PhD in Information Technology and Electrical Engineering

Università degli Studi di Napoli Federico II

PhD Student: Gabriele Piantadosi

XXIX Cycle

Training and Research Activities Report – Second Year

Tutor: **Prof. Carlo Sansone**
Co-Tutor: **Prof. Mario Sansone**

Student

I graduated in Computer Engineering; currently, I am attending the second year of PhD in Information Technology and Electrical Engineering - ITEE- XXIX Cycle at the University of Naples Federico II, under the supervision of Prof. Carlo Sansone and Prof. Mario Sansone. I was awarded a MIUR research grant.

Study Activities

Module	Type	Professor	Date	H	CFU
Project Management per la Ricerca	Ad-Hoc	Guido Capaldo	04/03/2015	20	3
Models, methods and software for Optimization	Ad-Hoc	Antonio Sforza	20/05/2015	12	4
Designing and writing scientific manuscripts for publication in English language scholarly journals and related topics	Ad-Hoc	Parker	17/06/2015	12	3
Cambridge English: Cambridge English: Advanced (CAE)	MS-Mod	Janet Parker (CLA)	09/09/2015	50	3
Network Security	Ad-Hoc	Simonpietro Romano	I semester	30	6

Seminars	Type	Lecturer	Date	H	CFU
Agent with Truly Perfect Recall	Int	Nils Bulling	28/04/2015	1	0,2
Social Signal Processing: understanding social interactions, through nonverbal behaviour analysis	Int	A. Vinciarelli	05/05/2015	2	0,4
Recent Advances in High Density EEG Research and its Epilepsy Applications	Int	Ceon Ramon	21/05/2015	2,5	0,5
La sintesi sonora dell'ingegnere Laurens Hammond QUANDO LA SCIENZA INCONTRA L'ARTE	Int	R. De Asmundis	09/11/2015	4	0,8
Predictable Real-Time Embedded Control Systems	Int	G. Buttazzo	16/11/2016	6	1,2
Test and Diagnosis of Integrated Circuits	Int	A. Bosio	17-18/11/2015	12	2,4
Hardware Security and Trust	Int	G. Di Natale	19-20/11/2015	12	2,4

	Credits year 1								Credits year 2								Credits year 3								G.Tot	Check
	Est.	bimonth						Tot	Est.	bimonth						Tot	Est.	bimonth						Tot		
		1	2	3	4	5	6			1	2	3	4	5	6			1	2	3	4	5	6			
Mod.	26	0	3	0	3	3	11	20	15	3	7	0	3	0	6	19	5							0	39	30-70
Sem.	13	2,4	1	4,8	1	1,5	2,3	13	12	0,2	0,9	0	0	6,8	0	7,9	5							0	20,9	10-30
Res.	21	7,6	6	5,2	6	5,5	0	30,3	33	6,8	2,1	10	7	3,2	4	33,1	50							0	63,4	80-140
	60	10	10	10	10	10	13,3	63,3	60	10	10	10	10	10	10	60	60	0	0	0	0	0	0	0	123,3	180

Research Activity

In recent years Dynamic Contrast Enhanced-Magnetic Resonance Imaging (DCE-MRI) has gained popularity as an important complementary diagnostic methodology for early detection of breast cancer [1]. Due to the huge amount of data of the 4D DCE-MRI volumes, automatic detection and diagnosis of suspicious ROIs is still an open problem[2,3]. One of the major issues in developing computer aided detection\diagnosis (CAD) systems for breast DCE-MRI is to detect the suspicious region of interests (ROIs) as sensibly as possible, while simultaneously minimising the number of false alarms. This task is made harder by the peculiarity of DCE-MRI breast examinations: breast movements due to inspiration, huge diversity of lesion types.

My whole research activity is mainly focused on developing a fully automated CAD system. My proposal (up to now) has been modelled as a series of successive refinements (fig. 1) applied on patient DCE-MRI images.

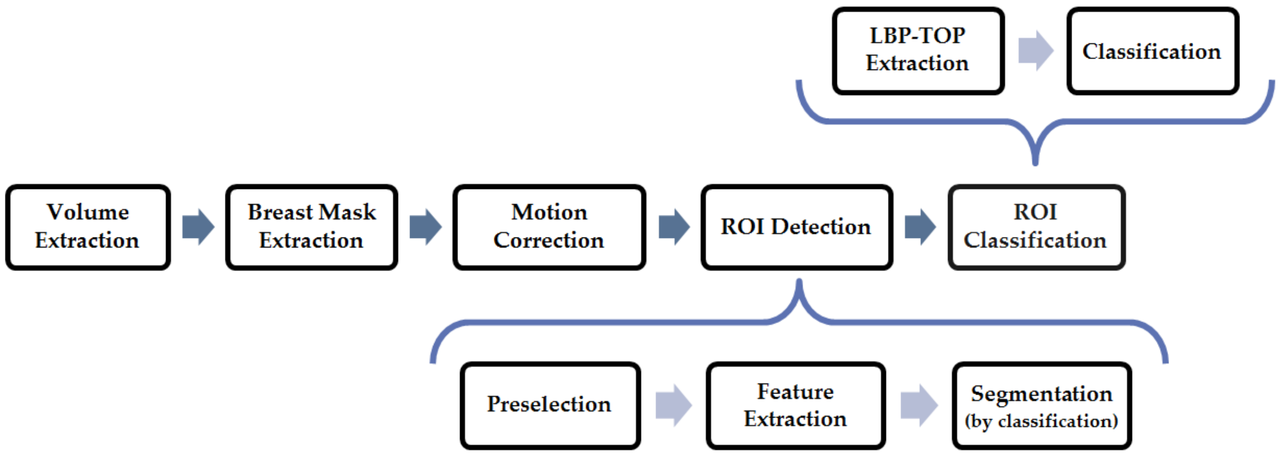

Fig.1: CAD proposal

To briefly summarize, the CAD proposal (object of the first year research activities [4]) consists of:

- **Volume Extraction:** DCE-MRI data basically consists of a 4D volume (3 spatial dimensions + 1 temporal dimension) produced by different protocols. For each Voxel a TIC (Time Intensity Curve) is extracted. This step prepares the data to be compatible with the next steps.
- **Breast Mask Extraction:** With the aim of reduce the computational cost of further steps and attenuate noise caused by extraneous voxel (VOlumetric piXEL) a binary mask representing only breast parenchyma and excluding background and other tissues is extracted.
- **Motion Correction:** It is well known [5] that some sort of motion correction technique should be performed before DCE-MRI data analysis in order to reduce movement artefacts (fig.2). I spent part of first year research activity to investigate which motion correction technique better fits the biomedical image registration problem.
- **Region of Interest (ROI) Detection:** Segmentation of the breast parenchyma could be approached as a classification problem. To improve the classification results (with respect to the ROI segmentation problem) a voxel-by-voxel pre-selection (as a threshold on some feature) was performed. Different sets of feature could be considered (spatial-temporal, textural, pharmacokinetic, etc…). The effect of different classifier was investigated. The result is a binary voxel-by-voxel labelling (intended for suspicious/not suspicious) whose union represents a Region of Interest (ROI) to be submitted to expert radiologist's advice or to next stages.
- **Classification:** To perform a fully automated detection, each ROI needs to be investigated to assess the lesion aggressiveness. Different sets of feature could be considered (geometric, textural, pharmacokinetic, etc…).

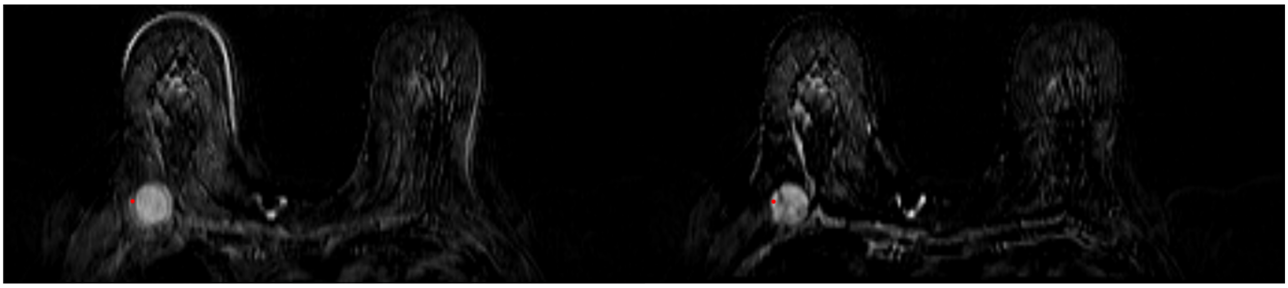

Fig.2: Sagittal view (by subtractive images) of a DCE-MRI volume before (left) and after (right) a 3D-FFD motion correction. In red the point later analysed.

During the second year I focused on investigating each step with the final aim of maximizing the accuracy (with respect to a gold-standard provided by an expert radiologist).

One of the topics addressed during the second year research activities is focused on Motion Correction Techniques (MTCs). During the first year, we investigate which MCT better fits the biomedical image registration problem [6] and we find out that it is not always appropriate to use a sophisticated motion correction technique such as a rigid MCT or non-rigid or free-form-deformation (FFD) MCT. Our results showed that a simple median filtering could be used assuming that small deformations can be considered as superimposed noise on a baseline image.

Our newest findings demonstrate that although the median filtering achieves, in general, better results with respect to other MCTs, no single MCT is always the better choice for all the patients. Another important issue is concerned with the use of only one MCT for registration of patient movements of different size (both small and large): in fact, in our preliminary experience, in some cases (see Figure 4) such as small movements, an inappropriate MCT can induce artefacts leading to inaccurate tumour assessment.

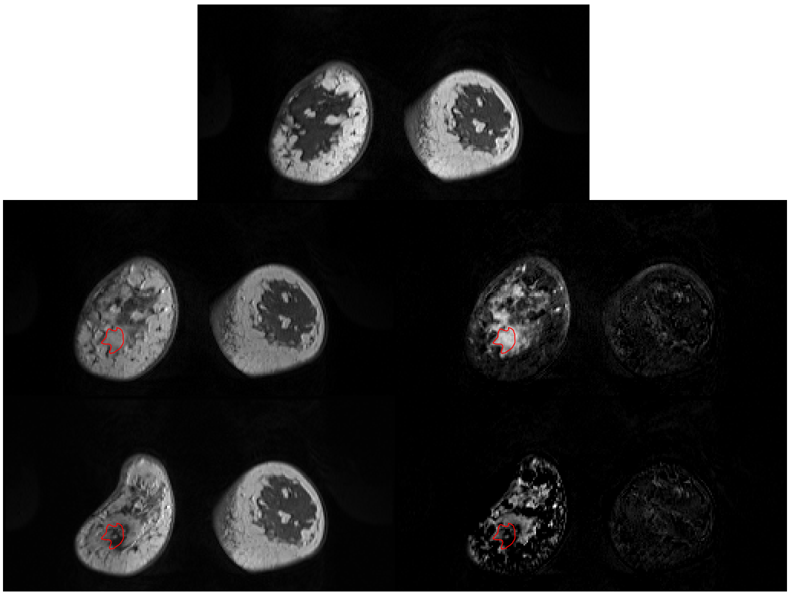

Fig.3: An illustrative case in which an inappropriate MCT (3D Free-Form Deformation with cubic interpolation) introduces evident artefacts leading to inaccurate evaluation. On the top row, a pre-contrast image is shown. On the middle row (without motion correction), the post-contrast image (about 3 min. after the injection) is shown on the left; the subtraction image on the right. An inappropriate MCT not only can introduce evident artefacts but also can impinge on the contrast agent effect undermining the final results. Specifically, we can observe a decrease of the enhancement in the manual segmented region of interest (in red).

These issues suggest that the choice of MCT should be specific for each exam and should be chosen before region of interest (ROI) analysis is made. We already assessed a novel model-based Quality Index (QI) for quantitative evaluation of MCT in breast DCE-MRI [6]. That QI takes into account the above mentioned issues by means of different kinetic models of blood plasma and of the extravascular extracellular space (EES) for tumour tissue [7].

In our work [11] we extend the previously proposed QI to rank the MCTs and obtain a data-driven selection of MCTs in breast DCE-MRI.

As far as the classification stage of the segmented lesions (automatic segmented ROI) is concerned, we propose [12] the use of Local Binary Pattern on Three Orthogonal Planes (LBP-TOP) features for the assessment of malignancy in breast DCE-MRI. Different classifiers (RF, MLP and SVM) as well as the contribution of a motion correction technique were evaluated.

Local Binary Pattern (LBP) [8] provides a very efficient set of feature by thresholding the neighbourhood of each pixel and considers the result as a binary number. As threshold, the luminance value of the pixel in the center of the neighbourhood is considered. Then the binary numbers are interpreted as a local pattern and an histogram of the occurrences for all the patterns of the image is calculated (fig.5).

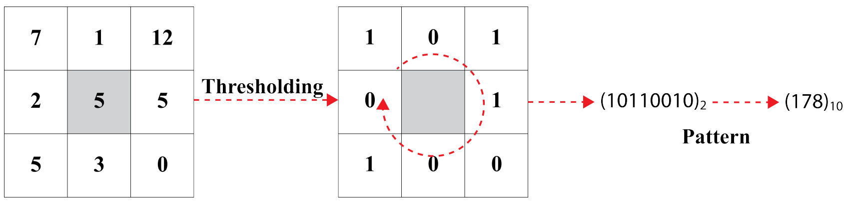

Fig.4: LBP strategy: from the image to a pattern.

To make LBP computationally simple and easy to be extended to a 4D volume, an operator based on co-occurrences of LBP on Three Orthogonal Planes (LBP-TOP) was also introduced [9]. LBP-TOP considers three orthogonal planes: XY, XT and YT, and concatenates LBP histograms in these three directions as shown in Fig. 6.

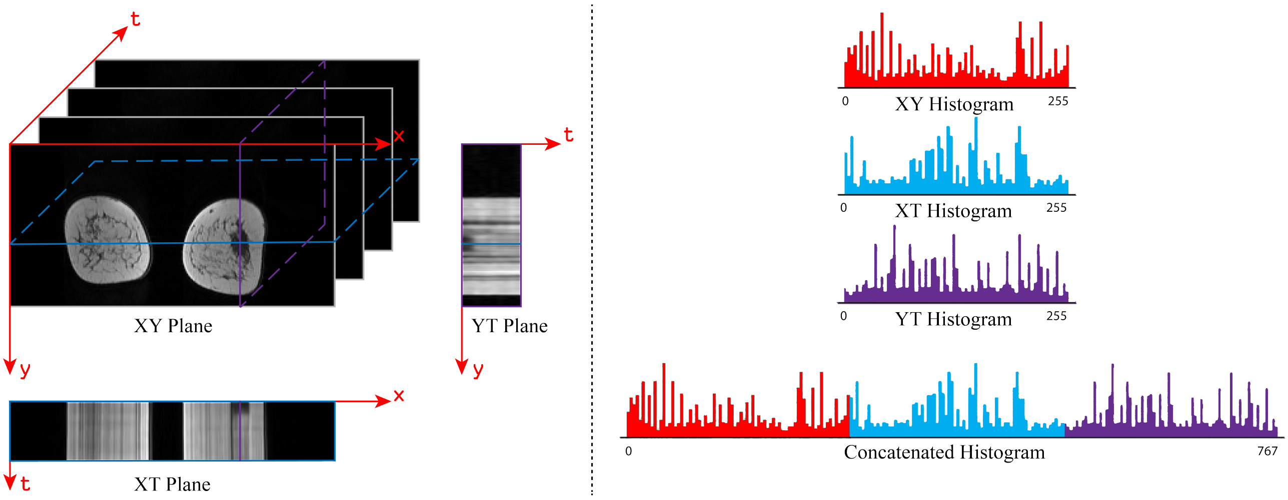

Fig.5: LBP-TOP extraction strategy starting from the 3D volume (a) till to the concatenates histogram (b) on the bottom-right

LBP-TOP were extracted from manually segmented ROIs for all patients in our database. Classification performance of LBP-TOP were assessed in a leave-one-out cross-validation.

Our results indicate that LBP-TOP combined with random forest classifier and median filtering with a 3px sliding windows as motion correction technique, achieves the highest accuracy with respect to literature proposals, when only the YT histogram is used.

Furthermore, the framework for advanced medical image remote analysis in a secure and versatile client-server environment at a low cost that I proposed during the first year [10], have been extend to a journal version [13].

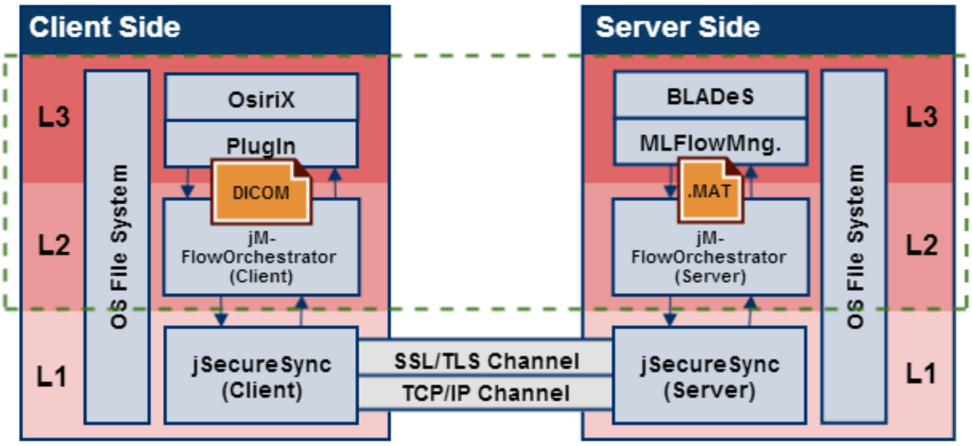

Fig.7: framework configuration in the specific context of DCE-MRI evaluation, by using OsiriX and the proposed CAD (Fig.1).

The framework (fig.7) briefly consists of three modules:

- **jSecureSync;** Running both on client side and on server side, it implements the multi-client/single-server model. Once communication is established, client and server side operate symmetrically. Takes charge of any security concerns. SSL/TLS channel security has been realised using a symmetric authentication policy (client-authenticated mode), issued during user registration as an authorized client.
- **jFlowOrchestrator:** Provides all services to perform brokerage between L3 and L1, by orchestrating the steps of each request and the server side computational flow progress. It also adapts the file format standard of the application layer (L3) at client side (DICOM) to the file format standard of the application level (L3) on server side (.MAT) and vice-versa.
- **Application Layer:** Could be hypothetically different according by the context and the software. The framework offer different interface for each side:
    - Client Side: a client side medical images processing software with a plugin system to interact with the described architecture.
    - Server Side: any advanced medical image processing framework able to interact with the infrastructure (in that specific context a Matlab environment running the CAD algorithm).

I also presented [13] an implementation of this framework, where OsiriX, a wide-spread medical image analysis software on Apple Workstation, is capable to perform remote image processing in a secure way.

Future works

Future works will treat the following topics:

- Testing new breast-mask extraction algorithms;
- Test different datasets (Pascale & USF collaborations);
- Explore new "habitat-based" features (USF collaboration);
- Develop new textural features for jointly spatial and temporal analysis;
- Prediction of the treatment outcome (USF collaboration);
- Further improve the performances of the QI for the data-driven selection of MCTs.

Some of that will involve the so far active collaboration with Istituto Nazionale Tumori - IRCCS "Fondazione G.Pascale". Moreover we have planned to start, in the next few days, a collaboration with the University of South Florida - Prof. Lawrence O. Hall (Department of Computer Science and Engineering). This collaboration will add important feature to the CAD architecture and to the final PhD dissertation results.

References:

[1] Lehman, C.D., et al.: MRI evaluation of the contralateral breast in women with recently diagnosed breast cancer. The New England Journal of Medicine 356, 1295-1303 (2007).

[2] Renz et al.: Detection and classification of contrast-enhancing masses by a fully automatic computer-assisted diagnosis system for breast MRI. J. Magnetic Resonance Imaging (2012)

[3] Vigniatti et al.: Performance of a fully automatic lesion detection system for breast DCE-MRI. J. Magnetic Resonance Imaging (2012)

[4] S. Marrone, G. Piantadosi, R. Fusco, A. Petrillo, M. Sansone, and C. Sansone, "Automatic lesion detection in breast DCE-MRI", in Image Analysis and Processing ICIAP 2013, pp. 359–368, Springer, (2013)

[5] C. Tanner, et al.: "Does registration improve the performance of a computer aided diagnosis system for dynamic contrast-enhanced MR mammography?" in Biomedical Imaging: Nano to Macro, 2006. 3rd IEEE International Symposium on. IEEE (2006)

[6] S. Marrone, G. Piantadosi, R. Fusco, A. Petrillo, M. Sansone, and C. Sansone, "A novel model-based measure for quality evaluation of image registration techniques in DCE-MRI" in IEEE 27th International Symposium on Computer-Based Medical Systems (CBMS), pp. 209-214, 27-29 May 2014, New York IEEE (2014)

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[8] Ojala, T., Pietikainen, M., Maenpaa, T.: Multiresolution gray-scale and rotation invariant texture classication with local binary patterns. IEEE Transactions on Pattern Analysis and Machine Intelligence 24, 971{987 (2002)

[9] Zhao, G., Pietikainen, M.: Dynamic texture recognition using local binary patterns with an application to facial expressions. IEEE Transactions on Pattern Analysis and Machine Intelligence 29, 915{928 (2007)

[10] G. Piantadosi, S. Marrone, M. Sansone, and C. Sansone, "A secure osirix plug-in for detecting suspicious lesions in breast DCE-MRI," in Algorithms and Architectures for Parallel Processing, 13th International Conference, ICA3PP 2013, pp. 217–224, Springer, (2013)

Products:

Conference proceedings

[11] G. Piantadosi, S. Marrone, R. Fusco, A. Petrillo, M. Sansone, and C. Sansone, ***"Data-driven selection of motion correction techniques in breast DCE-MRI"*** *in IEEE International Symposium on Medical Measurements and Applications (MeMeA), pp. 273-278, 07-09 May 2015, Torino, Italy, (2015).*

[12] G. Piantadosi, R. Fusco, A. Petrillo, M. Sansone, and C. Sansone, ***"LBP-TOP for Volume Lesion Classification in Breast DCE-MRI"****, in International Conference on Image Analysis and Processing (ICIAP), pp. 647-657, 07-11 Sep 2015, Genova, Italy, (2015).*

Jurnals

[13] G. Piantadosi, S. Marrone, M. Sansone, C. Sansone, **“A secure, scalable and versatile multi-layer client–server architecture for remote intelligent data processing”**, Journal of Reliable Intelligent Environments, vol. 1, no. 2-4, pp. 173-187, (2015).