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Content-Based Mammografic Image Retrieval Tool (HRIMAC) to assist issuing breast cancer diagnosis (TIC2002-04160-C02)

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Abstract

The HRIMAC project is intended to work as a content-based image retrieval in order to access to a specific tipology of digital mammographic images stored in large databases. Given the example image, the retrieval will be performed according to certain similarity criteria. When issuing a diagnosis from a mammographic image, HRIMAC will search in several available databases in order to provide the *n* most related mammograms according to the criteria specified in the search. Thus, each search will retrieve a reduced set of cases (digital mammograms) that are very similar to the one under study and about to be diagnosed. Typical criteria of similarity are the shape of microcalcification clusters, the presence of certain spiculated lesions and the shape of the masses. The analysis of these pathological cases will, with no doubt, help the radiologist in his diagnosis and therefore, will increase the efficiency of the interpretation.

The main goal of the project is to develop a web-based computing tool that will allow radiologists to assess the diagnosis of breast cancer from digitised mammograms. In order to achieve that goal, it will be necessary blending Computer Vision techniques (aimed to the efficient feature selection) with Artificial Learning algorithms (intended to the feature selection and the association of clinical cases).

The system can also be used as a training tool. Specialists can get acquainted with the typical symptoms found when assessing digital mammograms by means of the examples provided by HRIMAC.

Keywords: Computer Vision, Artificial Learning, Advanced Interfaces, Breast cancer detection and diagnosis. Content based image retrieval (CBIR). Computer Aided Diagnosis (CAD).

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1 Project goals

The main goal of this project is to provide to the radiologist of a computer software on a web platform to aid him/her on the evaluation of mammal cancer diagnosis using digital mammographic images stored in large databases.

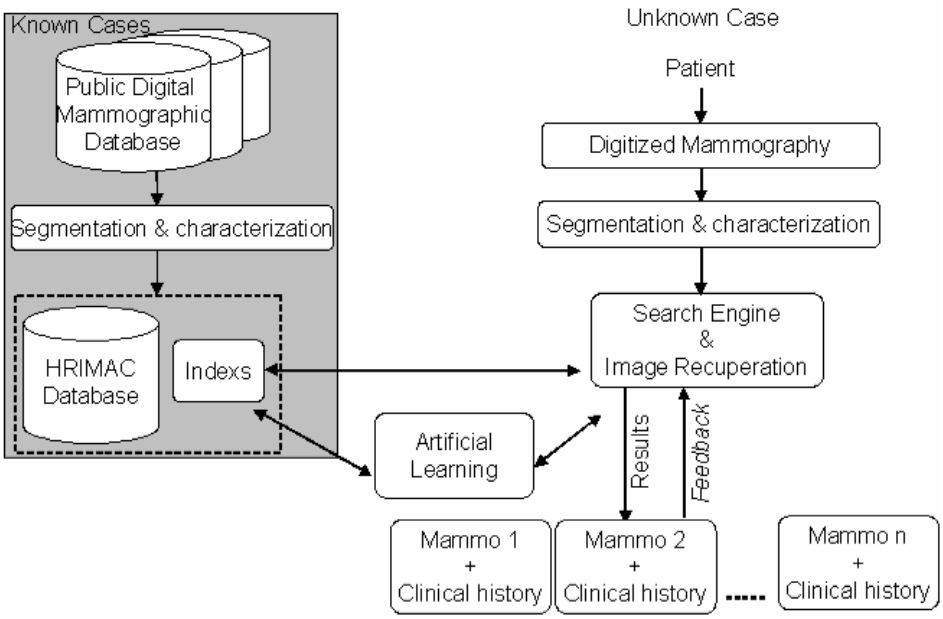
A medical diagnosis is normally issued on the basis of a visual recognition of the external abnormalities presented by the patient or from X-ray, magnetic resonance, computer tomography images, and others. In any case it is usual to relate the present case with others appearing in the literature. In this sense we want to remark that the extended medical literature related with mammal cancer contains a large number of example images and normally, non-pathological cases are compared with the most typical pathologies. It is known that medical treatment is more effective when it is provided from the disease initial stages. Therefore, it is very important to have the right tools that allow to find in a quick and precise way example images that complement the object case of study. In this way the diagnosis can be made with a higher confidence.

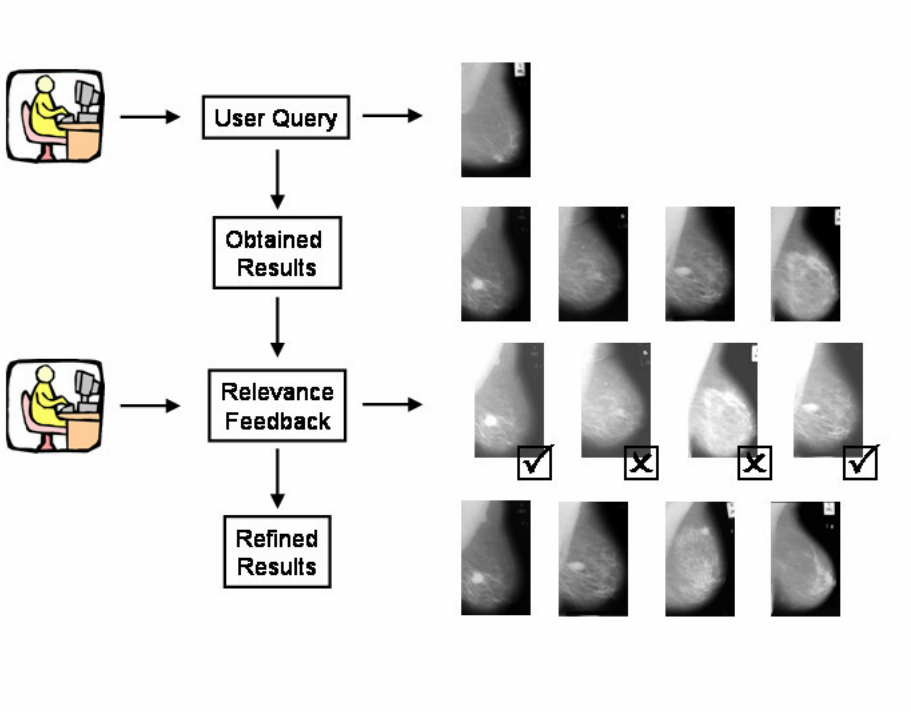
The HRIMAC project wants to create a Content-Based Image Retrieval system (CBIR) for mammographic images. Therefore, given the example image HRIMAC, will allow the retrieval of digital mammographic images from different public data bases following certain given affinity criteria. Every search will provide a limited number of cases with certain characteristics (like for example the shape of the clusters of microcalcifications, the presence of certain type of spicular lesions, the shape of masses, etc) that are similar to the mammogram that is being studied and diagnosed. The analysis of this pathological cases can, without any doubt, help to the radiologist to diagnose with a major degree of confidence and to improve the efficiency of the interpretation.

The development of Computer-Aided Diagnosis systems (CAD) applied to medicine has been one of the main research lines in the last years in computer disciplines like Computer Vision and Artificial Intelligence. However, the majority of these systems are designed in order to issue a second diagnosis. This can generate doubts and decrease the confidence in the affected collectives (both medical and patients). On the contrary, the objective of the HRIMAC project is not the issue of a diagnosis. HRIMAC will be a help tool for the specialist to obtain a set of cases very similar to the one that is evaluated at the moment. Therefore HRIMAC will be a “diagnosis aiding tool” and not a “diagnosis issuing tool”.

From this perspective, HRIMAC offers many documentation possibilities of cases of special relevance for the case being analyzed at every moment: the intelligent access to public large mammographic databases (MIAS, Nijmegen, University of South Florida, Lawrence Livermore National Laboratories/University of California at San Francisco (LLNL), University of Washington, etc.), instead of being restricted to the memory of similar cases in a given team of a local medical center. Obviously, the search of relevant information in large databases is not an easy task and many times if the search method is not the proper one the search is not viable. Therefore one of the aims of the project is to create a simple and efficient search tool.

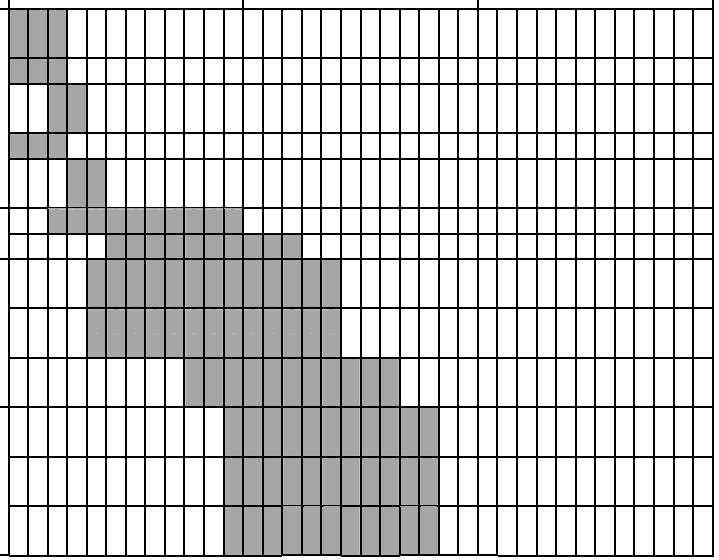
Moreover, HRIMAC can be also used as a didactic tool to help on the formation of young radiologists specialized on reading mammograms. HRIMAC will allow to show examples of typical cases of the different symptoms registered in the analysis of mammographic images. Moreover, in this cases when the user requires it, HRIMAC can suggest a diagnosis, fact that will complete its formation capabilities.


Known Cases
Public Digital Mammographic Database
Segmentation & characterization
HRIMAC Database
Indexs
Unknown Case
Patient
Digitized Mammography
Segmentation & characterization
Search Engine & Image Recuperation
Artificial Learning
Results
Feedback
Mammo 1 + Clinical history
Mammo 2 + Clinical history
Mammo n + Clinical history


User Query
Obtained Results
Relevance Feedback
Refined Results

Cronogram:

Activities/Tasks	Center of development	Responsible person and involved persons	First year (*)	Second year (*)	Third year (*)
A1.1 Analysis of documentation and bibliography about CBIR systems	UdG (EVC)	J.Freixenet–J.Solá–R.Martí–FPI1			
A1.2 Analysis of documentation and bibliography about CAD systems	UdG (EVC)	J.Martí–J.Español–E.Golobardes			
A1.3 Analysis of results given by existent CAD systems.	UdG (EVC)	R.García–FPI1–J.M.Garrell–R. Bassaganyas			
A1.4 Study of the structure of the public mammographic databases	UdG (EVC)	J.Martí–FPI1–C.Vallespí			
A1.5 Specification of requirements	UdG (EVC)	J.Martí–J.Español–J.Pont–E. Golobardes			
A2.1 Design and implementation of segmentation algorithms	UdG (EVC)	R.García–P.Planiol–FPI1–R.Martí			
A2.2 Design and implementation of characterization algorithms.	UdG (EVC)	J.Martí–P.Planiol–V.Ila–FPI1–R. Martí			
A3.1 Analysis and design of algorithms of selection of local characteristics.	URL (EAA)	E.Golobardes–D.Vernet–C.Vallespí J.Camps–E.Bautista			
A3.2 Analysis and design of algorithms of selection of global characteristics.	URL (EAA)	J.M.Garrell–M.Salamó–C.Vallespí E.Golabardes–E.Bernadó			
A3.3 Analysis, design and implementation of algorithms of selection of characteristics.	URL (EAA)	E.Golobardes–D.Vernet–M.Salamó C.Vallespí–J.M.Garrell–E.Bernadó			
A4.1 Evaluation of the local characteristics in mamographies in retrieval algorithms.	UdG (EVC) URL (EAA)	J.Martí–FPI1–R. Martí–M.Salomó E.Golabardes–C.Vallespí–J.Camps			
A4.2 Evaluation of the global characteristics in mamographies in retrieval algorithms.	UdG (EVC) URL (EAA)	J.Martí–FPI1–R.Martí–M.Salomó E.Golabardes–C.Vallespí–J.Camps			
A4.3 Integration of the local and global characteristics of mamographies in the retrieval algorithms.	UdG (EVC) URL (EAA)	J.Martí–FPI1–R. Martí–M.Salomó E.Golabardes–C.Vallespí–J.Camps			



Activities/Tasks	Center of development	Responsible person and involved persons	First year (*)	Second year (*)	Third year (*)
A5.1 Analysis, design and implementation of indexing algorithms.	URL (EAA)	J.M.Garell–E.Golobardes M.Salomó–C.Vallespí–FPI2			
A5.2 Analysis, design and implementation of index consulting algorithms.	URL (EAA)	E.Bernadó–J.M.Garrell–J.Camps D.Vernet–FPI2			
A5.3 Analysis, design and implementation of index actualization algorithms.	URL (EAA)	E.Golobardes–J.M.Garrell– FPI2–C.Vallespí M.Salomó–E.Bernadó			
A6.1 Design of the searching interface	UdG (EVC)	R. García–R. Martí–E.Bautista J.Pont–J.Español			
A6.2 Design of the interface that presents the search results.	UdG (EVC)	J.Freixenet–J.Solá–R.Bassaganyas J.Español			
A6.3 Analysis, design and implementation of the user interface.	UdG (EVC)	J.Martí–FPI1–V.Ila			
A7.1 Analysis of the user interaction with the system to improve the search results.	URL (EAA)	J.M.Garrell– E.Golobardes E.Bernadó–J.Camps–D.Vernet			
A7.2 Analysis, design and implementation of a new search in order to improve the results.	URL (EAA)	E.Bernadó–E.Golobardes M.Salomó–C.Vallespí–J.M.Garrell			
A8.1 Integration of algorithms	UdG (EVC)	J.Martí–FPI1–C.Vallespí–R.Martí FPI2			
A8.2 Organization of users	UdG (EVC)	R.García–R.Martí–P.Planiol R. Bassaganyas			
A9.1 Design of the tests.	UdG (ELM)	J.Español–J.Martí–E.Golobardes R.Bassaganyas			
A9.2 Development of the efficiency tests over study cases.	UdG (ELM)	J.Pont–R.Bassaganyas–R.García			
A10.1 Analysis of the results of the efficiency tests.	UdG (ELM)	R.Bassaganyas–J.Martí–FPI1 R.Martí–R.García			
A10.2 Analysis, design and implementation of possible improvements.	UdG (EVC)	R.García–R.Martí–J.Español E.Golobardes			
A11.1 Writing of project memory and user and installation manuals.	UdG (EVC)	J.Freixenet–R.Martí–J.Camps			
A11.2 Visits and talks to hospitals and medical centers	UdG (ELM)	R.Bassaganyas–J.Martí E.Golobardes			
A11.3 Writing of scientific papers	UdG (EVC) UdG (ELM) URL (EAA)	J.Martí–R.Bassaganyas E.Golobardes and the rest of the project personnel.			

2 Goals achievement

2.1 Activities performed during the first year of the project

During the first year of the project there were several meetings to organize the coordination of the different tasks that had to be developed (shown in the cronogram above) and several of the sub-objectives of the tasks were developed.

In relation with task 1 “Analysis of the architecture of a CBIR system aimed to medical images” all the programmed activities were performed. An internal report of the University of Girona was made exposing the state of the art in CBIR and CAD systems.

In relation with task 2 “Design and implementation of segmentation and characterization algorithms for digital mammograms” 5 different types of segmentation and characterization algorithms have been developed and implemented:

Type 1: Global segmentation algorithms: These segmentation algorithms detect the interest region of the image, by distinguishing the mammal region from the pectoral muscle region and by removing the labels or marks sometimes present in mammograms. Two algorithms have been implemented: one of them performs the image segmentation in large regions and determines the mammogram type (CC or MLO). In case of a MLO it determines the orientation of the breasts. The second algorithms removes the pectoral muscle zone, the labels and the marks and determines the interest area of the breast.

Type 2: These are the algorithms that in the interest zone of the breast detect in an automatic form some points that probably belong to an abnormality zone (seed zone). This can be a microcalcification or a mass. These type of algorithms are a substitute of the common technique were the radiologist indicates manually that a given pixel is a part of an abnormality. Three different algorithm of this kind have been implemented: the first one is based on the histogram of the interest zone, the second one is related to statistical calculations and the third one is an hybrid method between both of them.

Type 3: Microcalcifications segmentation algorithms. These algorithms are specifically made to segment this type of abnormality. Three types of different algorithms have been design and implemented: the first one is based in region growing methods, the second one is based in mathematical morphology and the third one is based in gradient techniques.

Type 4: Masses segmentation algorithms: Two algorithms have been designed and implemented to specifically segment oval-shape masses. The first one is based on texture information and the second one is based in contour information. Both base the growing criteria on the shape characteristics of the region.

Type 5: Abnormalities characterization algorithms. The analysis and implementation of these algorithms has been made having in account the region shape, texture and pixels grey level distribution. The region shape characterization has been based in moments and Fourier Transform characteristics. The texture

characteristics have been described with statistical methods (like co-occurrence matrix, parametrical masks and energy).

In relation with task 3: "Analysis, design and implementation of characteristics selection algorithms" we have analysed the problem using Case Based Reasoning (CBR) techniques (artificial learning techniques) in order to be able to identify the relevant attributes in mammographic images. The results we have obtained allow the characterization of a mammographic image by using an attributes vector. We are exploring new systems of knowledge representation to allow a more detailed and specific characterization for each mammogram. With this results we have tested CBR systems that allow the retrieval of mammographic images with a high degree of success.

In relation with task 5: "Analysis, design and implementation of indexing algorithms", we have explored two different lines. In the first one we have implemented algorithms related with the maintenance of the cases memory of a CBR system that allow to re-organize, to re-order or to index the cases bank according to they degree of use. On the other hand we have developed a method that allows to group the cases in sub-sets according to certain criteria. This provides of a major efficiency in the retrieval phase due to the reduction of the size of the cases memory.

On the other hand, some advances related to task 6 (design and implementation of the interface) were made. Specifically, the interface architecture, the coordination process that controls the database and the segmentation and characterization processes have been developed. The project interface can be reached at the web address http://micros4.udg.es/hrimac

2.2. Activities performed during the second year of the project:

This second year has been very important in the sense that the directive team of the Girona Hospital "Hospital Universitari Doctor Josep Trueta" has decided to purchase a digital mammograph for its radio diagnosis services and specifically for the mammal radiology unit. We want to remark that both Dr. Pont (researcher in this Project) and Dr. Martí (principal researcher of the project) have actively participated in the conversations with the directive team of the Hospital. It is obvious that the HRIMAC project has been one of the motivations to incorporate this new equipment. Moreover, we have participated in the establishment of the conditions that the commercial companies participating in the contest offering the equipment have to accomplish. In this way the data acquisition will be in the Standard format DICOM and will be compatible with the HRIMAC system. The new mammograph is supposed to be installed in the Hospital before the end of 2004. In this way, the database of the system will be constantly updated and in a constant grow. The feedback between the technical team and the medical team will be done on the basis of cases treated and diagnosed directly by the medical team.

In this second year we have also maintained coordination meetings to distribute and develop the tasks for the second period. In summary the following jobs have been performed:

In relation with task 2 "Design and implementation of digital mammograms segmentation and characterization algorithms" all the previously programmed activities were performed. Specifically, the abnormalities segmentation algorithms (both of masses and microcalcifications) developed in the previous year, have both been integrated in the application prototype. This integration has also had in account the coherence of the segmentation result in the CC and MLO images.

In relation with task 4 “Analysis, design and implementation of digital mammograms retrieval algorithms” we have worked with algorithms using both Case Based Reasoning and Genetic Programming. This task has suffered from a certain degree of delay. This has been done on purpose due to the good news about the acquisition of the digital mammograph at the Girona hospital. We decided to wait to have real data obtained with this new mammograph to develop sub-tasks 4.1 and 4.2.

In relation with task 6 “Analysis, design and implatation of the user interface and specification of the search parameters” all the programmed activities have been performed. The medical and technical team have designed and analyzed the initial proposal and as a result, the search interface, the results interface and the interface that informs about the studied case have been implemented. Finally, in relation with task 8 “Development of the prototype” sub-task 8.1 (integration and fusion of algorithms) has been started.

2.3 **Activities to be performed to the end of the project**.

During the third year of the project the real implementation of the CAD system HRIMAC in the Girona hospital will be performed. The prototype of HRIMAC will be installed in a hospital room next to the diagnosis station and next to the acquisition room were the digital mammograph will be installed. As we have mentioned, the fact that the cases entered in the HRIMAC prototype are cases treated directly by the radiologists team will largely facilitate the implantation of the radiologists necessities in the system. During this year one or several of the members of our technical team will work regularly from the work station installed in the hospital. On the other hand, the activities planned for the third year are the ones planned at the initial stages of the project. In fact the implementation of the project is part of task 8, already started during the second year.

3 Results

3.1 Formation of personnel:

Two PhD thesis have already been successfully developed in relation with this project:

Dr. Xavier Muñoz (Universitat de Girona)
Dr. Maria Salamó (Universitat Ramon Llull)

One PhD thesis has been submitted to the committee and will be defended in December by:

Mr. Jaume Bacardit (Universitat Ramon Llull)

Five other thesis are currently being developed by:

Mr. Xavier Canaleta (Universitat Ramon Llull)
Mr. Albert Fornells (Universitat Ramon Llull)
Mr. Arnau Oliver (Universitat de Girona)
Mr. David Raba (Universitat de Girona)
Mr. David Vernet (Universitat Ramon Llull)

3.2. Collaboration with national and international groups:

We want to remark that we have presented the project in different national and international conferences. There was a presentation in the national conference on radiology (organized by SERAM) and in the national conference on shape recognition and image analysis (organized by AERFAI). We were also at the International Workshop on Digital Mammography which is a world reference. We assisted also to some local meetings and conference. We have presented our project and research lines at the CNM (Centro Nacional de Microelectrónica, Barcelona) at the invitation of Dr. Cabruja. We also want to remark our visit to Parc Taulí, the hospital center of Sabadell, were the mammal radiology unit, directed by Dr. Sentís has two digital mammographs on station. Dr. Sentís has shown a lot of interest in the HRIMAC project and we are going to consider future collaborations with his team.

On the other hand the PhD. Student A. Oliver (whose supervisor is J. Freixenet) performed a 3 month research stay at the University of East Anglia (Norwich, United Kingdom) with the research group Information Systems. As a result of this stay, as it was planned, we have written a journal paper that is being currently reviewed.

The project has also involved the participation on the "Spanish web of data mining and automatic learning" (TIC 2002-11124-E) formed by 130 investigators from 17 research groups of 18 universities. The principal investigator is Dr. José Riquelme (University of Seville).

We are also working on the preparation of a European project called MARISA: Major Accident Reduction through Inherent Safety.

3.3 Publications derived from the project:

J. Martí; J. Freixenet; D. Raba; A. Bosch; J. Pont; J. Español; R. Bassaganyas; E. Golobardes y X. Canaleta, "HRIMAC - Una Herramienta de Recuperación de Imágenes Mamográficas por Análisis de Contenido para el Asesoramiento en el Diagnóstico de Cáncer de Mama", Actas del VI Congreso Nacional de Informática de la Salud (INFORSALUD 2003).

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M. Salamó, E. Golobardes. Global, Local and Mixed Rough Sets Case Base Maintenance Techniques. Setè Congrés Català d'Intel•ligència Artificial (CCIA 2004). To appear in IOS Press. Barcelona, Octubre 2004

M. Salamó, E. Golobardes. Dynamic Case-Based Maintenance. IX Ibero-American Conference on Artificial Intelligence (IBERAMIA 2004). To appear. Puebla, México, Octubre 2004

M. Salamó. Integració de la teoria dels Rough Sets dins del Raonament Basat en Casos per potenciar la fase de recuperació. La defensa de la tesis está prevista durante la primera quincena de Octubre 2004.

A. Fornells (Trabajo de un curso de doctorado, directora de tesis: Elisabet Golobardes). Aplicació de restriccions sintàctiques i semàntiques en la Programació Genètica per la construcció de funcions aplicables a la detecció de càncer de pit mitjançant raonament basat en casos. Curso de doctorado: Computación evolutiva. Barcelona, 20 de Junio de 2004

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