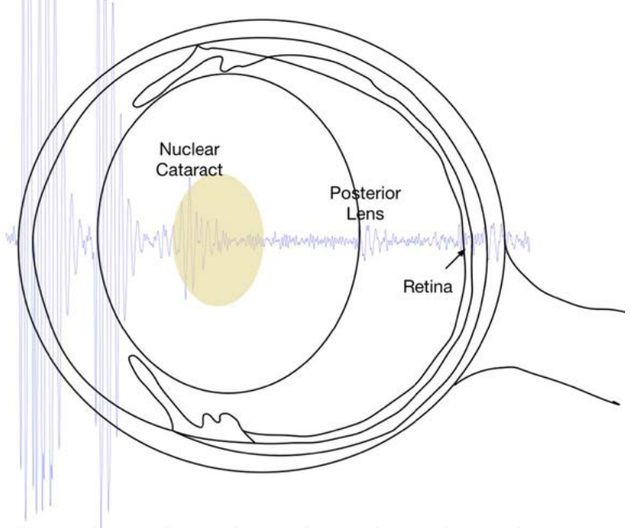
Development of New Methodologies Based On Ultrasound Techniques for In-vivo Cataract Characterization

Cataract is a pathology associated to the loss of the normal lens transparency, and its progression can result in the total loss of vision, being responsible for about 48% of the total registered cases according to the World Health Organization. For clinical prognostic and therapeutic purposes, it is therefore decisive its early detection and the classification of its evolution phase.



PROJECT WEBPAGE URL
https://www.it.pt/Projects/Index/1866

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Funding Agencies	
PTDC/DTP-PIC/0419/2012	**9,600€**
Start Date	01/06/2013
Ending Date	01/06/2015
Indicators	
Journal Papers	2
Conference papers	8
National Conferences	3
Prototype	1
Patents	1 (pending)
Concluded PhD	1
Concluded MSc	2

Two Main Publications

M. C. Caixinha, J. Amaro, M. J. Santos, F. Perdigão, M. Gomes, J. B. Santos, **In-vivo Automatic Nuclear Cataract Detection and Classification in an Animal Model by Ultrasounds,** IEEE Trans. on Biomedical Engineering, Vol. PP, No. 99, pp. 1 - 1, February, 2016

M. C. Caixinha, E. V. Velte, M. J. Santos, F. Perdigão, J. Amaro, M. Gomes, J. B. Santos, **Automatic Cataract Classification based on Ultrasound Techniques using Machine Learning: A comparative Study,** International Congress on Ultrasonics - ICU, Metz, France, May, 2015

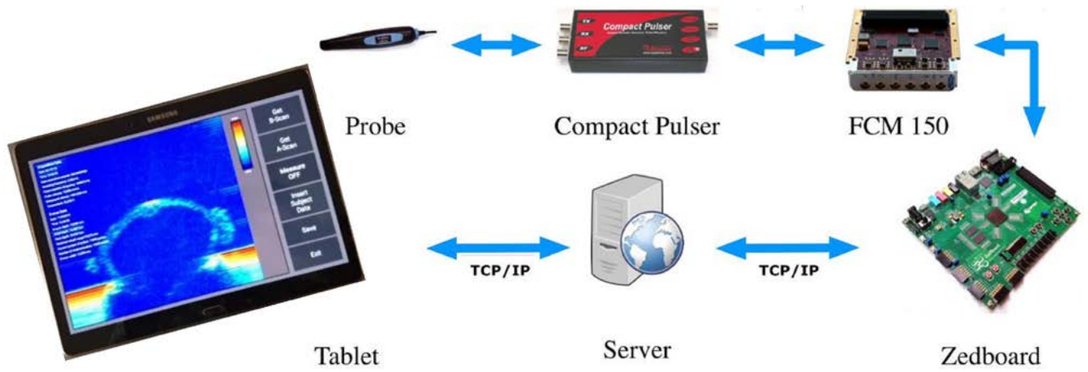

Fig. 1 ESUS system architecture, for automatic cataract detection and eyes' features extraction.

GENERAL MOTIVATION AND OBJECTIVES

Cataract is a clouding or opacity that develops in the crystalline lens of the eye, and its progression can result in the total loss of vision. This disease is responsible for about 48% of blindness registered cases and likely to increase given the aging of world's population and of cataract appearance related with age. For clinical prognostic and therapeutic purposes, it is very important to identify the cataract type and the disease stages especially in its early stages. The utilization of noninvasive methodologies of ultrasounds can have, in this regard, a crucial role allowing for a quick and efficient cataract detection and classification. The use of ultrasounds reveals also of particular interest to estimate accurately the cataract hardness, namely of dense or nuclear cataracts, an important parameter to be known by a doctor when performing the Phacoemulsification surgery, which is the most common surgical technique used in the developed countries for cataract removal. In the Phacoemulsification procedure, cataractous lenses are fragmented using laser radiation energy whose level to employ is directly related with the cataract hardness; an inappropriate selection of the phacoemulsification energy level underlies the main surgical complications, and so great importance to estimate accurately the cataract hardness.

CHALLENGE

Automatic cataract detection, classification, and hardness estimation using non-invasive ultrasound techniques, with processing carried out in real time using a low-cost SoC architecture.

WORK DESCRIPTION AND ACHIEVEMENTS

Under the research conducted on the project CATARATA (PTDC/DTP-PIC/0419/2012), the team have been able to detect, characterised and evaluated cataract hardness, by mean of the use A-scan ultrasounds in the range of 20MHz–25MHz, in both ex-vivo, and in-vivo, using proper animal models; in-vivo studies were conducted using healthy rats and with induced cataract with different degrees of severity, while ex-vivo studies also considered lenses from porcines. A database of acquired eyes' A-scan signals has been created, and manually labelled, using current state-of-the-art Lens Opacities Classification System, Version III (LOCS III) for cataracts' classification. Numerous features in the time and frequency domains were extracted from these signals and then used to train and test different classifiers in order to accurately identify the healthy and cataracts lenses. Precision, sensitivity and specificity above 99% were obtained with Support Vector Machines (SVM), and Random Forest (RF) classifiers. Also the statistical significance of each feature was evaluated in order to select the proper ones for a practical real-time implementation.

Leveraged on project CATARATA's results, it has also been developed a new Eye Scan Ultrasound System (ESUS) for automatic cataract detection and classification at real-time. The ESUS system is able to make all signal processing from A-scan signal acquisition to displaying cataract's classification. The system is built up on a ZeadBoard, a low-cost, and easy reprogrammable development board based in the System-on-Chip (SoC) Zynq- 7000 architecture of Xilinx. Acquired signals, after being processed are securely stored in a server. An app for an Android device as also been developed that can wirelessly access the server and display the A-scan and B-scan of the eye's data ultrasound acquisition, with the identification of the eye's structures, and the cataract and its severity characteristics when this is present.