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 – First Year

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

Università degli Studi di Napoli Federico II

Student

I graduated in Computer Engineering; currently, I am attending the first 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.

Sturdy Activities

Module	Type	Professor	Date	H	CFU
Theory and Applications of Piecewise Smooth Dynamical Sys.	Ad-Hoc	J. Hogan	16/06/2014	15	3
Corso di Euro Progettazione	Ad-Hoc	G. Varchetta	30/10/2014	15	3
Cambridge English: First Certificate in English (FCE)	MS-Mod	J. Parker (CLA)	28/11/2014	50	3
The Entrepreneurial Analysis of Engineering Research Projects	Ad-Hoc	L. Iandoli	20/02/2015	15	3
Grafica computazionale e laboratorio	MS-Mod	L. D'Amore	20/02/2015	48	6
Three core issues for the Internet: things, security and economics	Ad-Hoc	H. Schulzrinne	20/02/2015	8	2

Seminars	Type	Lecturer	Date	H	CFU
A Cloud-Based Collaborative Platform for Medical Research	Ext	S. Benkner	07/04/2014	2	0,4
High Performance Computing – Overview and State of the Art	Ext	S. Benkner	08/04/2014	2	0,4
Building Knowledge and Intelligence from Big Data	Ext	F. Xhafa	08/04/2014	2	0,4
Programming and Tuning Support for Future Parallel Systems	Ext	S. Benkner	09/04/2014	2	0,4
Modelling the process of data collection for Collective Intelligence	Ext	F. Xhafa	10/04/2014	2	0,4
Building Knowledge and Intelligence from Big Data Streams	Ext	F. Xhafa	14/04/2014	2	0,4
Image analysis and computer aided detection in screening	Ext	N. Karssemeijer	05/05/2014	2	0,4
High-dimensional pattern recognition via sparse representation	Int	A. Yang	04/06/2014	2	0,4
Control System Design Using Energy Properties of Physical Systems	Int	A. Donarie	23/06/2014	1	0,2
MISS2014 (Medical Imaging Summer School 2014)	Ext	Doctoral School	01/08/2014	24	4,8
Reliability and Availability Modelling in Practice	Int	K. Trivedi	05/11/2014	3	0,6
Capacity Planning for Infrastructure-as-a-Service Cloud	Int	K. Trivedi	07/11/2014	2	0,4
Developmental Robotics for Embodied Language Learning	Int	A. Cangelosi	10/10/2014	1+4	1
UML Profiles for the specification of non functional properties of sw.	Int	S. Bernardi	26/11/2014	2,5	0,5
Smoothed Particle Machine Perception: a proposed method for sensor fusion and physical-spacial perception	Int	N. Hockings	14/01/2015	1	0,2
Risk management meets model checking: fault tree analysis and model-based testing via games	Int	M. Stoelinga	20/01/2015	2	0,4
Joint location and design optimization for resource allocation in software defined virtual networks	Int	A.Tulillo e C.Sterle	21/01/2015	2	0,4
State of the art in Power Converters for High Voltage DC transmission systems	Int	P. Ladoux	28/01/2015	2	0,4
Efficient service distribution in next generation cloud networks	Int	A. Tulino	10/02/2015	4,5	0,9

	Credits Summary year 1							
	Est.	bimonth						Tot
		1	2	3	4	5	6	
Modules	26	0	3	0	3	3	11	20
Seminars	13	2,4	1	4,8	1	1,5	2,3	13
Research	21	7,6	6	5,2	6	5,5	0	30,3
	60	10	10	10	10	10	13,3	63,3

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]. It has demonstrated a great potential in screening of high-risk women, in staging newly diagnosed breast cancer patients and in assessing therapy effects [2] thanks to its minimal invasiveness and to the possibility to visualize 3D high resolution dynamic (functional) information not available with conventional RX imaging [3,4,5]. 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. It is worth noting that, while several works addressed so far the problem of automatically classifying breast lesions in DCE-MRI [5,8], the automatic detection of suspicious ROIs is still an open problem [6,7].

My research activity is mainly focused on develop a fully automated CAD system [14] that improve the literature proposal stated in [9]. My proposal (up to now) has been modelled as a series of successive refinements (fig. 1) applied on patient DCE-MRI images.

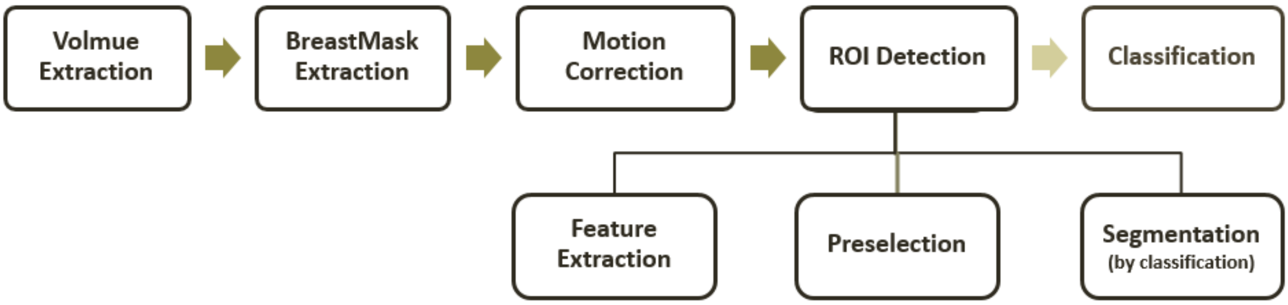

Fig.1: CAD proposal

Each step needs to be deeply investigated with the final aim of maximize the accuracy (with respect of a gold-standard provided by an expert radiologist).

- **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 Curse) 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 [10] 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 research activity to investigate which motion correction technique better fits the biomedical image registration problem. Moreover, as a product of my research activity, I suggest a novel quality measure for motion correction techniques (detailed later).
- **Region of Interest (ROI) Detection:** Segmentation of the breast parenchyma could be approached as a classification problem. To improve the classification results (with respect of 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…).

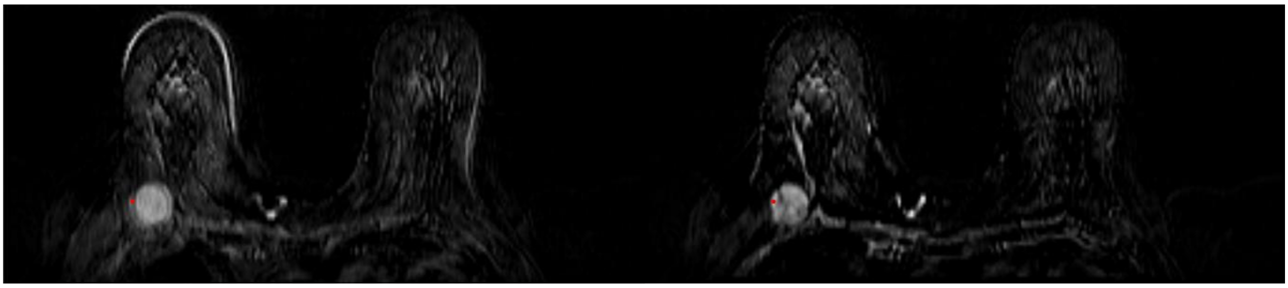

Fig.2: Sagittal view (by subtractive images) of a DCE-MRI volume before (left) and after (right) a 3D-FFD motion correction. In red the point later analysed.

As already said, in my research activity I focused on Motion Correction techniques. I investigate which motion correction technique better fits the biomedical image registration problem: a rigid motion correction provides a combination of affine transformations that include rotation, scaling, translation, and other affine transforms. However, these transformations are not able to adequately model soft tissues deformations, such as those of the breast parenchyma. Therefore, non-rigid or free-form-deformation (FFD) [11] transformations could be required. It is not always appropriate to use a sophisticated motion correction technique: I showed that a simple median filtering could be used assuming that small deformations can be considered as superimposed noise on a baseline image. It should be emphasised that most of existing techniques assume that voxel intensity remains constant while a spatial transformation occurs. In DCE-MRI data, on the contrary, both a spatial transformation and a variation of signal intensity due to contrast agent (CA) flow occur. This issue suggests that assessment of motion correction should be performed via a tracer-kinetics-aware approach.

I assess a novel model-based measure for quality evaluation of image registration techniques in breast DCE-MRI. That measure 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 [12]. The CA concentration Ct(t) has been calculated from the DCE-MRI data (Signal Intensity - SI(t)) using the approach presented in [13]. After registration, the DCE-MRI data were fitted to the kinetic model solving a non-linear curve-fitting problem in the non linear least-squares sense. By calculating squared 2-norm of the residual:

$$(Ct^{fitted}(t) - Ct^{measured}(t))^2$$

It is possible to obtain a goodness-of-fit (GOF) indicator. A better GOF (lower values) indicates a better motion correction (fig.3).

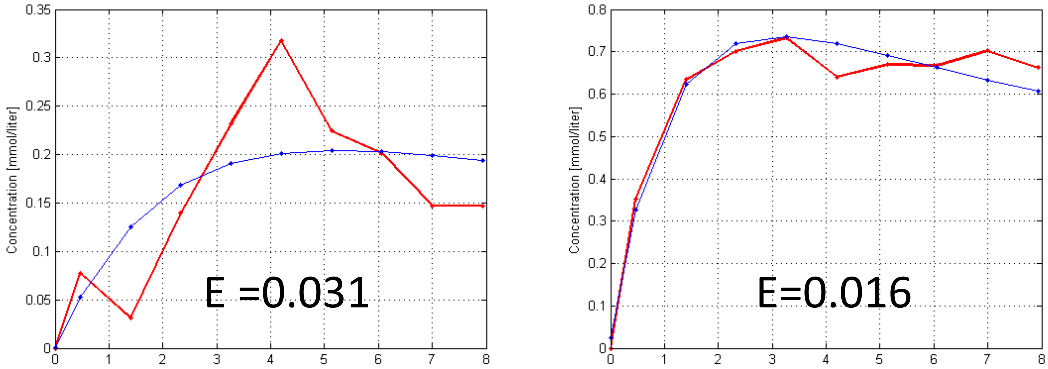

Fig.3: Fitting (blue) of DCE-MRI sampled data (red) before (on the left) and after (on the right) the motion correction effect (referred to Fig.2).

As far as the model underlying the novel metric, I investigate the Tofts-Kermode (TK) model [12], the Extended Tofts-Kermode (ETK) model [12] and the Hatyon-Brady (HB) model [16].

I am also investigating free-form deformation for motion correction techniques; by taking into account the contrast agent flow within tissues (by aim of the above models) is possible to improve the motion correction of artefacts into the soft tissues of breast.

Moreover, I also proposed a framework [15] for advanced medical image remote analysis in a secure and versatile client-server environment at a low cost.

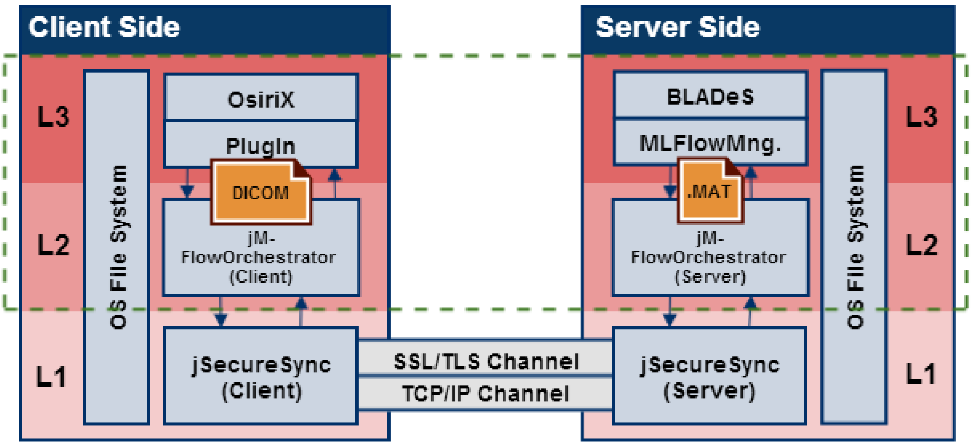

Fig.4: framework configuration in the specific context of DCE-MRI evaluation, by using OsiriX and the proposed CAD (Fig.1).

The framework (fig.4) 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. The procedure for authentication and authorization through certificates is achieved by means of Java services, using Java Authentication and Authorization Service (JAAS) classes.

- **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 [15] 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.

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] Olsen, O., et al.: Screening for breast cancer with mammography. Cochrane Database of Systematic Reviews CD001877 (2001)

[3] El-Kwae, et al.: Detection of Suspected Malignant Patterns in Three-Dimensional Magnetic Resonance Breast Images Journal of Digital Imaging (1998)

[4] Twellmann, T., et al.: Image fusion for dynamic contrast enhanced magnetic resonance imaging BioMedical Engineering OnLine (2004)

[5] Levman, et al.: Classification of dynamic contrast-enhanced magnetic resonance breast lesion by support vector machines. IEEE Transaction on Medical Imaging (2008)

[6] 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)

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

[8] Fusco, R., et al.: A Multiple Classifier System for Classification of Breast Lesions Using Dynamic and Morphological Features in DCE-MRI. SSPR \& SPR 2012, LNCS 7626, pp. 684–692, (2012)

[9] H.D. Cheng, at al.: Approaches for automated detection and classification of masses in mammogram. J. of Pattern Recognition Society (2005)

[10] 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)

[11] D. Rueckert, et al.: “Nonrigid registration using free-form deformations: application to breast mr images,” Medical Imaging, IEEE Transactions on, vol. 18, no. 8, pp. 712–721, (1999)

[12] P. S. Tofts: “Modeling tracer kinetics in dynamic gd-dtpa mr imaging”, Journal of Magnetic Resonance Imaging, vol. 7, no. 1, pp. 91–101, (1997)

[13] M. C. Schabel, et al.: “Pharmacokinetic mapping for lesion classification in dynamic breast mri,” Journal of Magnetic Resonance Imaging, vol. 31, no. 6, pp. 1371–1378, (2010)

[14] 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)

[15] 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)

[16] P. Hayton, M. Brady, L. Tarassenko and N. Moore: ”Analysis of dynamic MR breast images using a model of contrast enhancement'”, Medical Image Analysis 1(2), (1997)

Products

1. 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.
2. 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 2015), IEEE, 2015. [UNDER REVIEW]