating a module for each machine instead of a full program able to comply with all of them, allows a greater flexibility and easiness in creating, installing, integrating and optimizing applications. This was developed by Edgar Ferreira.

Regarding the Clinical Management Area, the *Management Module* to be created will allow organized visualization of information present in DB, namely examination images and reports, consultations reports, and will also enable scheduling of examinations, where it will be possible to select day and hour, laterality, ocular region to analysis, examination, and machine (if several machines are able to perform the same examination). This was developed by me.

The other Clinical Management Item that appears in the scheme is the *Data Mining Module*. This has as a goal to allow advanced images visualization, data search, and all tasks related to information extraction aiming to improve diagnosis. This module is to be accessed through the Management one, and was partially implemented by Edgar Ferreira.

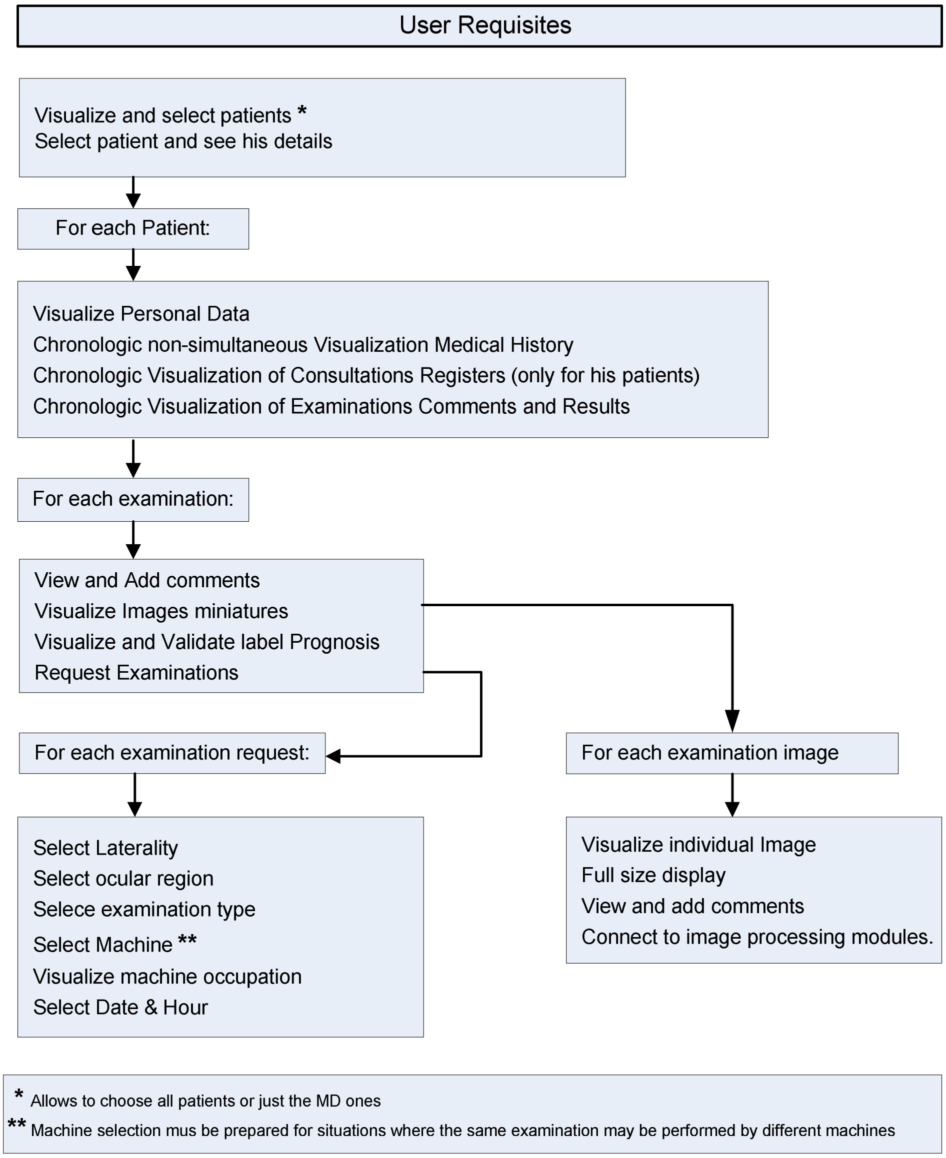
5.2.2. Application Architecture

Following the guidance of our Project Engineering Supervisor, application architecture was to be modular, this meaning, there would exist a global main application, that would allow users login, and each of the secondary applications (Management, Acquisition and DM) would run as a plugin. A plugin (or plug-in) is a computer program that can, or must, interact with another program to provide a certain, usually very specific, function[29].

They have the advantages of partitioning software development and simplify possible future changes and updates. Also, this modular development allows creating personalized solutions for possible costumers, since these modules may be re-arranged to suit particular needs.

5.2.3. Management Application Requisites

Software requisites have been briefly described in Chapter 4, and this sub-section will detailed enounce the defined requisites for the Management Module.



Schematic 4- Management module user requisites

Paired with end user requisites, which are mainly related to navigation and visualization options of the application, are the Functional Requisites, which are related to implementation details. Defined requisites are depicted bellow, in Schematic 5.

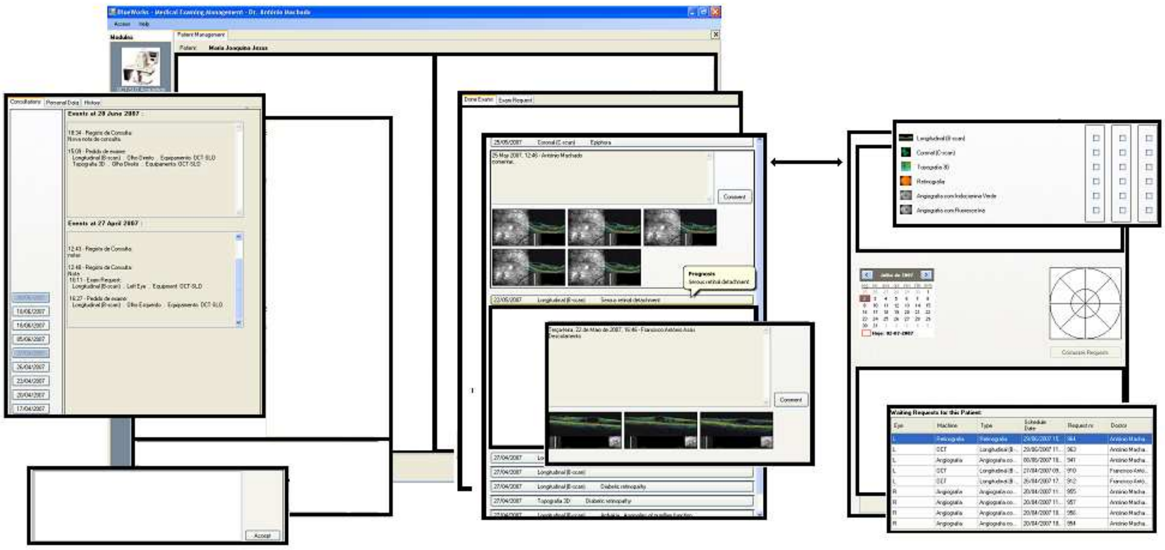
Functional Requisites

Modular construction;
Colapsible menus;
Allow sections redimentioning
Prevent excess memory ocupation with examinations;
Prevent DB Access on regular navigation in the application, specifficaly in the following situations:

- Visualizing a patient and returning to the main menu.
- Visualizing na image and returning to the patient menu.
- Changing examination in examination schedule.
- Changing machine in examination schedule.

Schematic 5 - Management module functional requisites

When referring to modular construction, *UserControls* (UC) are the logic blocks which allow implementing these. By using UCs, it is possible to divide the application in subsections, and individually create each of them. This development strategy permits to replace or change sections in an easier way than full hard-coded programs, as it may be visually perceived in the bellow scheme.



Schematic 6- How components are decomposed into UserControls

5.2.4. Software tools

These applications were created using C# (C-Sharp), which is an object-oriented language based on C++, using Microsoft Visual Studio© development environment. DB was created using Sybase PowerDesigner, and after implementation DB engine was Microsoft

SQLServer2003©.

5.2.5. Clinical Management Module

As said, Clinical Management Module is a plugin which allows managing patient's clinical data, also providing connection to machines and to DM module. This description will focus on functionalities description, paired with reference to the functions who implement them.

This module is composed of a `BaseUC`, which provides the `plugin` interface to allow the linkage to the main application, and has one of three UCs displayed in it, namely: `mainMenuUC`, `ECRManagmentUC`, and `imageDisplayUC`., whose respectively allow to visualize all patients, visualize information regarding one patient and his examinations, and to visualize one individual image.

MainMenuUC

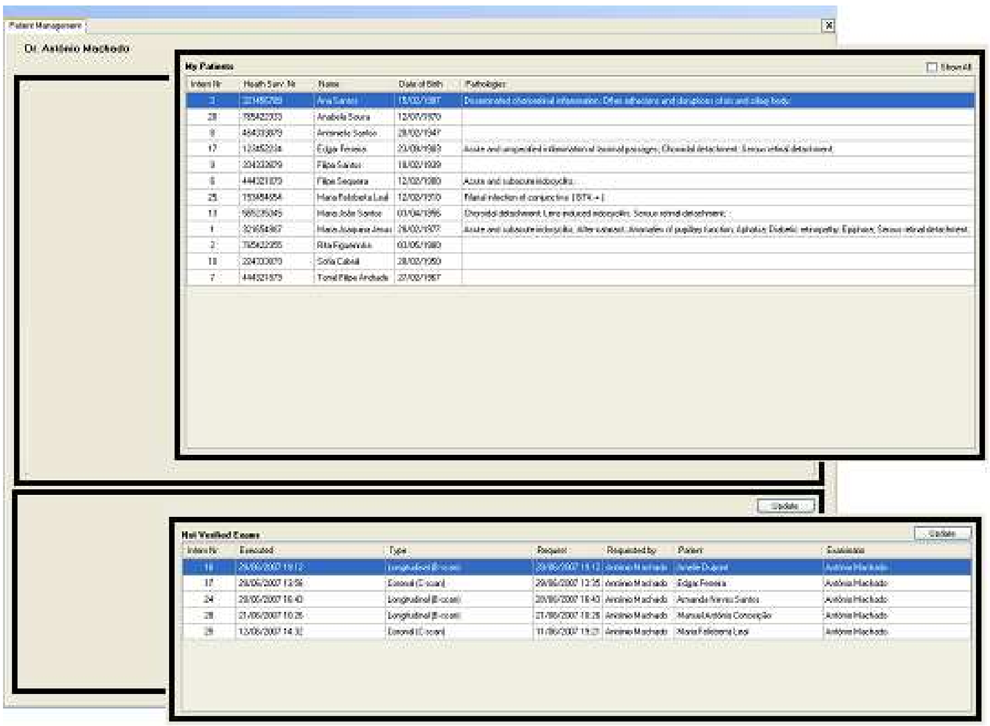


Figure 9 - MainMenu UC

This UC just serves as base for other 2 UCs, `PatientListUC` and `WarningsUC`. The top one, `PatientListUC`, contains a list of MD's patients, and by checking the `ShowAllPatients` box in the top right corner, it is possible to view all CCC patients (`checkBox_ShowAll_CheckedChanged`). Columns show patient name, ID number, observed pathologies in existing examination, and date of birth. Each column may be ordered in an ascendant or descendant fashion, and it is possible to resize all of them.

The lower `WarningsUC` contains a list of recently answered examinations requests that have yet no been observed by the MD. Both this lists are cached, and are refreshed by pressing the *Refresh* button on the top-right corner of `WarningsUC` (`reloadWarnings`, or when returning to this menu after visualizing one patient (`UpdateUnchekedExams`).

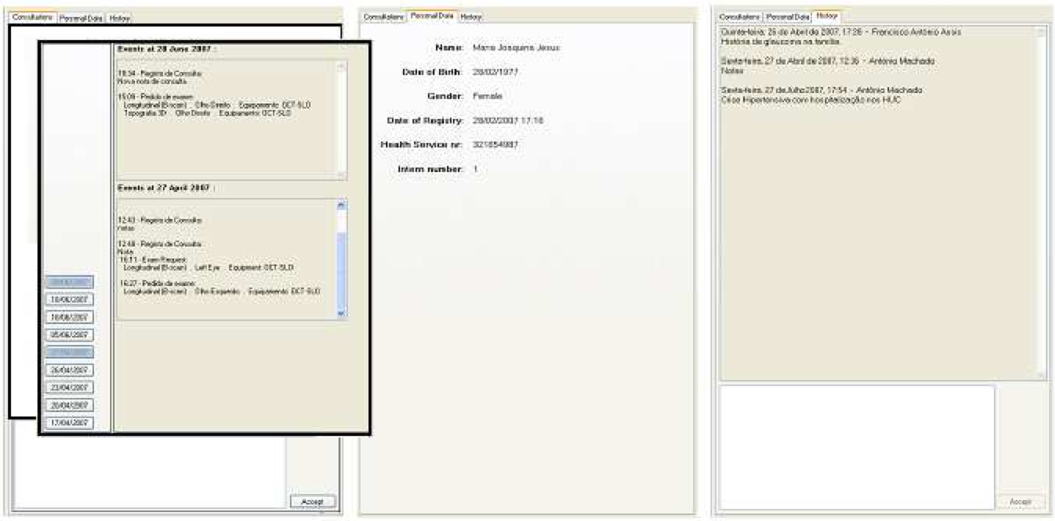
By double clicking on a register line, in either table, program opens the `ECRmanagment` (`OpenSelectedPatient`).

ECR Management UC

This is a base module for other two UCs: `PatientManagment` and `ExaminationManagment`. Since these are respectively on the left and right sides of the UC, a split-container allowing horizontal resize was implemented. Also, the button allowing closing and discarding from memory a patient data and returning to the `MainMenuUC` was here implemented (`ReturnToMedicMainMenuButton_Click`)

Patient Management UC

On the left side of `ECRmanagment` is the `PatientManagmentUC`. This is composed of three sheets, containing respectively information regarding consultations, personal data information, and history.



Consultations Page   Personal Data   Medical History

Figure 10 - PatientManagment tabs

MD may add information to History (`newHistoricalEntry_Click`), where it will be available to all CCC MDs, being the entries automatically signed with current date and his name. The consultation visualization page is implemented on a separated UC, named `PatientManagment_ConsultationDataUC`, but the textbox and respective button which allows adding text to consultations belongs to this UC (`newConsultationButton_Click`).

PatientManagment_ConsultationDataUC

This UC presents a chronological ordered set of buttons in a left stripe. This stripe is resizable (`splitContainer1_SplitterMoved`) and each button corresponds to a day in which patient was consulted. By clicking these buttons (`Cons_ButtonClick`), written text on that day will appear (`addConsultationToInterface`). When text is written in the existing textbox, it will be added to that day consultation, either by adding text to existing consultation(`GetIdOfTodaysEvent`) on that day, or by creating a new one (`addNewConsultation_method`).

Consultation Management UC

As said in the `ECRManagmentUC`, the left side show is reserved for examinations visualization and requests. There are two tabs: the first one displays the examinations and the second allows requesting new examinations.

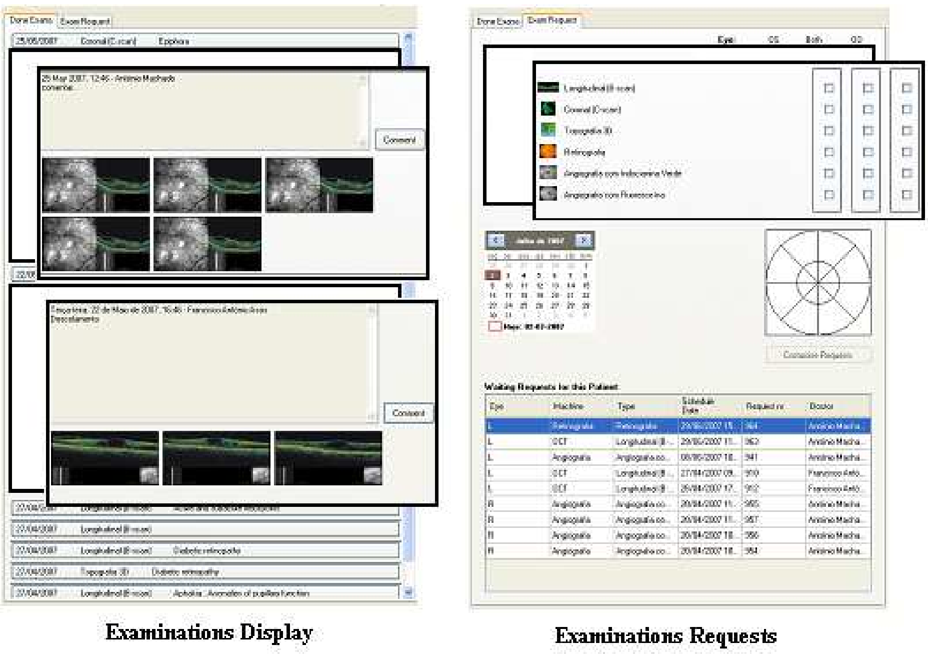


Figure 11 – Examination management tabs

The examination display panel shows a group of buttons, chronological ordered, labeled with date, examination type, and detected diseases. By hover the mouse over the button (`ExamListButtonHover`), a tooltip will appear where these diseases may be all viewed. When one of these buttons is pressed (`ExamListButtonClick`), it expands a panel below it which contains an `ExamContentUC`. Also, these buttons color indicates if the pathologies detected are only a technician prognosis (shown in red) or have already been validated (regular UC color). Due to memory management issues and information access speed, only the three most-recent examinations are cached when visualizing a patient. Others examinations consulted will query the DB for results retrieval.

The second panel contains details for requesting examinations. It allows selecting examination type and laterality, examination date and ocular fundus area to be analyzed. It also shows examinations requested for that patient that have not yet been answered. The component that displays examinations and allows selecting laterality is implemented in an individual UC (`Exams_Request`). When at least one examination is selected, pressing the *Customize Request* button (`requestExam_button_Click`) will display a popup window allowing to customize and schedule this request (`bookRequest`).

ExamContent UC

This control is divided in two sections: The top one displays notes attached to the exam, and the lower one displays the examination images miniatures.

Figure 12 - ExamContent UC

These sections are both vertically resizable, and in the right side of the superior one are displayed two buttons. The top one is for diagnosis validation purposes, only appears when that has not yet been done by a MD, and when pressed calls a `Prognosis` popup window. The lower allows to add notes and comments to the examination as a whole (individual images comments are also allowed, but in a different section) by calling an `AddComment` popup window.

By double-clicking in one of the images (`ImageClicked`), `imageDisplayUC` will replace the existing loaded control on `baseUC`.

AddComment Window

This is a simple window which allows adding comment text to the existing ones. While editing, a one entry memory undo is available (`UndoCommentAdd_button_Click`), and changes are only saved if window is closed through the *Save* button (`saveChanges_buton_Click`).

PrognosisValidation Window

This window was designed for diagnosis validation purposes. It easily allows to add or remove ICD-10 tags to the prognosis.

ImageDisplayUC

This UC is one of the three which cycle trough the `BaseUC`. As said, it is open by double clicking in a miniature image, and its main function is to display a full size picture of the image gathered during the examination.

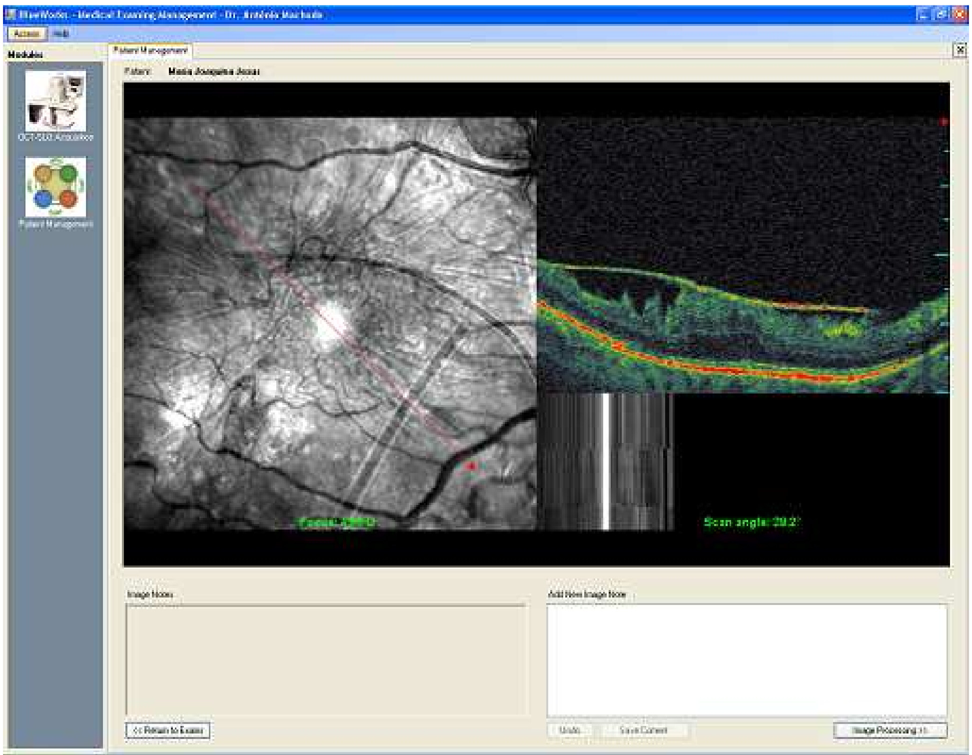


Figure 13 - ImageDisplay UC

This UC also allows adding notes and comments to the image, and accessing the image processing module (`buttonImageProcess_Click`).

BookRequest Window

This window allows to customize requests done in the `RequestPanel`. Existing requests are listed and may be cycled through the left bar, where the ones already customized appear in green whereas the others are colored in red.

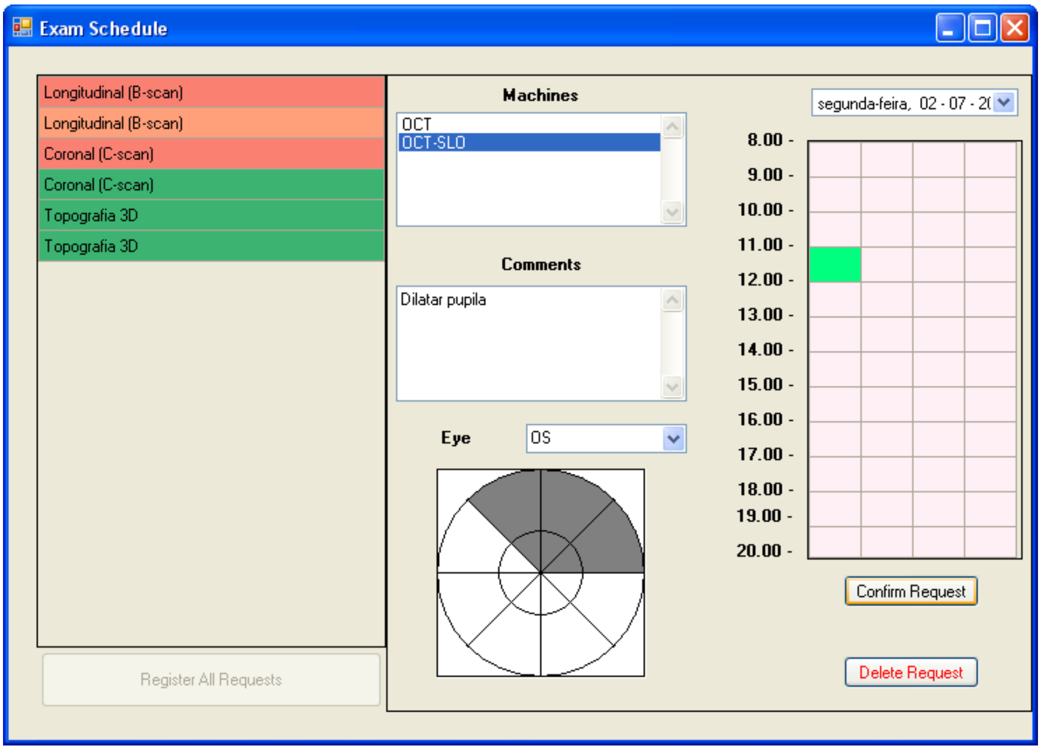


Figure 14 - Window to customize examination request

For each of the examinations, it is possible to re-define ocular area to analyze, write a small message to the technician who will execute the examination, and select the machine to perform it. For each machine and day, an occupation schedule is presented in the right section of the window, and only unoccupied time slots may be chosen.

While cycling trough examinations and machines, individual configurations of each request are maintained in cache. Anytime, a request may be confirmed (`button_ValidateExam_Click`), changed (`button_ChangeReq_Click`) or deleted (`button_removeReq_Click`). When all requests are confirmed (`checkIfAllAreValidated`), pressing the *Register All Patients* button will store requests on the DB (`button_SendReqToDB_Click`) and return to the main menu.

5.3. Diagnostic Aid

As said in the objectives, this section contains the developed work in medical image processing, and image and examinations classification according to pathologies.

5.3.1. Image Processing

From the methods searched during the execution of this project, the major disadvantage was the lack of robustness, or absence of details regarding that. Also, the techniques used were quite complex, and due to time constraints it was impossible to successfully implement some of them during the project execution.

Being so, adopted solution was a KIS (Keep It Simple)[30] approach to the problem. Instead of creating an algorithm that would identify and relate simultaneously all characteristics, or process the entire image as a whole, the process of comprehending an image was decomposed in several sequential steps.

5.3.1.1. Image processing steps

Again with the help of project medical supervisor, it was understood which image information – anatomical structures and abnormalities on them – were used to identify each of the diseases.

1. Image Analyzing
   1.1. First, it would be necessary to identify the position of the Retina Pigmented Epithelium, as this structure will serve as baseline for the identification of the remaining characteristics. RPE is easily identified by its red color, horizontal line shape, and position regarding to the image (it is the lower red line of the image, if two of them exist).
   1.2. Second, it is necessary to define the position of the frontier between the retinal structures and the vitreous (or the empty space, in the cases of vitreous detachment).

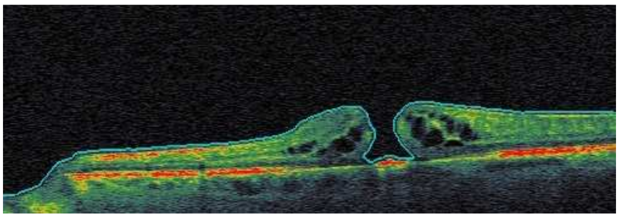


Figure 15 – RAL on a macular hole image

This frontier is neither the Inner Limiting Membrane (ILM) nor is the hyaloid membrane; it is a subjective border with no clinical meaning, but useful for image processing, which was denominated as Retina Anterior Layer (RAL).

1.3. Third, and knowing that when existent, detachments are always adjacent to the top or bottom layer of the RPE, it is necessary to find them. Detachments find is made by running along the RPE and analyzing for above (or below) the existence of empty spaces that further have retinal (or scleral) tissue.

1.4. Finally, by sweeping the remaining area below RAL and above EP or detachments, which corresponds to the retinal tissue, it is possible to search for edemas.

By analyzing the values obtained for these three elements, interpretation of data may be done:

2. Image Understanding

2.1. If detachments are above the RPE, they are retinal detachments.

2.2. If detachments are below the RPE, they are RPE detachments.

2.3. By using the information of 1.1; 1.2 and 2.1, it is possible to determine the retinal thickness along the OCT analysis line.

2.4. By knowing the minimum thickness of the retina in the central part of the image, or the number of abrupt variations on it, it is possible to determine the existence macular or lamellar hole.

Exception made to step 2.3, which is required as a NN input, image understanding steps are to be performed by the NN.

5.3.1.2. Tasks Division

The image analysis steps were equally divided among the project students.

Armanda	Detect edemas and measure edemas and detachments
Edgar	Detect EP and EP detachment
Paulo	Detect RAL and retinal detachment

However, due to an unexpected constraint, these tasks were mainly performed by Edgar and Armanda.

5.3.1.3. Colormaps

As said before, OCT measures the amount of light which is reflected by a structure when it is illuminated with a laser beam. By sweeping the retina, a bi-dimensional array of intensities is created, where each array cell stores the reflectivity value of the biological structures present on that area. When normalizing these values to the interval between zero and one, value one would represent the maximum reflectance obtained and zero the minimum. This type of matrixes correspond to a grayscale image, where 0 represents black color (no light reflected) and 1 white color. However, in order to improve human comprehension of the image, a colormap is applied, and machine output is a RGB image.

A colormap consists on an association between pixel values and colors, where each color is represented by a triple of red, green, and blue values that result in a particular color[31].

This mapping is made by verifying the gray value of each pixel, lookup the colormap for the three values that represent it, and replace it. An example of applying one is depicted in the following picture,

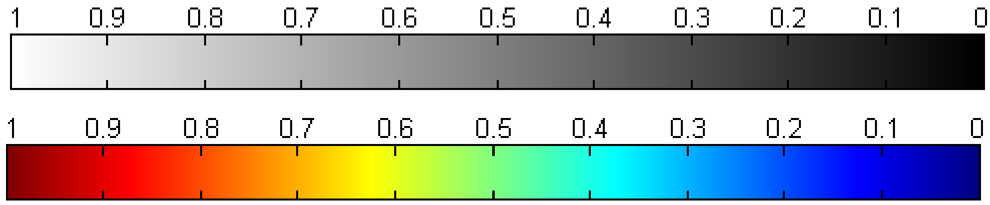


Figure 16 – Original Grayscale space and the same space after colormap is applied

5.3.1.4. Original reflectance matrix retrieval

The usual process to transform a RGB image to grayscale is to average the three components, according to the formula:

$$GrayScale = \frac{R + G + B}{3}$$

However, when a colormap was applied, this process does not retrieve the original image. The reverse process of applying a colormap is the comparison of the RGB values with the ones of the colormap, and replacement the pixel value with the matching grayscale.

Since we did not have access to either the applied colormap or the original intensity matrix, some sort of transform had to be applied to try to return to the original intensity map. Our approach was to attempt to find a proportion between RGB components that would allow obtaining a more accurate image. So, by observing the image and by knowing that the PE was the most reflective structure in the eye, it was immediately perceivable that the red color codified the higher values of reflectance. Further image observation revealed that the noise was mainly black, and the retina structure was mainly green, so the descendent sequence of correspondence between reflectance values and color would be: red, green, blue. A possible colormap, subjectively created, is shown in Figure 17.

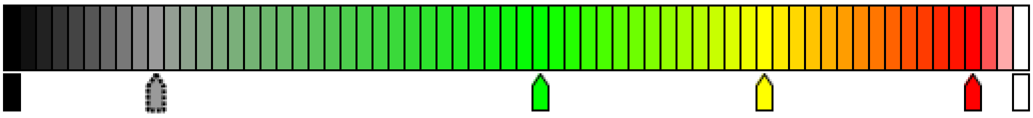


Figure 17 – Possible OCT-SLO colormap

Avoiding the creation of a reverse colormap, our approach was to average the sum of RGB components, with green component being more relevant that the blue, and red more that green one. Subjective chosen values for this were:

$$GrayScale = \frac{B + 2G + 4R}{1 + 2 + 4}$$

Although we were sure this process would not retrieve the original image, the results of applying this method were reasonable good, and are shown in the next figures:

Figure 18 – Original Image

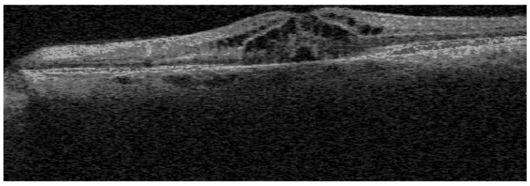


Figure 19 – Typical grayscale transformation

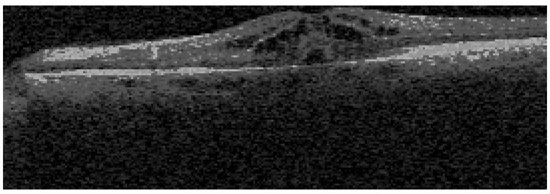


Figure 21 – Our averaged grayscale transformation

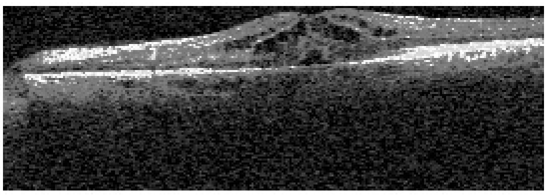


Figure 20 – Averaged grayscale with contrast maximization

By subtracting the image minimum value and dividing it by its maximum, image is enhanced by contrast maximization, as is shown in Figure 20.

Our approach showed a better distinction between red and green colors, being the RPE distinctly whiter than the remaining image, but having as drawback higher noise levels.

5.3.1.5. Preprocessing

After obtaining a grayscale image, the next task is to identify the amount of noise present in it. This task was accomplished by dividing the OCT image in 5 horizontal rectangles, and calculating the mean value and standard deviation of each one of the stripes.

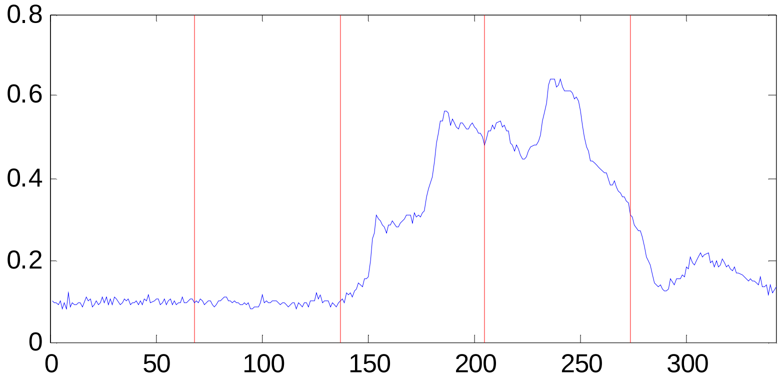


Figure 22 – Mean value of each row of Figure 24 OCT image. Red stripes represent the rectangles frontiers.

Due to OCT image characteristics, one of these stripes is most likely to be only composed of noise. So, in order to identify it, mean values of each stripe are compared, and the one with smallest mean is assumed to be only composed of noise.

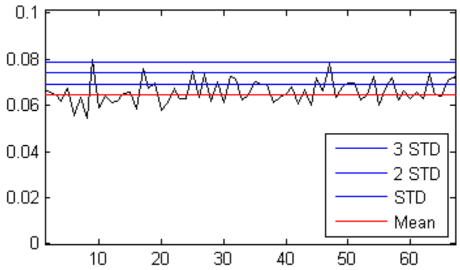


Figure 23 – Detail of Figure 22, showing mean noise value, added with multiples of standard deviation

This value may be used to either remove noise by applying a threshold filter, followed by a median one, or it may be kept for further image processing without denoising.

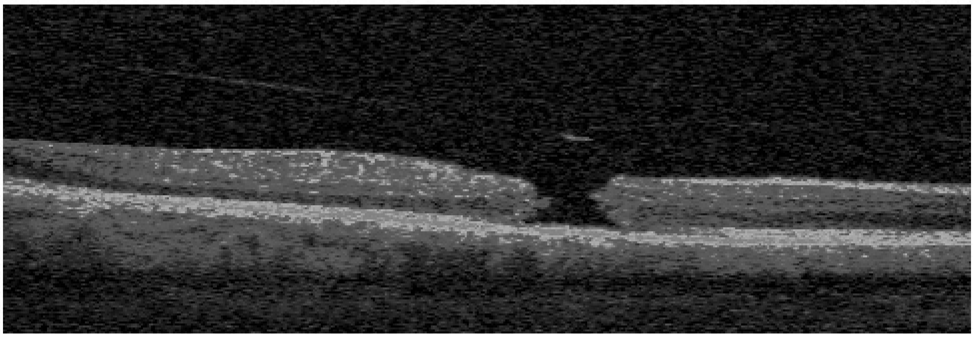


Figure 24 – OCT original image

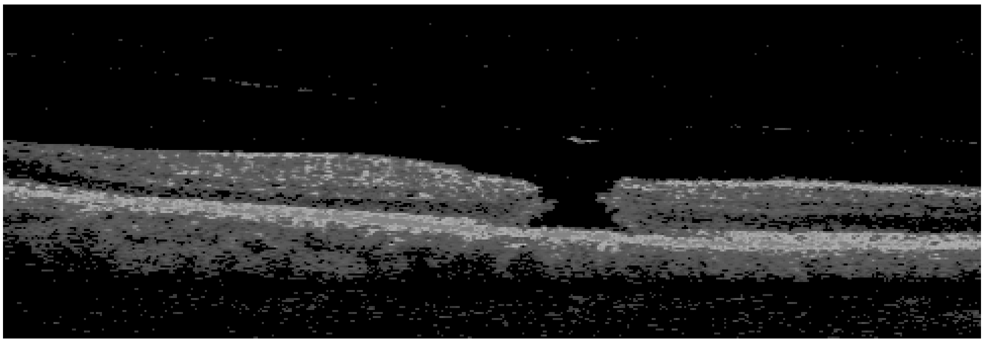


Figure 25 – OCT image after using mean 3 times mean value for noise removal

5.3.1.6. DropFall Algorithms

Drop Fall algorithm is a classical segmentation algorithm often used in character segmentation because of its simplicity and effectiveness in application. Firstly advanced by G. Congedo in 1995, Drop Fall algorithm mimics the motions of a falling raindrop that falls from above the characters rolls along the contour of the characters and cuts through the contour when it cannot fall further [32].

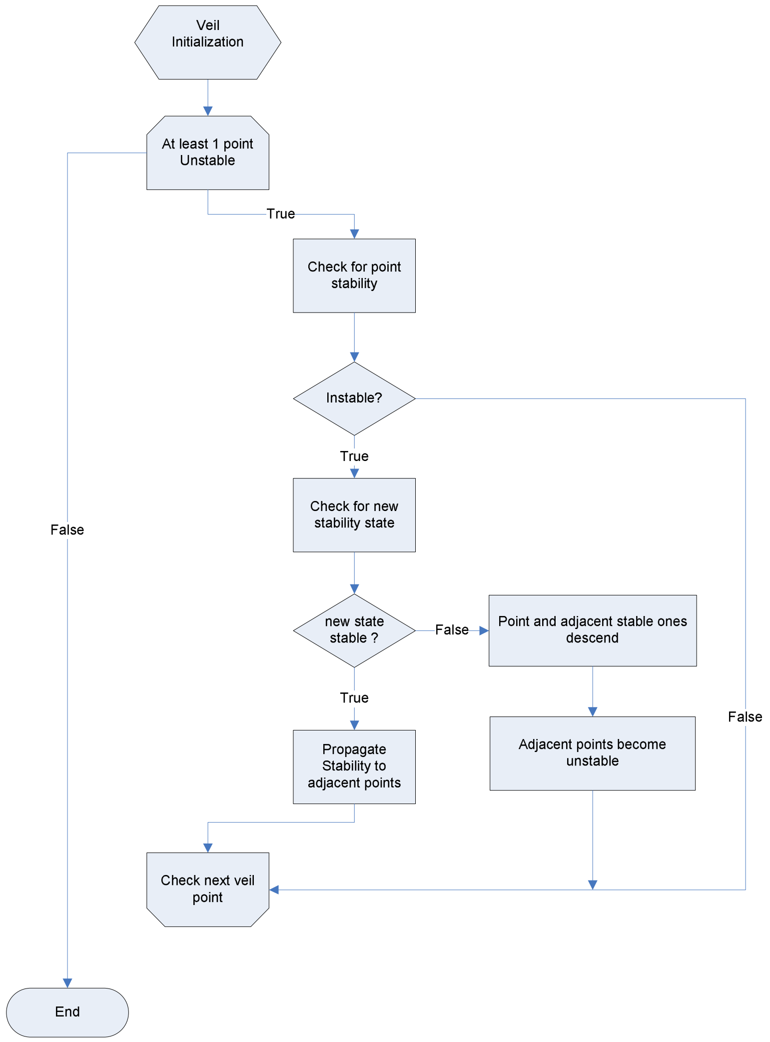
Since the retina has a special horizontal shape, this idea was recycled by simulating a horizontal stripe of drops falling, in a similar way as a veil falling over an object.

It was used the concept of local stability to determine if a portion of the veil has found an object and must stop falling, or, by opposite, it has nothing below it and must keep falling.

A point is designated as stable when it has relative high intensity pixels below him. This threshold intensity is calculated in function of the existing noise in the image, more specifically the average noise in the image summed with three times its standard deviation. This is done because noise has a semi-Gaussian probabilistic distribution, and theoretically this allows excluding 99.85% of the noise.

When a point stabilizes it propagates stability mode to points adjacent to him. When a point is unstable and keeps falling, he also destabilizes points adjacent to him, thus pulling them down.

The initial flowchart illustrating this idea is depicted in Schematic 7.



Schematic 7 – Dropfall flowchart

Algorithm options:

`Treshold` is a vector of numbers, used to calculate stability threshold (ST), and may have one or two elements. If it has just one element, ST will be that one. If it has two elements, ST will be calculated accordingly to the following formula:

$$(Noise_{mean} \times FirstValue) + (Noise_{StandardDeviation} \times SecondValue)$$

`TEFY` and `TEFX` define the size of the block below a pixel who is analyzed in order determine stability. `TEFY` and `TEFX` define respectively the vertical (downwards direction) and horizontal (to each side) extra size of this block. By extra size we are stating that:

$$Vertical\ Analysis\ Size = 1 + TEFY$$

$$Horizontal\ Analysis\ Size = 1 + 2 \times TEFX$$

As an example, the resulting analysis block for TEFX =2 and TEFX =2 is depicted in figure 24. Also note that, when this block has more than one element, the pixels mean value is used for calculations.

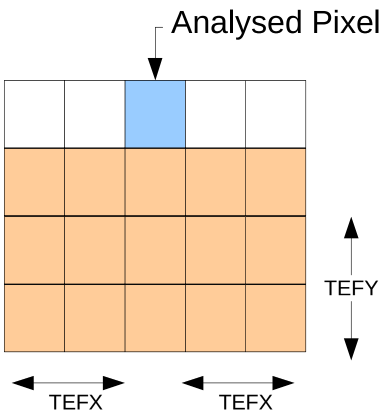


Figure 26 – Analysis Area

DPE and DPD define the stabilization and destabilization propagation length to each side of the analyzed. As said before, when a veil point changes its state, this new state is propagated to veil adjacent points.

While developing and testing the initial algorithm, some flaws where detected. One of those was in situations where some points didn't descend as fast as their neighbors, once adjacent points stabilized on the RAL, the descendent points would continue destabilizing them and pushing them down.

In order to overcome this, three changes were added:

- One of the ways to prevent points from falling, would be to create an operating mode that, when active, would only propagate instability to adjacent points above the one being analyzed. This mode was called Conditional Stabilization and may be enable or disabled by changing the value of EC.
- Other addressed issue was the assurance of finding the interest structure when a certain length of the veil stabilized simultaneously. In order to prevent further algorithm iterations to remove this stabilized points from their position, immutability concept was created.

  IMUTABILIDADE define the length of consecutive stable points needed for them became immutable. Once they are labeled immutable, they will become unchanged until the end of the algorithm process. If IMUTABILIDADE=0, no verification will be executed.
- When the analyzed point is labeled unstable, normal operating mode would classify adjacent points as unstable. However, there is the possibility of them being pulled down to an interest zone, and the fact that they are labeled unstable would cause that region to be ignored. This aspect compelled us to create PV, an acronyms for *Propagation/Verification* that may take P or V values. When propagation mode is active, it simply propagates unstable state to points within DPD range. When

verification mode is active, points within the same range are verified one by one.

These three actualizations improved the algorithm's ability to indentify structures, although it was still unable to deal with images showing portions of the hyaloid.

5.3.1.7. Results and future developments

The noise-based threshold idea produced interesting results, and should be applied to the other algorithms, where it will almost certainly improve their performance.

As for the dropfall algorithm, its general quality is low, since whenever there is a partial visible hyaloid membrane (which happens in most of the images) two distinct features are detected as one: portions of the hyaloid and portions of the RAL. This duality makes it unable to successfully detect one of them

Possible future work to improve this double detection is to divide detected features in segments, and ignores the ones which are coincident with RAL. Then, by using segments extrapolation or repeating the process in the discarded section with lower thresholds, it is probable that the hyaloid location may be reconstructed. A different approach to this hyaloid detection goal is to introduce a Tension factor, preventing the veil from over-dropping. Some experiments were made towards this tension approach, but without achieving a working algorithm.

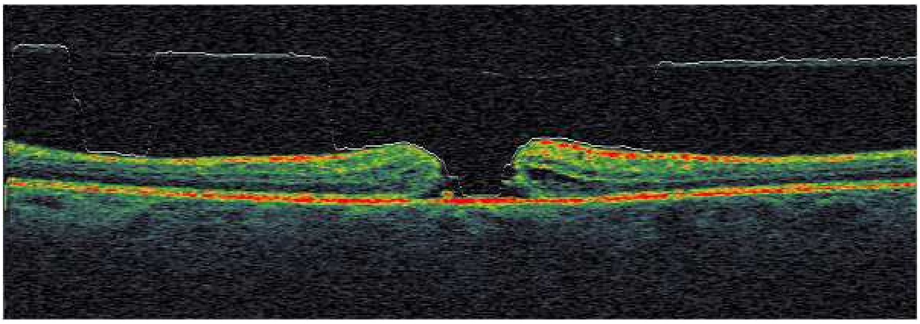
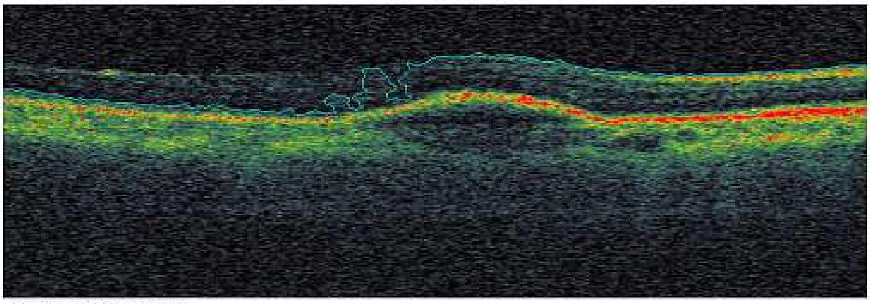
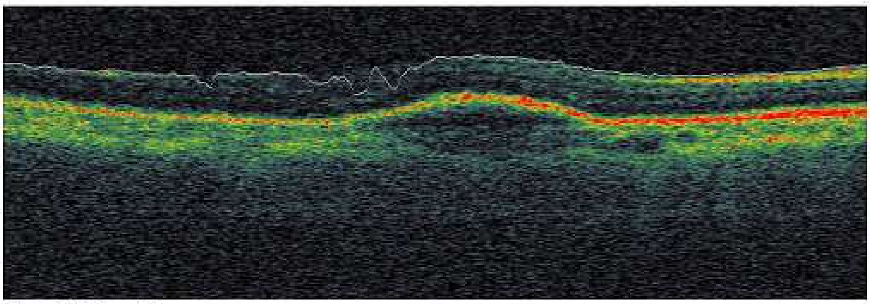


Figure 27 - Dropfall algorithm on image with hyaloid

However, for low intensity images without visible hyaloids, sensibility detecting RAL improves when compared to the other algorithm, as is depicted in Figure 28.



Original Algoritm



Dropfall algorithm

Figure 28 - Comparison between RAL detection in low-intensity images

Speed is also a measure of algorithm performance, and for the dropfall one, it is proportional to the distance between RAL and image top, such that typical processing times ranged between 10 and 60 seconds. One possible way to improve this is to analyses the mean-rows-value graphic in order to define a different starting point other than the image top. Also, if this idea is used to initialize the veil below the hyaloid, algorithm performance for RAL detection may greatly improve

5.3.2. Neural Networks

A neural network is an interconnected assembly of simple processing elements, units or nodes, whose functionality is loosely based on the animal brain. The processing ability of the network is stored in the inter-unit connection strengths, or weights, obtained by a process of adaptation to, or learning from, a set of training patterns. After it has been adequately trained, it can provide appropriate responses to new data coming[33][34].

5.3.2.1. Data Compilation

First step to initialize the neural network training was to compile the data. This was accomplished by processing each image with the algorithms to extract RAL, EP, edemas and detachments. Stored data for each of the images was:

- Number of abrupt variations in the RAL
- Number of separated regions of detachments above RPE
- Total volume of probable detachments
- Number of separated regions of possible edema
- Total volume of probable edema region
- Minimum value of retinal thickness

Afterwards, images were manually classified with a three code digit, accordingly to identified features, not existing ones. This was made to allow NN to learn how to relate identified features with pathologies, leaving as only source of error the performance of the algorithms to indentify retinal structures. An example of such classification is illustrated in Figure 29, where although image shows a regular retina, algorithms understood a less dense layer of photoreceptors as a retinal serous detachment, which is the input to the NN.

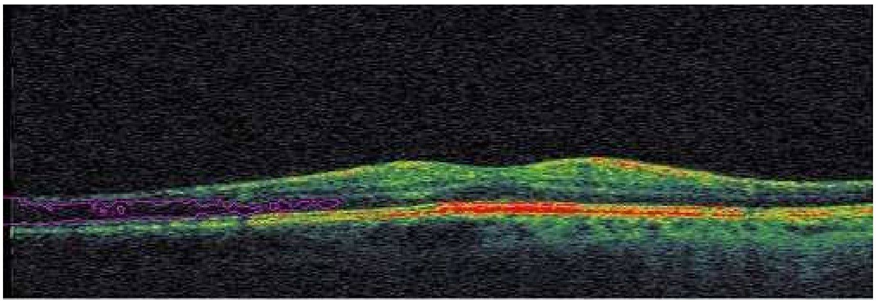


Figure 29 – Erroneous serous detachment classified retinal image

The first element output was 1 if there were macular holes present in the image, or 0 if not. The second output was 1 for serous detachment, or macular hole with detachment, and zero if all retina was adhered to the PE. The third output ranged between zero and two, and was proportional to the total amount of existing edema.

Lamellar Holes and EP serous detachments were not trained due to the low amount of examples of those pathologies in the gathered dataset. However, when available, experience acquired in this work will greatly help to retrain the NN.

5.3.2.2. Architecture

When creating a neural network, architecture is of utmost importance. If there are too few neurons, there will not be enough network plasticity, and it will be unable to adjust to the point. On the other hand, if there are too much neurons, NN may *overfit* to data, losing the ability to generalize similar situations. A small illustration of this may be seen in Figure 30, where in a given set of point obtained from a noisy exponential system, when simulated with too many neurons, looses the ability to classify the shown-in-red test observation as belonging to it.

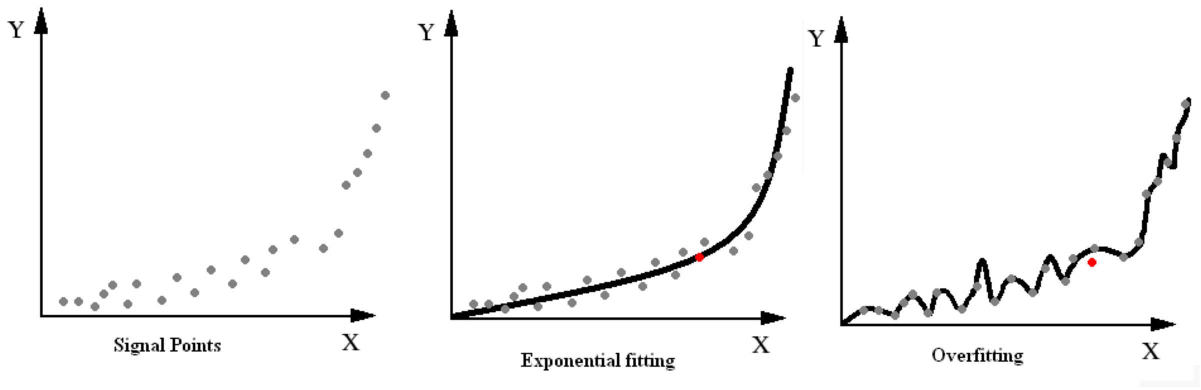


Figure 30 – Neural Network overfit illustration. Notice the red simulation dot.

NN structure was created using Matlab® function `nntool`. Chosen structure was a one-hidden-layer feed-forward NN, and since the desired output consisted of three elements, whose values were comprised in the [0 ; 2] interval, output layer was defined as three linear neurons. Hidden layer used from three up to six neurons, values subjectively considered having enough range to find the optimum configuration. Tested activation functions for the hidden-layer were the hyperbolic tangent sigmoid (*tansig*) and the logaritmic-sigmoid (*logsig*) ones.

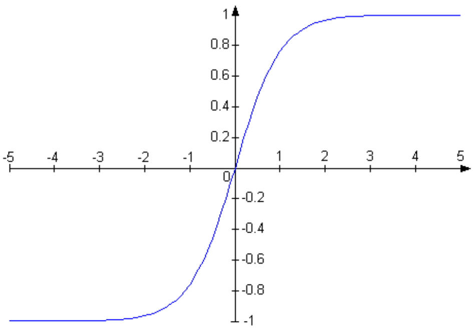


Figure 31 – Tansig transfer function

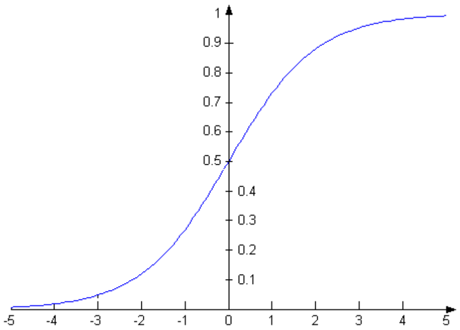


Figure 32 – Logsig transfer function

$$tansig(n) = \frac{2}{1+e^{-2n}} - 1$$

$$logsig(n) = \frac{1}{1+e^{-n}}$$

These were chosen due to their good performance, as it was studied and tested throughout this scholar year in the *Neural Network and Fuzzy Logic* class.

5.3.2.3. Training

Initial attempts to train the network used 80% of random data entries to train the NN, and the remaining to test it. The training method script implemented was the Moore-Penrose pseudo inverse of a matrix. Since the first attempts with 3 neurons were moderately successful, NN plasticity was augmented by increasing the number of neurons. Performance was expected to improve with this change, and several learning rates and normalization combinations were attempted.

Table 24 – Pseudo inverse NN training without cross-validation

							Error			
n1	n2	F1	F2	LR	Epochs	Norm.	Train	Test	Total	**%Success**
3	3	logsig	purelin	0.15	5000	no	5	17	22	88,04%
3	3	tansig	purelin	0.1	5000	yes	3	12	15	91,85%
6	3	tansig	purelin	0.01	5000	yes	1	20	21	88,59%
6	3	tansig	purelin	0.01	5000	no	2	21	23	87,50%
6	3	tansig	purelin	0.1	5000	yes	3	21	24	86,96%
6	3	tansig	purelin	0.1	5000	no	3	14	17	90,76%
6	3	tansig	purelin	0.001	5000	yes	2	18	20	89,13%
6	3	tansig	purelin	0.001	5000	no	3	21	24	86,96%
6	3	tansig	purelin	0.5	5000	yes	1	26	27	85,33%
6	3	tansig	purelin	0.5	5000	no	1	17	18	90,22%
6	3	tansig	purelin	0.2	5000	yes	2	15	17	90,76%
6	3	tansig	purelin	0.2	5000	no	2	31	33	82,07%
6	3	tansig	purelin	0.15	5000	yes	1	19	20	89,13%

6	3	tansig	purelin	0.15	5000	no	1	14	15	91,85%
6	3	tansig	purelin	0.05	5000	yes	3	32	35	80,98%
6	3	tansig	purelin	0.05	5000	no	0	24	24	86,96%
6	3	logsig	purelin	0.1	5000	yes	5	14	19	89,67%
6	3	logsig	purelin	0.1	5000	no	1	21	22	88,04%
6	3	logsig	purelin	0.15	5000	yes	1	16	17	90,76%
6	3	logsig	purelin	0.15	5000	no	4	11	15	91,85%

Since the minimum number of errors did not decrease, it could be being caused by an unrepresentative training data set. To attempt to overcome this limitation, cross-validation was implemented: Five different data-sets were created, each one of them with a different group of 80% of data defined for training purposes, and the remaining for validation. By doing this the probability of have a full-problem-representative dataset increased.

NN where then trained and tested separately with each of these sets, and the obtained results are shown in Table 25. In this cross-validation approach, Levenberg-Marquardt training method was used.

Table 25 – CrossValidation training results

Architecture		DataSet1			DataSet2			DataSet3			DataSet4			DataSet5		
Layer1	Layer2	TrE	TeE	S (%)	TrE	TeE	S (%)	TrE	TeE	S (%)	TrE	TeE	S (%)	TrE	TeE	S (%)
3 - tansig	3-purelin	6	2	95,65	19	4	87,50	5	1	96,74	5	3	95,65	6	3	95,11
4 - tansig	3- purelin	5	2	96,20	30	11	77,72	8	2	94,57	3	6	95,11	2	7	95,11
5 - tansig	3- purelin	6	3	95,11	6	1	96,20	6	3	95,11	2	3	97,28	4	3	96,20
6 - tansig	3- purelin	7	3	94,57	6	3	95,11	7	2	95,11	2	5	96,20	1	9	94,57
3 - logsig	3 -purelin	5	2	96,20	9	2	94,02	4	1	97,28	5	3	95,65	3	7	94,57
4 - logsig	3- purelin	6	4	94,57	8	3	94,02	6	1	96,20	4	4	95,65	3	4	96,20
5 - logsig	3- purelin	5	3	95,65	7	2	95,11	9	4	92,93	6	6	93,48	1	7	95,65
6 - logsig	3- purelin	5	4	95,11	3	2	97,28	4	2	96,74	4	9	92,93	2	4	96,74

TrE - Training Error

TeE - Test Error

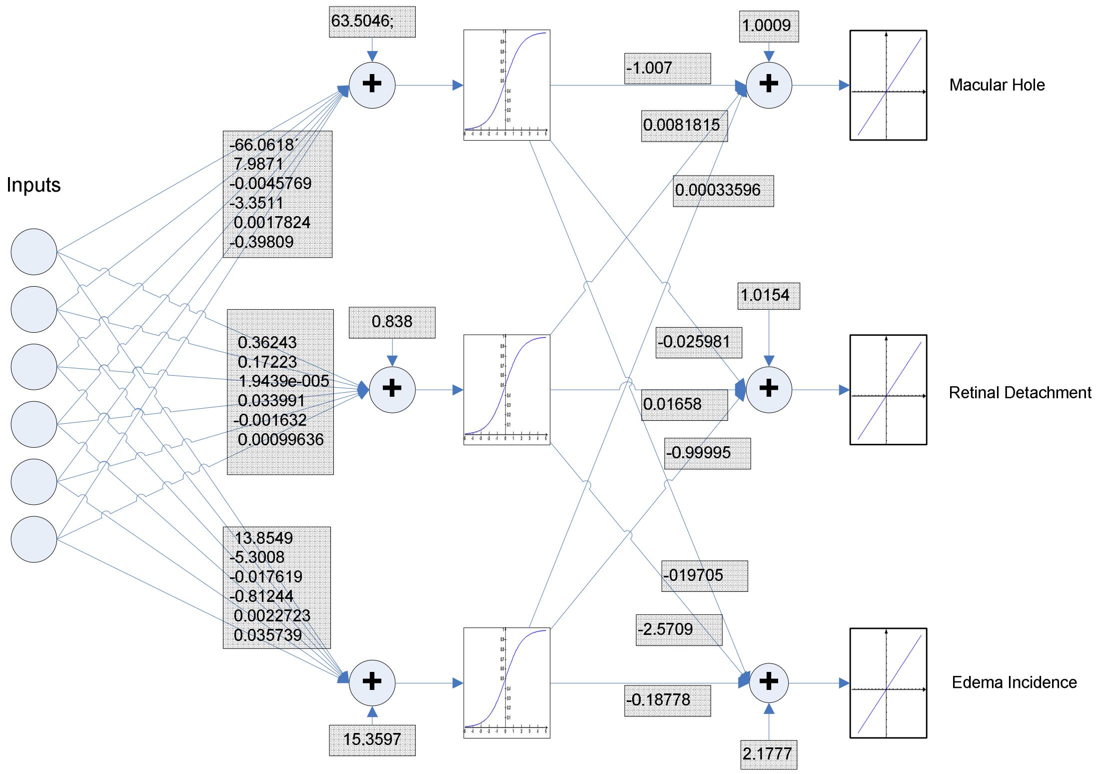
S - Percentage of success

Each time a network was trained, new random weights were generated. The relevance of this is related to local and global minima. When training a NN, goal is to minimize the error function. However, during the process to find the smallest possible error value, it is possible to find a local minimum and erroneously assume that the found solution is optimum.

Since the point-of-convergence of the minimum search function depends on the algorithm options, but mainly on the initial weight values, by repeating the process of training the NN chances of not ending on a local minima increases. Acknowledging this, each of the networks was trained a minimum of ten times, and only the best results appear in Table 25.

5.3.2.4. Results and Discussion

Success rates were improved by using the Levenberg-Marquardt training instead of the Moore-Penrose pseudo inverse, and cross-validation. It appears that the both activation functions have identical performance, and that three neurons are enough to achieve correct classification.



Schematic 8 – Neural network final configuration

Classification success of 97.3% using characteristics extracted from 184 valid images is fairly acceptable, thus allowing concluding that the selected architecture is able to perform the task without overfit.

Performance improvement may be achieved by increasing the amount of samples available for training, and by increasing number of attempts for global minima find in each of the cross-validation datasets.

Also, since there is a large number of existing architectures that were not tested in this work, addressing this issue deserves additional research.

5.3.3. Full Examination Classification

One examination is composed of several images, but for labeling it, a single tag must be used. This tag will be the detected diseases throughout all the images.

A small experiment was made in this field, where tag would be the most common diagnosis among all the images. For evaluating this, 36 examinations were used, with an average of 15 images per exam. For the NN learnt pathologies, this method proved successful for 26 of the examinations, which corresponds to 72% of success. The reasons for obtained errors where:

- In low intensity images, EP was not correctly detected (3 examinations)
- Sometimes edema area are incorrectly labeled as detachment (3 examinations)
- Impending macular hole classified as detachment (1 examination)
- Low quantity of well-acquired images in the examination (3 examinations)

Although it is a rudimentary method, it achieved an interesting success rate. It may be improved by automatically discard invalid examinations images, implement an adaptative thresholds to suit image intensity in existing algorithms, and by teaching the NN to recognize the characteristic trapezoidal shape of impending holes.

6. Conclusions and Future Purposes

6.1. Conclusions

The goal to reduced subjectivity in medical practice was not achieved, although the foundations to enable it were created. It was created an integration and information management tool, which will allow an easier access to data, and within the remaining time executed work showed promising results.

Algorithms for identification of retinal anatomic structures in OCT images were created, with success rates between 80 and 99 percent.

A neural network for features classification was created, and achieved 97% of success for macular holes, retinal detachments and edema identification.

System overall success in classifying data depends both on extracted features and network performance, which allows to predict that classification is correct in at least 78% of the images.

Using the most common image result as a whole examination classification has proven successful only in 73% of the cases, meaning that a better method to understand the examination as a whole must be created

6.2. Future Purposes

CCC improvement next tasks will be related to the integration of further equipments and examination. Also, developed software should incorporate additional information from other medical specialties, namely endocrinology, and include a module to track pharmacologic drugs.

Also, it should be created a tool to allow overlapped visualization of different examination of the same retinal area images, thus allowing OCT images from different acquisition angles to be interpolated and analyzed as a whole.

Regarding image processing, dropfall algorithm may be improved by adding a horizontal tension constraint, or an iterative region-of-interest search. Also, searching the graphic mean value of each row in order to define the starting point of the veil would also greatly improve its time-efficiency. Performed noise analysis may be used to discard invalid images and to adjust several developed algorithms parameters in an automated fashion.

New algorithms for integrated examinations should also be searched and implemented, in an attempt to obtain the best image-processing efficiency possible

As for the diagnosis-aid system based on neural networks, future developments are dependent of future integrated examinations, although performance improvement may be attempted using different network architectures. Furthermore, connection to the administrative software module should enable data-mining queries in order to improve the amount of related information available to diagnosis, and optimize the management efficiency of CCC.

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[35] – CCC: Adapted from: www.ccci.pt – August 2007

Attachment 1

Compilation of E-mail exchanged with 2soft regarding installation of 2softClinic

As cores servem para mais facilmente identificar o emissor, tendo a seguinte correspondência:

Paulo Barbeiro
Daniel (2soft)
Nuno Videira (CCC)

From: paulobarbeiro@gmail.com
To: geral@2soft.pt
Date: Sep 12, 2006 5:53 PM
Subject: Projecto para Centro Cirurgico de Coimbra com Jorge Saraiva

Boa tarde

O meu nome é Paulo Barbeiro, e fui aí na passada sexta.feira dia 1 de Setembro com o meu orientador de projecto, o Eng. Jorge Saraiva. Nessa ocasião fiquei de recolher e enviar informações acerca da Base de dados do Centro Cirúrgico de Coimbra (CCC)

Enviei-as para o e.mail que me indicaram (daniel@2soft.pt), mas ainda não obtive resposta. Não sei se o e-mail é inexistente, se ficou retido nos filtros de Spam, ou se simplesmente ainda não tiveram tempo para me responder.

Cumprimentos
Paulo Barbeiro

Criação e Disponibilização da BD em Access, das tabelas em XLS e dos printscreens das tabelas no servidor da ISA

From: paulobarbeiro@gmail.com
to: info@ccci.pt
date: Sep 20, 2006 4:01 PM
subject: Reunião acerca do novo sistema informático

Boa Tarde

Amanha dia 21 de Setembro, vêm a Coimbra elementos da empresa 2soft, que será a responsável pela instalação e adaptação do novo software de gestão.
De modo a debater algumas especificidades relativas a isso, gostaria de saber se será possível reunir com o Nuno e a Srª Enfermeira Odete no Centro Cirúrgico de Coimbra ás 11 horas.

Com os melhores cumprimentos
Paulo Barbeiro

From: paulobarbeiro@gmail.com
To: Nuno Videira <info@ccci.pt>, "Daniel. 2SOFT" <Daniel@2soft.pt>, Jorge Saraiva <jsaraiva@isa.pt>
Date: Oct 3, 2006 1:53 PM
Subject: Calendariazação

Boa tarde.

Segue em anexo um esboço da calendarização para a instalação do software na clinica.
Serão sempre necessários ajustes, até porque ainda não sabemos qual será a data de inicio da mesma.

Daniel:

Os prazos parecem viáveis ? ou serão necessários tempos diferentes para as actividades ?

Os grupos estão bem definidos ?

Nuno:

O inicio da instalação depende do levantamento físico dos itens nos armazéns.
Quando isso estiver concluído, envie-me um e-mail ou contacte-me pelo 916610102
Será também necessário saber quantas pessoas vão integrar cada grupo, de modo a programar a logística das acções de formação

Por favor enviem e-mail de resposta a confirmar a recepção deste.

Com os melhores cumprimentos
Paulo Barbeiro

NOTE: See Project Attachment 2

From: "Daniel.2SOFT" <daniel@2soft.pt>
To: Paulo Barbeiro <paulobarbeiro@gmail.com>
Date: Oct 4, 2006 10:21 AM
Subject: RE: Calendariazação

oi,
Confirmo o e-mail

cumps,
Daniel Lopes

From: paulobarbeiro@gmail.com
To: "Daniel. 2SOFT" <Daniel@2soft.pt>, Jorge Saraiva <jsaraiva@isa.pt>, Jorge@2soft.pt
Date: Oct 6, 2006 6:22 PM
Subject: Instalação no CCC

Boa tarde

Liguei para o CCC para saber em que ponto estava o inventário, mas disseram-me que o Nuno estava de férias (como ele tinha dito na nossa reunião).
Estivemos na 4ª lá, e a Enfermeira Odete disse-nos que tinham pessoas a trabalhar nisso, mas tiveram um "boom" de admissões (+ de 300 novos clientes em 4 dias), pelo que tiveram de mobilizar recursos para isso. Na 2ª feira vou ligar do novo para lá, e julgo que falando com o Nuno já se pode calendarizar uma data exacta para se fazer a instalação.
Durante este fim de semana vou fazer um protótipo de especificação de tarefas a executar, que depois enviarei para vossa aprovação.

Cumprimentos
Paulo Barbeiro

From: paulobarbeiro@gmail.com
to: Nuno Videira <info@ccci.pt>, "Daniel. 2SOFT" <Daniel@2soft.pt>, jorge@2soft.pt, Jorge Saraiva <jsaraiva@isa.pt>
Date: Oct 9, 2006 10:42 AM
Subject: Calendarização

Bom dia

De modo a definir melhor o processo de instalação, peço a vossa colaboração para completar o documento em anexo.
Ele foi feito de um modo bastante rudimentar e intuitivo, mas julgo que depois de completo será bastante útil para coordenar as actividades.
Daniel:
Rever a parte de preparação, instalação, problemas e respectivos planos de contingencia, e Inicialização da Base de Dados.
Rever os Programa das diversas acções de formação (se for impossível devido para já programar já todas, pelo menos o programa das 2 primeiras).

Fornecer em estimativa a duração de cada acção de formação
Rever a lista de equipamento necessário para dar formação.

Da vossa experiencia, qual a proporção adequada de formandos-PCs
que optimiza o processo de aprendizagem e experimentação?
Nuno:
Compilar uma lista discriminada dos formandos em cada acção de formação.
Se devido a tempo for complicado disponibilizar já toda a informação, definir pelo menos os 2 primeiros grupos, e fornecer um numero aproximado de pessoas que assistirão ás outras.
Também será necessário saber qual a hora preferencial para a formação
Com os melhores cumprimentos
Paulo Barbeiro

From: paulobarbeiro@gmail.com
To: "Daniel. 2SOFT" <Daniel@2soft.pt>, jorge@2soft.pt, Jorge Saraiva <jsaraiva@isa.pt>
Date: Oct 9, 2006 12:17 PM
Subject: Instalação CCC

Bom dia

Acabei de falar ao telefone com o Nuno Videira, e o levantamento fisico de existencias ainda está a decorrer.
Em principio ficará pronto durante a semana que vem, e no final desta já devo ter a data exacta.

Cumprimentos
Paulo Barbeiro

From: paulobarbeiro@gmail.com
To: "Daniel. 2SOFT" <Daniel@2soft.pt>
CC: Jorge Saraiva <jsaraiva@isa.pt>
Date: Oct 20, 2006 10:18 AM
Subject: Instalação CCC

Bom Dia.

Falei ontem com o Nuno Videira, e a instalação poderá começar na próxima 5ª feira.
É uma boa data para vós ? Se não, quais a alternativas ?
Sempre reviram o documento que enviei na semana passada?

Por favor confirmem a recepção deste e-mail

Cumprimentos
Paulo Barbeiro

Paulo Barbeiro <paulobarbeiro@gmail.com>
To: "Daniel. 2SOFT" <Daniel@2soft.pt>, Jorge Saraiva <jsaraiva@isa.pt>
Date: Oct 23, 2006 1:47 PM
Subject: Inicio da instalação no CCCI

Bom Dia.

Enviei sexta passada um e-mail a perguntar se é possível iniciar a instalação esta 5ª feira, dia 26 de Outubro.
Receberam-no?

Cumprimentos
Paulo Barbeiro

From: "Daniel.2SOFT" <daniel@2soft.pt>
To: Paulo Barbeiro <paulobarbeiro@gmail.com>
Cc: Jorge Morais <jorge@2soft.pt>, jsaraiva@isa.pt
Date: Oct 24, 2006 9:47 AM
Subject: RE: Inicio da instalação no CCCI

Sim, fica agendado para Quinta Feira

Pela manhã procedemos à instalação do software,
Pela tarde daremos formação
na àrea de stocks:
abertura de fichas de artigo, fornecedores e entrada do inventário.

na àrea clínica
abertura de fichas de médicos, horários, marcação.

A tarde estará sempre condicionada pelo decorrer dos trabalhos de instalação.

cumps,
Daniel Lopes

[Daniel.2SOFT]

From: Paulo Barbeiro <paulobarbeiro@gmail.com>
To: Nuno Videira <info@ccci.pt>
Date: Oct 24, 2006 1:22 PM
Subject: Fwd: Inicio da instalação no CCCI

Boa tarde

A sugestão da 2soft é fazer a formação durante a tarde do dia de instalação
O que lhe parece ?

Há disponibilidade da vossa parte para tal?

Cumprimentos
Paulo Barbeiro

From: Intercir - Info <info@ccci.pt >
To: Paulo Barbeiro <paulobarbeiro@gmail.com>
Date: Oct 24, 2006 4:17 PM
Subject: Re: Fwd: Inicio da instalação no CCCI

Boa tarde Paulo

Não há problema, pode ser perfeitamente.

Cumprimentos

Nuno Videira

From: Paulo Barbeiro <paulobarbeiro@gmail.com>
To: "Daniel. 2SOFT" <Daniel@2soft.pt>, Nuno Videira <info@ccci.pt>, Jorge Saraiva <jsaraiva@isa.pt>, jorge@2soft.pt
Date: Oct 25, 2006 12:37 PM
Subject: Fwd: Fwd: Inicio da instalação no CCCI

Boa tarde

Está assim confirmada a instalação para amanha, quinta feira, e a formação durante a tarde

Cumprimentos
Paulo Barbeiro

---------- Forwarded message ----------
From: **Intercir - Info** <info@ccci.pt>
Date: Oct 24, 2006 4:17 PM
Subject: Re: Fwd: Inicio da instalação no CCCI
To: Paulo Barbeiro <paulobarbeiro@gmail.com>

Boa tarde Paulo

Não há problema, pode ser perfeitamente.

Cumprimentos
Nuno Videira

From: Paulo Barbeiro <paulobarbeiro@gmail.com>
To: "Daniel. 2SOFT" <Daniel@2soft.pt>, jorge@2soft.pt, Jorge Saraiva <jsaraiva@isa.pt>
Date: Dec 12, 2006 2:15 PM
Subject: calendarização e dados para instalação

Boa Tarde

Acerca da conversão dos dados, julgo que ela seja possível utilizando o SqlServer 2000 ou 2005, com os drivers apropriados.
A 2soft tem esse software?
Se sim, o processo para o SqlServer 2005 full é descrito no seguinte link
http://www.databasejournal.com/features/mssql/article.php/3580216

Os drivers para o foxpro tem de ser descarregado do site da microsoft
http://msdn.microsoft.com/vfoxpro/downloads/updates/odbc/default.aspx.

Pedi a um amigo para testar a importação da tabela doente e funcionou
Ele utilizou o driver OLE DB
http://www.microsoft.com/downloads/details.aspx?FamilyId=E1A87D8F-2D58-491F-A0FA-95A3289C5FD4&displaylang=en.

Os passos foram os seguintes:
1) fazes o importar, depois escolhes o driver oledb para fox
2) depois propriedades, e escolhes a origem dos dados
(aquilo tem um ficheiro .dbc que teoricamente devia ter todas as
tabelas, mas dá-me ideia que ele não as identifica sozinho)
3) ele cria tabela destino e atribui os tipos de dados sozinho
(dá-me ideia que só os datetime é que têm de ser definidos manualmente)

Se estiverem a utilizar o SqlServer 2000 ele também tem esta opção nas
Client Tools no Enterprise Manager.

Por favor experimentem e digam-me qual o resultado.

Fiz download de uma ferramenta que converte bases de dados, e vou experimentar usá-la na BD do CMOC
para extrair as tabelas.
http://www.sharewareconnection.com/database-convert.htm

Se hoje algum de nós conseguir fazer isso, julgo que se pode marcar para 5ª de tarde mais uma sessão de instalação e formação, desta vez para os consultórios.

No caso de ainda não conseguirmos converter os dados, a formação que falta incidirá sobre Controlo de Internamentos, Refeições (no caso desse módulo já estar criado e adaptado), continuação na gestão de stocks, e que assuntos mais?

Que aspectos do vosso software falta abordar e qual a vossa previsão para o tempo que isso consumirá?

Cumprimentos
Paulo Barbeiro

From: "Daniel.2SOFT" <daniel@2soft.pt>
To: Paulo Barbeiro <paulobarbeiro@gmail.com>, jorge@2soft.pt, Jorge Saraiva <jsaraiva@isa.pt>
Date: Dec 12, 2006 4:48 PM
Subject: RE: calendarização e dados para instalação

Olá Paulo,

Da última vez que aí estive a questão dos consultórios ficou arredada para segundo plano.
De modo que 5ª feira avançamos com importação de dados do hígia para se fazerem testes sobre os internamentos e, gestão de stocks.

cumps,
Daniel Lopes

From: Paulo Barbeiro <paulobarbeiro@gmail.com>
To: "Daniel. 2SOFT" <daniel@2soft.pt>, Nuno Videira <info@ccci.pt>
Date: Dec 13, 2006 5:14 PM
Subject: Re: calendarização e dados para instalação

Boa tarde.

Ok, parece-me bem. Para que horas combinamos o inicio da formação? Precisam que se prepare alguma coisa (sala, pcs,..)?

Cumprimentos
Paulo Barbeiro

--- Preparação Apresentação Intercalar / Época de Exames ---

From: Paulo Barbeiro <paulobarbeiro@gmail.com>
To: "Daniel. 2SOFT" <Daniel@2soft.pt>
Date: Feb 21, 2007 5:11 PM
Subject: finalização da instalação no CCC

Boa tarde.

Como não fui ao CCC na ultima sessão de instalação/formação que houve, gostaria se saber qual o ponto da situação da substituição do Higea pelo vosso 2soft clinic.

Já conseguiram automatizar a importação de dados?
Qual a vossa previsão para o nr de sessões de formação que são ainda necessários?

Cumprimentos
Paulo Barbeiro

From: "Daniel.2SOFT" <daniel@2soft.pt>
To: Paulo Barbeiro <paulobarbeiro@gmail.com>
Date: Feb 21, 2007 6:24 PM
Subject: RE: finalização da instalação no CCC

Olá, Paulo

Estivemos a fazer umas experiências das quais resultaram algumas alterações que é necessário implementar e que ainda não fiz.

Cumprimentos,
Daniel Lopes

From:Paulo Barbeiro <paulobarbeiro@gmail.com>
To: "Daniel. 2SOFT" <daniel@2soft.pt>
Date: Feb 21, 2007 7:06 PM
Subject: Re: finalização da instalação no CCC

Têm alguma previsão de quando é que isso estará pronto?
Relativamente à formação, julgo que a formação básica já está completa. Eventualmente faltarão alguns aspectos avançados na gestão de stock, certo?
Quantas sessões mais prevêem necessitar?

Cumprimentos

From: Paulo Barbeiro <paulobarbeiro@gmail.com>
To: "Daniel. 2SOFT" <Daniel@2soft.pt>, Jorge Saraiva <jsaraiva@isa.pt>
Date: Apr 11, 2007 6:52 PM
Subject: CCC

Boa tarde

Qual o ponto da situação da importação dos registos do Higea para a vossa aplicação?
Qual a vossa previsão para uma data para conclusão da instalação/formação ?

Cumprimentos
Paulo Barbeiro

---- PNEUMOTORAX ---

From: Paulo Barbeiro <paulobarbeiro@gmail.com>
To: Jorge Saraiva <jsaraiva@isa.pt>
Date: Jun 5, 2007 12:14 PM
Subject: Retoma dos trabalhos

Bom dia

Os exames médicos que fiz esta 6ª indicaram melhorias, pelo que já estou de volta ao trabalho. O tempo em casa não foi tão produtivo quanto desejaria, mas tentarei compensar agora nesta fase final,

Acerca do e-mail que segue em anexo, ao qual nunca mais obtivemos resposta e o Jorge disse que iria ligar ao Daniel, houve algum feedback por parte deles?

Cumprimentos
Paulo Barbeiro

---------- Forwarded message ----------
From: **Paulo Barbeiro** <paulobarbeiro@gmail.com>
Date: Apr 11, 2007 6:52 PM
Subject: CCC
To: "Daniel. 2SOFT" <Daniel@2soft.pt>, Jorge Saraiva <jsaraiva@isa.pt>

Boa tarde

Qual o ponto da situação da importação dos registos do Higea para a vossa aplicação?
Qual a vossa previsão para uma data para conclusão da instalação/formação ?

Cumprimentos
Paulo Barbeiro

Attachment 2

Sent document to 2soft requesting help for defining tasks to execute during installation

Note 1 – Document format has been changed

Note 2 – There was no reply to this request

Tarefas Instalação 2softClinic

Preparação do Servidor

- Desligar Terminais ?
- Recolha de dados já existentes ?

Instalação

- Instalação e configuração da Aplicação no Servidor
- Instalação e configuração da Aplicação nos 9 terminais actualmente existentes.
- Configuração e testes globais ao sistema instalado.

Problemas Possíveis:

1. O servidor não aceita a instalação da aplicação
2. O servidor não consegue comunicar com os terminais.
3. …

Plano de Contingência:

Backup de dados no servidor e formatação deste.

Instalação num disco que posteriormente se ligará ao servidor

2.0 Verificação do estado da rede

3.0 ….

Inicialização da Base de Dados:

- Importação da informação já existente
- Adaptação de tabelas (se necessário)

Acção de Formação #1

Programa:

- Introdução à navegação no software.
- Explicação geral das funcionalidades do modulo de gestão de stocks e facturação.
- Explicação e Demonstração de:
    - Processo de controlo de existências
        - Existências
        - Entradas
        - Saídas
    - Geração automática de encomendas.
    - Pesquisas de itens: preços, fornecedores
    -

Perfil dos formandos:

- Responsáveis pela manutenção de stocks.
- Responsáveis pela facturação.

Formandos:

- Nuno Videira
-
-

Formadores:

- Daniel
- Jorge

Material Necessário:

- Sala com espaço para *X* mesas e cadeiras.
- Parede ou Tela para projecção.
- Projector *DataShow*.
- *X* PC's com o software 2SoftClinic Instalado.

Acção de Formação #2

Programa:

- Introdução à navegação no software.
- Explicação geral das funcionalidades do modulo de gestão de médicos.
- Explicação e Demonstração de:
    - Inserir médicos na base de dados.
    - Edição de horários.
    - Pesquisas.
    -

Perfil dos formandos:

- Utilizadores responsáveis pela gestão clínica

Formandos:

- Nuno Videira
-
-

Formadores:

- Daniel
- Jorge

Material Necessário:

- Sala com espaço para *X* mesas e cadeiras
- Parede ou Tela para projecção
- Projector *DataShow*
- *X* PC's com o software 2SoftClinic instalado

Acção de Formação #3

Programa:

- Introdução à navegação no software
- Explicação geral das funcionalidades do modulo de gestão de consultas
- Explicação e Demonstração de:
    - Pesquisas na agenda
    - Edição de Agenda
    -

Perfil dos formandos:

- Usuários responsáveis pela admissão de pacientes, marcações de consultas.

Formandos:

- Nuno Videira
-

Formadores:

- Daniel
- Jorge

Material Necessário:

- Sala com espaço para *X* mesas e cadeiras
- Parede ou Tela para projecção
- Projector *DataShow*
- *X* PC's com o software 2SoftClinic instalado

Acção de Formação #4

Programa:

- Introdução à navegação no software
- Explicação geral das funcionalidades do modulo de gestão ########
- Explicação e Demonstração de:
    -
    -
    -

Perfil dos formandos:

- Usuários responsáveis por ########

Formandos:

- Nuno Videira
-

Formadores:

- Daniel
- Jorge

Material Necessário:

- Sala com espaço para *X* mesas e cadeiras
- Parede ou Tela para projecção
- Projector *DataShow*
- *X* PC's com o software 2SoftClinic instalado
-

Acção de Formação #5

Programa:

- Introdução à navegação no software
- Explicação geral das funcionalidades do modulo de gestão ########
- Explicação e Demonstração de:
    -
    -
    -

Perfil dos formandos:

- Usuários responsáveis por ###########
-

Formandos:

- Nuno Videira
-
-

Formadores:

- Daniel
- Jorge

Material Necessário:

- Sala com espaço para *X* mesas e cadeiras
- Parede ou Tela para projecção
- Projector *DataShow*
- *X* PC's com o software 2SoftClinic instalado
-