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MARIE SKŁODOWSKA-CURIE ACTIONS

Individual Fellowships (IF)
Call: H2020-MSCA-IF-2016

PART B

"PREDICATE"

"comPuteR-aidEd diagnosis using Deep learning and radIomiCs for prostATE cancer"

This proposal is to be evaluated as:

Standard GF

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0 LIST OF PARTICIPANTS

Participants	Legal Entity Short Name	Academic	Non-academic	Country	Dept. / Division / Laboratory	Supervisor	Role of Partner Organisation
Beneficiary							
Universitat de Girona	UdG	✓		Spain	Computer Vision and Robotics Institute (Vi-COROB)	Dr. Robert Martí	
Partner Organisation							
Florida State University	FSU	✓		USA	Scientific Computing	Prof. A. Meyer-Baese	Host outgoing phase

Note that:

- Any inter-relationship between different participating institutions or individuals (e.g. family ties, shared premises or facilities, joint ownership, financial interest, overlapping staff or directors, etc.) must be declared and justified in this part of the proposal;
- The information in the table for non-academic beneficiaries must be based on current data, not projections;
- The data provided relating to the capacity of the participating institutions will be subject to verification during the Grant Agreement preparation phase.

1 EXCELLENCE

1.1 Quality and credibility of the research/innovation action

1.1.1 Introduction

In Europe, prostate cancer is reported to be the most frequently diagnosed cancer among men and thus one of the leading causes of death of cancer[1]. Currently, addressing this issue is a major public debate, where the implementation of appropriate screening methods and subsequent treatments is key. In this regard, the European Randomised Study of Screening for Prostate Cancer (ERSPC) is conducted to investigate the potential benefits of a population-based screening[2]. The screening consists of a Prostate-Specific Antigen (PSA) test and depending of the PSA level measured, an additional "blind" biopsy is carried out. Despite that mortality significantly has been decreasing, the employed screening strategy suffers of a high rate of over-diagnosis and over-treatment[3], and misses the more aggressive cancers in the Central Gland (CG). **Thus, additionally to cancer detection, the screening methods need to estimate the cancer aggressiveness to allow clinicians to act accordingly.**

In addition, the investigators of the ERSPC have concluded that the use of *"multi-parametric Magnetic Resonance Imaging (MRI) (mp-MRI) and the development of new markers are the hope for the future"*. That is why, Computer-Aided Diagnosis (CAD) systems, revolved around mono- and currently mp-MRI are developed by the medical imaging community, and have given rise to the field of **radiomics** consisting in automatically extracting large a number of quantitative features[4]. Recently, Lemaître *et al.* extensively reviewed the developed CAD systems for prostate cancer detection[5]. The developed CAD systems are designed under the same architecture composed of: (i) pre-processing, (ii) registration-segmentation, (iii) feature detection, (iv) feature extraction/selection, and (v) feature classification. The available MRI modalities during prostate exam are T_2-Weighted (T_2-W)-MRI, Dynamic Contrast-Enhanced (DCE)-MRI, Diffusion Weighted (DW)-MRI and the derived Apparent Diffusion Coefficient (ADC) map, and Magnetic Resonance Spectroscopy Imaging (MRSI). **Currently, no CAD system has been developed using all the available imaging modalities and taking into account the radiomics signature but they discarded their potential for discriminating power to diagnose prostate cancer.** The closest attempts have used three of these modalities and have discarded MRSI[6,7]. This latter, however, has been shown to be extremely helpful to grade cancer aggressiveness particularly in the CG[8], which is the most challenging zone in terms of cancer detection. **Furthermore, the current research mainly focus on the cancer delineation rather than on the cancer aggressiveness assessment.**

Therefore, the aim of this project is to design a CAD system able to both **detect and assess** prostate cancers using all currently available **mp-MRI** modalities and the **radiomics** paradigm, by analyzing different automated and traditional imaging features.

1.1.2 Research methodologies

Data acquisition: The unavailability of a public dataset in medical imaging is a major drawback. Currently, no mp-MRI prostate data are publicly available, implying that no fair comparisons can be drawn between the different developed CAD systems. Recently, Lemaître *et al.* have launched a beta web-platform[9] intended for reporting the evaluation of CAD systems. A mp-MRI dataset is made available, containing 60 patients and the following modalities: T_2-W-MRI, DW-MRI, DCE-MRI, and MRSI. Furthermore, the data are acquired from both 1.5 T and 3.0 T MRI scanner. Multiple ground-truths (i.e., prostate zones, cancer lesions) are compiled by experienced radiologists and additional biopsy tests. However, the web-platform needs to be completed before

[1] J. Ferlay et al. "Cancer incidence and mortality patterns in Europe: Estimates for 40 countries in 2012". In: *Eur. J. of Cancer* 49.6 (2013).

[2] F. H. Schroder et al. "Screening and prostate cancer mortality: results of the European Randomised Study of Screening for Prostate Cancer (ERSPC) at 13 years of follow-up". In: *The Lancet* 384.9959 (2015).

[3] C. Delpierre et al. "Life expectancy estimates as a key factor in over-treatment: the case of prostate cancer". In: *Cancer Epi.* 37.4 (2013).

[4] Philippe Lambin et al. "Radiomics: extracting more information from medical images using advanced feature analysis". In: *European journal of cancer* 48.4 (2012), pp. 441–446.

[5] G. Lemaître et al. "Computer-Aided Detection and Diagnosis for Prostate Cancer based on mono and multi-parametric MRI: A review". In: *Comp. in Bio. and Med.* 60 (2015).

[6] G. Litjens et al. "Computer-aided detection of prostate cancer in MRI". in: *Med. Imag., IEEE Trans. on* 33.5 (2014).

[7] S. Viswanath et al. "Enhanced multi-protocol analysis via intelligent supervised embedding (EMPrAvISE): detecting prostate cancer on multi-parametric MRI". in: *Proc. SPIE 7963, Med. Imag. 2011: Computer-Aided Diagnosis*. 2011.

[8] E. K. Vos et al. "Multiparametric Magnetic Resonance Imaging for Discriminating Low-Grade From High-Grade Prostate Cancer." In: *Inves. Rad.* (2015).

[9] `http://i2cvb.github.io/`

being made fully available. **Consequently, we will finalise the dataset and release it publicly through our web-platform.**

Pre-processing: MRI images are corrupted by different phenomena: (i) bias field, (ii) noise, and (iii) inter-patient variations. In this regard, particular attention to correct each of these drawbacks will be given. MRI images are affected by the inhomogeneity of the MRI field called bias field, resulting in a smooth variation of the intensities across each image. Although bias correction methods are commonly used to enhance brain MRI images, only one CAD system for prostate has reported to use such pre-processing[10], concluding that N3 algorithm[11] yields to better classification performance than other methods. Recently, Lin *et al.*[12] have proposed a method combining the N3 algorithm with the Fuzzy C-Means algorithm which outperforms the original methods, in terms of breast segmentation. **Therefore, we will compare these state-of-the-art methods, by ensuring the benefit of the method of Lin *et al.* for our specific application.** Apart from the bias field, MRI images are also degraded by a Rician noise. Similarly to bias correction, only two CAD systems have filtered the images using wavelet-based techniques[13,14], which offer a proper theoretical baseline for Rician corruption[15]. Non-Local Means-based denoising techniques have extensively and successively been used for other MRI applications, but never for MRI prostate images. **Thus, we will evaluate the Non-Local Means-based techniques[16] and wavelet-based technique to select the appropriate method for our application.** Lemaître *et al.* have developed a normalisation technique using the Rician properties of the MRI signal[17], which outperforms the previous methods for T_2-W-MRI images. Additionally, they have developed a method to standardized DCE-MRI data, showing the benefit when detecting prostate cancer in comparison with un-normalized data and quantitative methods. **Thus, we will extend this work to DW-MRI modalities and on larger cohort of patient to test the reliability of these methods.** MRSI is a modality related to one dimensional signal, and the enhancing techniques differ from the one used in MRI. The MRSI spectra have to be corrected for several phenomena: phase correction, water and lipid residuals filtering, baseline correction, frequency alignment, and normalisation. These enhancement techniques have been investigated by Lemaître *et al.* in a study focusing on the MRSI modality for prostate cancer detection[18]; **this knowledge will be the basis of MRSI enhancement.**

Segmentation: To achieve robust cancer detection, the classification has to be carried out only in the prostate area, motivating the need to perform a segmentation of the organ in the MRI images. Furthermore, as mentioned in Sect. 1.1.1, the *a-priori* membership of a voxel to belong to a zone (i.e., Peripheral Zone or CG) has a high potential to increase the performance to assess the aggressiveness of prostate cancer. Therefore, the prostate zones need to be segmented instead of solely the prostate organ. Previous segmentation methods only used T_2-W-MRI modality and sometimes ADC map. **Thus, we will design a hybrid system to segment the prostate zones, based on Convolutional Neural Networks (CNN) and Active Shape Models using all mp-MRI images.** The choice of CNN is motivated by the recent breakthrough of deep-learning in multiple fields of computer vision although it has still not been extensively used in the field of medical imaging.

Registration: In mp-MRI, the data are collected in a sequential manner, involving a possible misalignment between the different modalities. Mitra *et al.* developed an automatic multi-modal non-rigid registration method[19], which has been shown to outperform the state-of-the-art methods. This method has initially been used for registration between T_2-W-MRI and Ultra-Sound prostate images; **therefore, we will extend this method to align our mp-MRI dataset.**

Detection and assessment: Up to now, CAD developed systems have solely focused on the detection of

[10] S. Viswanath et al. "Integrating structural and functional imaging for computer assisted detection of prostate cancer on multi-protocol in vivo 3 Tesla MRI". in: *Proc. SPIE 7260, Med. Imag. 2009*. Vol. 7260. 2009.

[11] J. G. Sled et al. "A nonparametric method for automatic correction of intensity nonuniformity in MRI data". In: *Med. Imag., IEEE Trans on* 17.1 (1998).

[12] M. Lin et al. "A new bias field correction method combining N3 and FCM for improved segmentation of breast density on MRI". in: *Med. Phy.* 38.1 (2011).

[13] S. Mallat. *A wavelet tour of signal processing, Third Edition: The sparse way*. 3rd. Academic Press, 2008.

[14] A. Pizurica et al. "A versatile wavelet domain noise filtration technique for medical imaging". In: *Med. Imag., IEEE Trans in* 22.3 (2003).

[15] R.D. Nowak. "Wavelet-based Rician noise removal for magnetic resonance imaging". In: *Image Proc., IEEE Trans. on* 8.10 (1999).

[16] J. V. Manjón et al. "New methods for MRI denoising based on sparseness and self-similarity." In: *Med. Image Anal.* 16.1 (2012).

[17] G. Lemaitre et al. "Normalization of T2W-MRI Prostate Images using Rician a priori". In: *SPIE Medical Imaging*. 2016, pp. 978529–978529.

[18] G. Lemaître. "Absolute quantification at 3 T". MA thesis. Université de Bourgogne, Heriot-Watt University, Universitat de Girona, 2011.

[19] J. Mitra et al. "A spline-based non-linear diffeomorphism for multimodal prostate registration". In: *Med. Image Anal.* 16.6 (2012).

prostate cancers, omitting a real assessment of the lesion aggressiveness. Lemaître *et al.* have extensively reviewed research carried out in each of the classification stage for the development of CAD for prostate cancer[20]. The use of discriminative features is certainly key and most probably the bottleneck of CAD systems, justifying the attention given by researchers to evaluate a multitude of low- and high-level visual features, inspired by computer vision or human perception. Deep-learning has been recently shown to be one of the most successful machine learning techniques in broad types of classification tasks. CNN has the ability to generate automatically low- and high-level visual features in the network itself[21] by only supplying the raw data as inputs. Additionally, CNN might be considered as a good candidate to automatically generate large number of features, which can be later analyzed. Furthermore, CNN can be trained using the Gleason grade obtained through biopsy in order to get an assessment of the aggressiveness of the cancer. **Thus, we will detect and assess prostate cancers with CNN and validate the classifier using Receiver Operating Characteristic analysis. In addition, we will investigate the low- and high-level features to find potential new markers which can be used by clinicians or other machine learning methods as the basis to determine the radiomics signature of prostate cancer and implement it into the radiological reading as well as in automated screening.**

Evaluation using PI-RADS: The European Society of Urogenital Radiology together with the American College of Radiology have recently published the Prostate Imaging and Reporting and Data System (PI-RADS), which is the standard way to assess and report prostate lesions using mp-MRI. This standard allows to assign a score depending on multiple criteria (e.g., intensity, texture, size of lesion, modality, zones). None of the current CAD systems offer a PI-RADS score when detecting potential lesions in mp-MRI. **Thus, we will report the output of our classification framework in terms of PI-RADS score, applying the provided criterion.**

1.1.3 Originality and innovative aspects of the research programs

In response to the urgent needs that the medical community is facing, the principal investigators seek to address the grand challenge in the **early detection and accurate assessment** of prostate cancer by (i) developing an advanced CAD system based on novel image analysis and data mining techniques and **PI-RADS** scores, and (ii) evaluating and validating it in the clinical practise. Mining imaging features in a non-invasive and cost-effective way is known as **radiomics**. The central premise of this study is that these imaging features quantify phenotypic characteristics of the entire tumour and reflect the underlying gene and protein expression patterns. **Correct decoding of the radiomics signature of prostate cancer in mp-MRI may allow differentiation between lethal and non lethal prostate cancers in a non-invasive manner at the time of detection.** This project will revolutionize prostate cancer screening by increasing its efficacy and decreasing negative side effects. PREDICATE will serve as a blueprint for screening and diagnosis of other cancers.

1.1.4 Gender dimension

Concerning the **gender issues**, it is worth to mention that there exists a perfect balance between the supervisor's gender (female) of this project and the fellow.

1.2 Quality and appropriateness of the training and of the two way transfer of knowledge between the researcher and the host

The main objective of the present project is to establish a mutually beneficial partnership between the host institute, the Florida State University (FSU), the fellow and the beneficiary, the Universitat de Girona (UdG), with the goal to develop the **first mp-MRI CAD system** for prostate cancer detection and diagnosis. The proposed research will allow the fellow to continue gaining experience in his former research line, the design of mp-MRI CAD systems portable to many other cancers such as breast and brain. The fellow will gain expertise in developing intelligent CAD systems, novel pre-processing techniques to be applied to prostate images and integrated in the CAD system, and in cancer research in general.

Prof. Meyer-Baese's lab will benefit tremendously from the fellow's experience in mp-MRI data analysis and deep learning techniques applied to medical imaging. Furthermore, her lab will benefit from additional gender imaging techniques (prostate) brought in by the fellow, **in both research and teaching**. Both FSU and ViCOROB will definitely benefit from this project in the incoming phase, capitalising on the works carried out

[20] Lemaître et al., "Computer-Aided Detection and Diagnosis for Prostate Cancer based on mono and multi-parametric MRI: A review".

[21] M. D. Zeiler and R. Fergus. "Visualizing and Understanding Convolutional Networks". In: *CoRR* (2013).

for the last decade in the area of prostate cancer. The fellow will play an indispensable role in the group by: training new researchers, superivising PhD candidates and MSc students, attracting for funding, applying for new grants/projects, establishing collaborations with other groups, contacting industry related agents, strengthen hospitals and health services relations, participating in seminars, publishing papers, and attending to conferences.

By carrying out his fellowship in Prof. Meyer-Bease's lab, the fellow will gain complementary competences. Indeed, FSU currently offers a **postdoctoral seminar series** at which postdocs can present and receive feedback on their research, as well as courses in pedagogy, grants management, organizational behavior, and the structure of colleges and universities. FSU also has several certificate programs aimed at providing additional training to postdocs. For example, the **Postdoctoral Certificate Program in Research** offers coursework in research ethics, mentoring, and becoming an independent investigator, as well as traditional journal club and research training experiences. The host's department has two visiting professors in radiology, Prof. K. Pinker-Domenig and M. Lobbes, specialized in prostate research who have strong connections to **General Electric (GE), Philips, and Siemens**, which will help the fellow in the development of adequate CAD solution for clinicians. Furthermore, FSU hosts the famous and only in US **National High Magnetic Field Laboratory**, a nucleus for developing and translating radiogemics research. The close proximity of the **Lee-Moffitt-Cancer Center**, the biggest in the Southeast of US, and the strong ties to **MD Anderson** ensure an additional link to the cutting edge clinical research in prostate cancer. FSU has an **biannual Industry Day** where medical companies as well as PhD students and postdocs present their research and new research lines can be exchanged and established. The fellow will participate in the **Technology Commercialization Accelerator Program (TCAP)**, modelled on the successful National Science Foundation Innovation Corps (I-Corps), to help researchers commercialize the fruits of their research. FSU is an **affirmative action and equal opportunity** employer supporting a culturally diverse educational and work environment. It ensures a flexible working environment for both men and women, incorporating a parental policy and support for staff on career breaks.

At both FSU and UdG, G. Lemaître will participate actively in weekly group meetings discussing current literature, grant applications, manuscripts, and programming/algorithmic problems. Additionally, G. Lemaître will mentor PhD students together with Prof. A. Meyer-Baese and Dr. R. Martí. Prof. A. Meyer-Baese will also share her expertise in clinical domain: patient management; understanding cutting-edge medical methods and techniques; collaborating with physicians; radiological sources and MR images management; database management, storage and processing. The lab is integrated in the Department of Scientific Computing, the first of its kind in the US, and will provide the fellow with expertise and tools in **data simulation and statistical analysis**. He will learn from her to proactively advance an institution's diversity goals: **in recruitment and graduating under-represented students; and provided funds to support graduate student recruitment and taking advantage of all opportunities to increase the diversity of the student body.**

Finally, G. Lemaître is the perfect candidate for the challenge of transferring knowledge between two international institutions, as his experience during his joint-PhD at UdG and Université de Bourgogne attests.

1.3 Quality of the supervision and the integration in the team/institution

Qualifications and experience of the supervisor(s) Prof. Meyer-Baese is an internationally and nationally recognized expert in her field and has won many scientific prizes and awards. Her core research is at the frontier of medical sciences and engineering, supervising 1 Marie-Curie Fellow, 6 post-docs and 35 graduate students. She has an outstanding publication record including 3 research monographs published by MIT Press and Elsevier, and more than 180 refereed journal and peer-reviewed conference papers in her field. She is also an outstanding citizen of the scientific community and very active in the organization of conferences and workshops as a Chair, serves on the Editorial Board of journals and as the Editor in Chief on many Special Issues in medical imaging. She led over twenty funded research projects in her field with a total volume of $6,000,000. She worked interdisciplinary with the world-famous MD Anderson and Lee-Moffitt Cancer Center, and the National High Magnetic Field Laboratory in cancer research.

Dr. R. Martí obtained his PhD in 2002 in mammographic image analysis from the University of East Anglia, UK and is currently an assistant professor of ViCOROB. Furthermore, he has been successively involved in the supervision of 8 PhD students in the last 5 years showing his outstanding ability in research mentoring, publishing around 30 high-impact peer-reviewed journals and 80 international recognized conferences. His main research

interests are in the field of medical image analysis, specially focusing on feature extraction, pattern-recognition and image registration and its application to mammographic and prostate image analysis and CAD system. He has participated as a researcher or principal investigator in various research projects funded by the Spanish and Catalan Governments (SMARTER and Proscan), EPSRC (UK), and EU FP7 (ASSURE) with a total funding over 1,000,000 €. Additionally, he also has directed R&D contracts with companies for over 50,000 €.

Hosting arrangements Prof. A. Meyer-Baese and Dr. R. Martí have demonstrated their expertise in supervising researchers. They have also the endeavor, knowledge, experience, and commitment to be able to offer the candidate appropriate support to continuously progress and to review his research plans, as well as providing the necessary feedback mechanisms. They will act as excellent mentors for this project. At the start of the project, the fellow, the scientist in charge and the host institutions — UdG and FSU represented by the Research & Technology Transfer Office (OITT) and the Office of Postdoctoral Affairs — will sign an **Agreement** (as annex to the employment contract), ensuring that the terms of the Grant Agreement will be complied as regards to rights and obligations of the intellectual property resulting from the project, the payments, reports, and deliverables and corresponding deadlines, publications, and communications. Additionally, a personal **Career Development** plan will be agreed with the scientist in charge, the fellow, and the host institutions and will be revised annually. G. Lemaître will establish a structured and regular communication with both scientists and all the members of theirs research groups and collaborators, to take full advantage of the arising research opportunities between the groups. Furthermore, he will keep records at both institutions, FSU and UdG, of all work progress and research findings, obtaining feedback by means of reports, monthly seminars, applying such feedback, and working in accordance with agreed schedules, milestones, deliverables, and research outputs, described in Sect. 3.

In the outgoing phase, he will also have access to datasets from his home institution and computational/institutional resources, computer clusters for intensive computation provided by the host institution, and excellent facilities and experience in scientific studies aiming at the evaluation of CAD methods for prostate cancer. For the re-integration of the researcher, the host will reincorporate the researcher into ViCOROB, which is part of the *TECNIO* recognized by the Catalan Government which allows their researchers to advance their career in an entrepreneurial environment and to be more effective with their managerial skills. Indeed, they will gain new skills: teamwork, personal development, project management, and entrepreneurship. Additionally, the European R&D Programs Unit at the OITT at the host institution UdG will offer assistance and support with all the administrative, legal and financial aspects related to the management and execution of the project, including the financial reporting, according to the terms established in the Grant Agreement.

1.4 Capacity of the researcher to reach and re-enforce a position of professional maturity in research

G. Lemaître has demonstrated to be a young and very talented researcher of a highly promising career in biomedical research. He demonstrated a highly independent research profile at the early PhD level stage. He acquired a very in-depth knowledge in the new and challenging area of prostate cancer research and wrote the first state-of-the-art journal paper in CAD systems in mp-MRI. The fellow will gain additional expertise in medical imaging by acquiring new large data analysis techniques applied to **medical imaging not only applicable to prostate cancer but also to breast cancer research**. He will become an expert in **radiomics** in cancer research and by being exposed to molecular phenotype analysis techniques in her lab, he will refine his knowledge and translate it to **radiogenomics**, an important future cancer research area. It should be noted that only few medical imaging experts have bioinformatics data analysis skills and this will constitute for the fellow an important step for further professional development and will add together with the learned skills in grant and paper writing and in establishing new interdisciplinary collaborations/networks to the profile of a very independent researcher. His knowledge about the scientific- and business-related aspects of prostate CAD system, together with the career development plan as part of the fellowship, will allow him to become an attractive candidate for academia with a strong profile for grants acquisition. **The current proposal could lead to the development of the first commercial CAD system in Europe.** This excellent and unique opportunity will allow the fellow to re-enforce his entrepreneurial skill with the help of OITT. Furthermore, there will be a customized **Personal Career Development Plan** in place based on mutual agreement describing the mentoring scheme, the expected training and research contributions (publications, participation workshops), research management activities of NIH grants, anticipated networking opportunities and public engagement.

2 IMPACT

2.1 Enhancing the potential and future career prospects of the researcher

The Marie Skłodowska-Curie Actions Individual Fellowship will provide the fellow the opportunity to broaden his skills further, and acquire new ones, to contribute to his personal *Carrier Plan* of becoming a leading scientist in his field. The current research proposal will allow him to acquire **significant experience in the field of cancer CAD systems** a trending area in cancer research in which he would like to focus his future research career. He will have access and will be trained in cancer imaging techniques, mp-MRI, MRSI, PET/CT, as well as in the large data analysis of medical data sets, **radiomics and radiogenomics**. He will also become experienced in development and establishment of intelligent CAD systems, in which the host has pioneered.

Furthermore, the fellow will develop a **large scientific, clinician, and industrial network** through his fellowship. The Meyer-Baese lab is linked with the MD Anderson Cancer Center, the Lee-Moffitt Cancer Center, the Sloan Kettering Cancer Center and Dana-Farber Cancer Institute, all world-leading centers for excellence in cancer research. The laboratory has established academic collaborations with other laboratories within the US (e.g. Prof. B. Daniels at Stanford, A. Wismueller at Rochester, and A. Laine at Columbia) and in the EU (e.g. Prof. T. Hellbich and Prof. K. Pinker-Domenig in Vienna, N. Karssemijer in Nijmegen, and J. Wildberger and M. Lobbes in Maastricht). Finally, the lab regularly works with the non-academic sector to strengthen its projects, including pharmaceutical and biotechnological companies such as Siemens, GE, Philips, Screenpoint, and IM3D. In addition, it holds an excellent colloqium series with external, internationally renowned biomedical speakers, as well as special postdoc and graduate students seminar. During the development of the project, the fellow will be able to acquire skills other than those related directly to scientific training. Among these skills, those related to project management are especially important since they will enable him to develop his future career as an independent researcher. Writing and critical reviewing of grants and papers is another vital aspect of the additional training that will be implemented within this fellowship. The training activities presented in Sect. 1.4 to which the fellow will take part, are essential in the final part of the fellowship to analyze, publish the data, and shortly after he applies for positions and grants to continue his career.

2.2 Quality of the proposed measures to exploit and disseminate the action results

Dissemination of the research results The scientific community will clearly benefit from the PREDICATE project through the publication of results and methods in **high-impact and open access journals** to accelerate dissemination, uptake of results and enable possible exploitation. The project findings will be presented at the **weekly postdoc seminar and lab group series**. The project findings will be carefully analyzed, with the support of the host institution. Those not considered to be patented, exploited commercially and transferred, will be made available to the scientific community by participating in **high-impact peer-reviewed journal articles and conference**. Research results will be shared to the research and clinician communities by reporting results in adequate support. The different novelties of the proposed CAD system will be presented in IEEE Transactions on Medical Imaging (IEEE TMI) (D2.3 and D4.2) and Medical Image Analysis (MedIA) (D3.2) while the evaluation of the CAD will be published in the Journal of Magnetic Resonance Imaging (JMRI). The step-wise clinical evaluation of the CAD system will be reported jointly with the radiologists in European Radiology and Investigative Radiology. The fellow will also attend both technical and medical conferences such as MICCAI, IEEE ISBI, SPIE Medical Imaging, ECR, and RSNA presenting there the preliminary results from year one and two. For the publication of scientific papers it will be followed the institutional policy of UdG on "Open Access to scientific information and communication" approved on December 2011 and implemented starting with 2012. Therefore, the scientific publications will be either included in a institutional repository DUGi[22] which is compliant with OpenAIRE[23] or published in scientific journals with supporting "Open Access". Furthermore, pre-print version will be made available on arXiv and Zenodo platform[24]. Additionally, G. Lemaître will create a project home page for the software (C2) and report findings, publications, and access to research data by using the Zenodo platform, as previously done for his scientific research[25]. Before publication, research data will be

[22] http://dugi.udg.edu

[23] https://www.openaire.eu/

[24] https://zenodo.org/ - funded by CERN/OpenAIRE/EU H2020

[25] http://i2cvb.github.io/

anonymized and deidentified. Furthermore, coverage of essential results will be pursued on community internet sites for medical imaging professionals, such as MedicalPhysicsWeb and AuntMinnie. The fellow will participate in the **SC XSEDE Data Simulation and Modeling Contest**. It is the most advanced, powerful, and robust collection of integrated advanced digital resources and services in the world. It is a single virtual system that scientists can use to interactively share computing resources, data, and expertise.

Exploitation of results and intellectual property In about three years a direct knowledge utilization from the proposed research in form of a first prototype of a CAD for prostate cancer detection and diagnosis will emerge that could be tested in clinical routine. This project offers a **high probability that Intellectual Property (IP) of significant commercial value due to its novelty — by being the first comprehensive CAD for prostate cancer — and its translational research applications for example in breast cancer research**. The hosts, hereby FSU and UdG, in accordance with the "European Charter for Researchers", confirm that the researcher will secure the benefits of the exploitation (if any) of R&D results through legal protection and, in particular, through appropriate protection of IP rights, including copyrights. According to the host's practise, National Legislation and the recommendations of the European IPR Helpdesk[26], upon commencement of the fellowship, along with the researcher's Work Contract, a specific Agreement on Collaboration and IPR will also be prepared. This will specify: (i) the foreground and background intellectual property (e.g., materials, datasets, publications, patents, etc.) entailed and the relevant ownership and access rights of the researcher and the hosts; (ii) the identification and protection of results (including the allocation of a staff member to be an intellectual property rights manager, through the use of laboratory laboratory notebooks); (iii) the tackling of confidentiality issues (e.g., through Confidentiality Agreements, Non-Disclosure Agreements for yet-unprotected invention-patents-results); and (iv) the routes of further exploitation which for the PREDICATE project could lead the first comprehensive CAD system for prostate cancer.

2.3 Quality of the proposed measures to communicate the action activities to different target audiences

Communication and public engagement strategy of the action The topic and potential results of this project are important for the general public. G. Lemaître has experience in public engagement with research projects. On several occasions he presented his work to a very broad scientific and non-scientific audience. He contacted consumer groups to advocate for his research and draw the attention to early detection and diagnosis to a very deadly cancer among men. Prostate cancer is extremely prevalent among African Americans in the US and talking to these under-represented and under-privileged groups will be extremely beneficial for the large-scale dissemination of the research results achieved in this project. The **annual Computational XPosition** is the lab's vehicle to present its research result to members outside FSU. The project is planned to take advantage of the worldwide spreading possibilities of both languages (Spanish and English) and have a similar communication procedure through **FSU research news and FSU channel and Girona press channel**, media, scientific-spreading blogs, digital media (the applicant is an active user of Facebook and Twitter with a science-lover network of contacts), press and TV (Communication 1 (C1), see Gantt chart). In addition, the applicant plans to participate in **Open-Doors activities day and organized lab tours** to attract high-school students for interdisciplinary research and for the new direction scientific computing as well as publishing blog post to popularize the pattern recognition and medical aspects of his research.

3 QUALITY AND EFFICIENCY OF THE IMPLEMENTATION

3.1 Coherence and effectiveness of the work plan

The proposal is split into 7 work packages (WPx): **WP1**: Data acquisition and dissemination (duration of 5 months); **WP2**: Pre-processing (duration of 7 months); **WP3**: Segmentation (duration of 7 months); **WP4**: Registration (duration of 7 months); **WP5**: Detection and assessment (duration of 8 months); **WP6**: PI-RADS evaluation (duration of 2 months); **WP7**: Project management (duration of 36 months).

The following deliverables (Dx) will be released during the project: **D1.1** mp-MRI database and report with dataset presentation and online availability of the dataset; **D1.2** Submit to Grand-Challenge at MICCAI 2018, "Prostate detection and grading using mp-MRI"; **D2.1** Submit to ISBI 2018, "Empirical evaluation of bias

[26] https://www.iprhelpdesk.eu/

field correction methods for mp-MRI" & "Empirical evaluation of noise reduction methods for mp-MRI"; **D2.2** Submit to MICCAI 2018, "Normalisation techniques for mp-MRI"; **D2.3** Submit to IEEE TMI, "Pre-processing tools for mp-MRI"; **D2.4** Toolbox for mp-MRI images pre-processing; **D3.1** Submit to PROMISE12 challenge of results using only T_2-W-MRI; **D3.2** Submit to MedIA, "Zonal segmentation of the prostate using deep-learning and mp-MRI"; **D3.3** Toolbox for mp-MRI images segmentation; **D4.1** Submit to SPIE Medical Imaging 2019, "Prostate registration using mp-MRI and spline-based non-linear diffeomorphism"; **D4.2** Toolbox for mp-MRI images registration; **D5.1** Submit to IEEE TMI, "Prostate cancer detection and assessment using deep-learning and mp-MRI"; **D5.2** Toolbox for mp-MRI images classification; **D6.1** Submit to JMRI, "Evaluation of a prostate CAD systems using PI-RADS". **D6.2** Toolbox for PI-RADS grading.

To achieve the proposed goals, the following milestones (Mx) are defined: **M1.1** Availability of mp-MRI dataset; **M1.2** Availability of ground-truth and anonymization/deidentification of the mp-MRI dataset; **M2.1** Implementation and results of pre-processing tools for mp-MRI; **M3.1** Implementation of state-of-the-art segmentation methods; **M3.2** Implementation and results of segmentation for mp-MRI prostate; **M4.1** Implementation of state-of-the-art registration methods; **M4.2** Implementation and results of registration for mp-MRI prostate; **M5.1** Implementation of traditional features for classification of prostate cancer; **M5.2** Implementation and results of CNN-based classification for prostate cancer detection; **M6.1** Completion of the framework.

3.2 Appropriateness of the allocation of tasks and resources

Each work package are subdivided into tasks (Tx): The WP1 for "Data acquisition and dissemination" is dedicated to work together with clinicians to collect the prostate mp-MRI and generate the associated ground-truth (T1.1 - 3 months). In parallel, a web-platform will be developed to host source code and dataset (T1.2 - 4 months). Additionally, the dataset will be anonymized and deidentified such that it can be proposed as Open Data on our web-platform (T1.3 - 1 months) and for a Grand-Challenge (T1.4 - within 6 months). The WP2 for "Pre-processing" is dedicated to evaluate the bias correction algorithms on our public dataset (T2.1 - 2 months), denoising methods (T2.2 - 2 months), develop a normalization methods DW-MRI modality (T2.3 - 2 months), and study pre-processing method for MRSI (T2.4 - 1 months). The WP3 for "Segmentation" is dedicated to the design (T3.1 - 2 months), development (T3.2 - 3 months), and evaluation (T3.3 - 2 months) of an hybrid segmentation method on the public dataset. The WP4 for "Registration" is dedicated to extend the current registration method (T4.1 - 4 months) and validate this method on the public dataset (T4.2 - 2 months). The WP5 for "Detection and assessment" is dedicated to the design (T5.1 - 2 months), development (T5.2 - 4 months), and evaluation (T5.3 - 2 months) of a deep-learning based prostate cancer detection system as well as is evaluation on the public dataset. The WP6 for " PI-RADS evaluation" is dedicated to translate (T6.1 - 1 month) and develop (T6.2 - 1 month) the classification results to a PI-RADS evaluation. The WP7 for " Project management" is dedicated the management of the project which will be a regular follow-up during the full duration of the fellowship, involving the experienced supervisors, clinicians, and the fellow.

3.3 Appropriateness of the management structure and procedures, including quality management and risk management

Three major tools are in place to ensure timely progress of the project. First, **weekly meetings** with Prof. A. Meyer-Baese and/or Dr. R. Martí will take place in which the fellow will present the main achievements of his work. These meetings will be specially focused on addressing any difficulties found and working together to overcome them. These meetings will provide unique opportunities to exchange ideas and develop new ones to complete the project. The candidate will present a written deliverable to the supervisors at 5 (D1.1), 12 (D2.1-3), 18 (D3.2), 29 (D4.1), and 34 (D5.1) months outlining achieved objectives and planned research and training activities for the following period. Second, a **project plan** has been established to easily monitor and evaluate the project against deliverables and milestones. Finally, the **annual researchers evaluation** ensures that the project is developing smoothly. The fellow has to complete a Contribution Review Form[27] with short- and long-term objectives. The Executive Committee of the Department composed of professors in the fellow's area review this evaluation and ensure the project's objectives are met. The combination of these three processes guarantees that the fellow will not face difficulties that could potentially block the project.

[27] https://www.sc.fsu.edu/forms/facultyperformance

FSU has a dedicated research support office for fellowships, **FSU Research Foundation**, which oversees the financial management and administration of all fellowships grants and contracts stemming from non-federal money, and will ensure all financial and reporting arrangements are met. They have an extensive experience in administrating grants of more than $300 million dollars. FSU has participated in many FP7 projects and is hosting Marie Curie Fellowships. The university has developed specific guidelines and processes on Marie Curie Actions to ensure that the contractual and reporting requirements are fully met.

As part of the **risk management**, tasks that may represent an issue have been identified and alternative plans established. The previous experience of the applicant in applying his developed machine learning approaches to research lines ranging from prostate, brain and skin cancer to retinal diseases, and the collective endeavor of all involved scientists and their research groups along with the intensive experience of the hosts institutions in managing projects, are indicative of the feasibility of this project. Nevertheless, G. Lemaître is well aware of the importance of developing a contingency plan to minimize the risks and present a mitigation strategy to surmount the possible issues: **Risk 1(R1)** Potential problems: Insufficient number of cases. Probability: low. Alternative strategies: Consult with major cancer centers in US and Spain. Contingency plan: Meeting and consulting with prostate cancer specialists at the Lee-Moffitt Center in Tampa, Florida; **Risk 2 (R2)** Potential problems: Insufficient pre-processing results. Probability: medium. Alternative strategies: Joint segmentation and registration implementation based on optical flow and active contour model. Contingency plan: Meeting and consulting with researcher and image registration expert Joachim Weickert, Saarland University (Germany); **Risk 3 (R3)** Potential problems: Non-representative feature extraction and poor classification results. Probability: Very low. Alternative strategies and contingency plan: apply dynamic texture techniques for spatio-temporal feature extraction and employ gray-level run-length matrix (GRRL) and gray level intensity size zone matrix (GLISZ). This methodology has been a successful approach in different applications, and the applicant has the associated theoretical knowledge. Consider selecting Random Forest Trees as alternative classifiers. Meeting and consulting with data mining expert, Claudia Plant, head of the scientific computing research group in the Helmholtz Zentrum in Munich; **Risk 4 (R4)** Description: Insufficient number of companies interested in the software. Probability: low. Contingency plan: (i) Seek and arrange meetings with companies and the industry sector to show beta-version of the software at early stage. (ii) Schedule the meetings efficiently by not waiting until the last stage of the fellowship. (iii) Invite companies to monitor the development of the software. Thus, they could make recommendations in terms of interface and practical operation under an end user perspective. (iv) Request for support from OITT at the UdG, a service devoted to give advice on knowledge and technology transfer between university and industry.

3.4 Appropriateness of the institutional environment (infrastructure)

Florida State University According to Shaingai's ARWUA, FSU is between the 200 best universities worldwide. Its research infrastructure includes one of the largest high magnetic field laboratory worldwide, closely related to this project. (i) Institutional resources: One 7 T, two 3 T and two high-end 1.5 T MR scanners for image acquisition, (ii) Clinical resources: Excellent facilities and experience in scientific studies aiming at the evaluation of CAD methods for MR mammography, counting on the collaboration of Prof. Adrian Barbu, a computer scientist with expertise in CAD design. This aspect can be essential for documenting the real-world impact of research progress in the project w.r.t. practical health care. (iii) Workstation facilities: office space equipped with a desktop computer and network connections. In addition, designated visitor offices are available. The DSC also manages approximately 30 servers for core network services using primarily generic Intel-compatible servers running CENTOS. The lab hosts 5 international visiting Professors which trains many post-docs and has many federal, European and private foundations projects all in interdisciplinary medical imaging research.

ViCOROB is a research institute specialized in computer vision and robotics at UdG. The laboratories of ViCOROB are well-equipped with computers, servers, and specific software required for processing clinically data acquired. The Image Analysis Lab has recently been equipped with 2 high-performance servers (featuring 4 quad-core processors and 128 GB of RAM), a Totoku MS31i2 Diagnostic Displays system, and access to the use of CESCA facilities (the Supercomputing research center in Barcelona) which offers supercomputing shared-memory and distributed-memory machines suitable when dealing with such huge amount of data. Furthermore, the fellow will have access to a wide range of scientific journals and books via institution authentication.

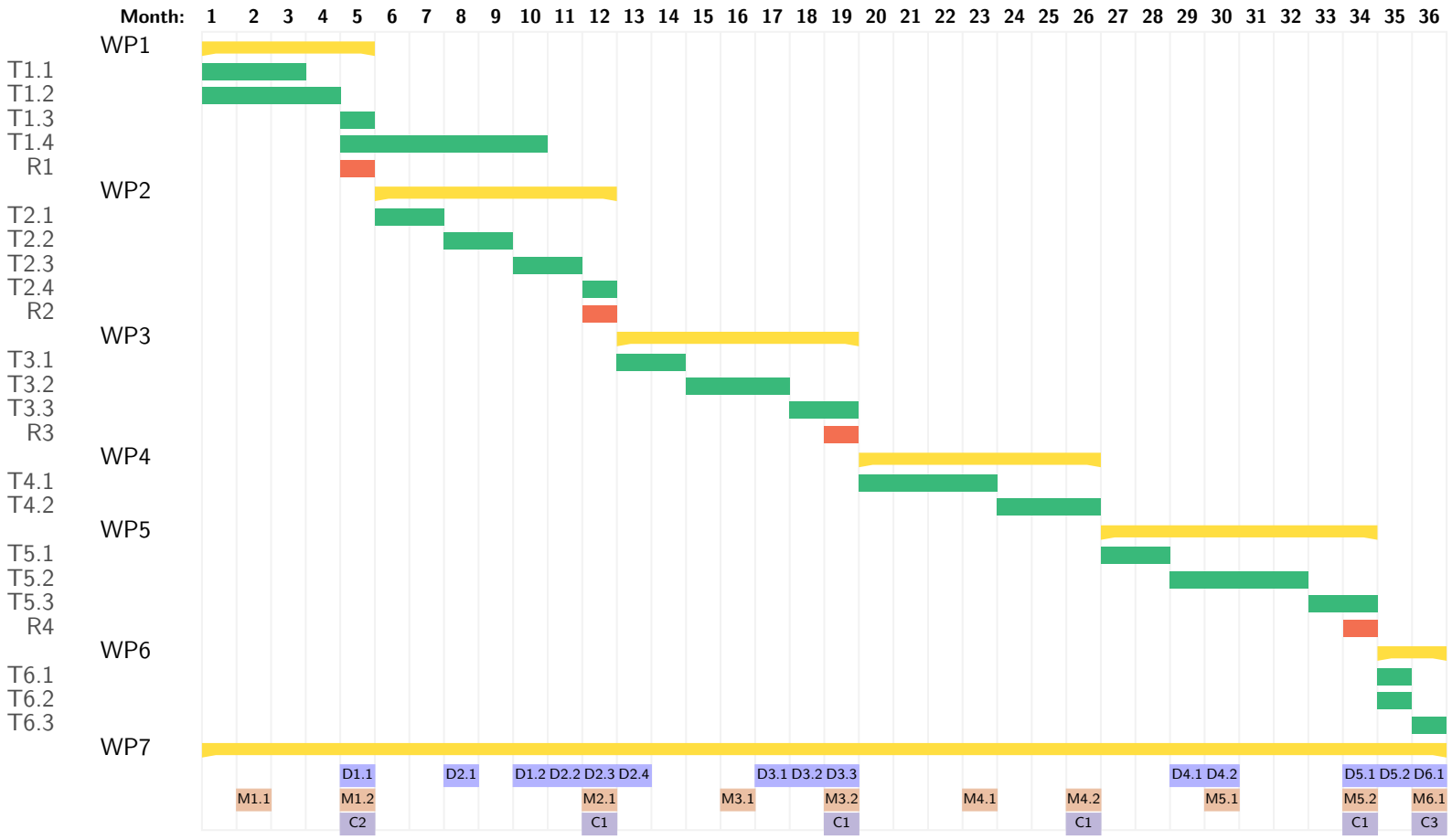

Figure 1: Gantt Chart of the proposal.

4 CV OF THE EXPERIENCED RESEARCHER

4.1 PERSONAL INFORMATION

Name: Guillaume Lemaître
Date of birth: 27th April 1988, 28 years old
Personal website: `https://sites.google.com/site/glemaitre58`

4.2 EDUCATION

07/2012 — 12/2016 **Co-joint PhD in Medical Imaging**
"Computer Aided Diagnosis system for prostatic biopsy guidance and follow-up fusing multi-modal imaging"
Supervised by Dr. R. Martí, Prof. F. Mériaudeau, Dr. J. Freixenet, and Dr. P. M. Walker
ViCOROB, Universitat de Girona — LE2I, Université de Bourgogne

09/2012 — 09/2014 **Master in Business Innovation and Technology Management**
"Valorisation of computerized technology in the health care sector"
Supervised by Dr. A. Bikfalvi and Dr. J. Llach
Universitat de Girona

09/2009 — 06/2011 **Master of Excellence Erasmus Mundus in Vision and Robotics**
"Absolute Quantification in 1H MRSI of the Prostate at 3.0 T"
Supervised by Dr. P. M. Walker
Université de Bourgogne, Universitat de Girona, Heriot-Watt University

09/2016 — 09/2009 **Bachelor Eng. Electronic, Signal, and Image**
Université de Bourgogne

4.3 WORKING EXPERIENCE

03/2015 — 03/2016 **Assistant professor (ATER)**
184 hours of lecturing in databases, pattern recognition, machine learning, software engineering, and image processing
Université de Bourgogne

06/2011 — 06/2012 **R&D researcher**
Barcelona Digital — ViCOROB, Universitat de Girona

4.4 FELLOWSHIPS

2012	**OMJ Grant**, Minitère Français des Affaires Etrangères et Européennes, France
2012	**FI-DGR PhD Grant**, Generalitat de Catalunya - AGAUR, Spain
2011	**Research Master Scholarship**, Burgundy Region, France
2010	**Erasmus Spanish Scholarship**, Spanish Ministry, Spain
2010	**Merit-based Scholarship**, French Ministry, France
2010	**Merit-based Scholarship dedicated to Research Masters**, Burgundy Region, France
2009	**Spanish Ministry Mobility Scholarship**, Spanish Ministry, Spain
2009	**Merit-based Scholarship**, French Ministry, France
2009	**Erasmus French Scholarship**, French Ministry, France
2009	**Mobility Grant**, Burgundy Region, France
2009	**Region Mobility Scholarship**, Burgundy Region, France
2009	**Rotary Scholarship**, Rotary Club Le Creusot, France
2009 — 2011	**Erasmus Mundus Grant**, Heriot-Watt University, Universitat de Girona, Université de Bourgogne, Scotland, Spain, France
2008	**Erasmus French Scholarship**, French Ministry, France
2008	**Mobility Grant**, Burgundy Region, France

4.5 AWARDS

July, 2008	**Student Autonomous Underwater Competition - Europe**, Nessie III - Heriot-Watt University
July, 2008	**THALES Special Award for innovation**, Nessie III - Heriot-Watt University

4.6 PARTICIPATION IN PUBLIC-FUNDED PROJECTS

- Temporal analysis and automatic detection of lesions in multi-modal images (IA-BioBreast)
- Identification of retinal diseases on OCT images (PHC MERLION)
- Erasmus+ educational project - Early Mastery `http://playfulcoding.udg.edu/teacher-guide/`

4.7 TEACHING

24 h **Medical Imaging: Segmentation and registration methods**
Master Erasmus Mundus ViBOT
Universitat de Girona

24 h **Pattern Recognition and Machine Learning**
Master Erasmus Mundus ViBOT, `https://github.com/ViBOT-Erasmus/B31XI-SI-Syllabus`
Université de Bourgogne

48 h **Introduction to image processing**
Master Erasmus Mundus ViBOT
Université de Bourgogne

16 h **Software engineering**
Master Erasmus Mundus ViBOT
Université de Bourgogne

74 h **Introduction to databases**
Bachelor of Electrical Engineering
Université de Bourgogne

4.8 COMMUNICATION

- Chair and actor in regular internal seminars at the Université de Bourgogne (RE-COOP)
- Chair of regular scientific reading groups
- Chair for Doctoral Day at the Université de Bourgogne (`http://le2i.github.io/doctoral-day-2015/`)

4.9 SUPERVISION

- Supervision of 1 MSc. student during his master thesis entitled "Automatic Classification Of SD-OCT Images"
- Supervision of 3 BSc. and MSc. students during their summer internships

4.10 OPEN SOURCE/DATA INITIATIVES

- Development of a reporting platform for code and data sharing in medical imaging `http://i2cvb.github.io/`
- Core developer of the `imbalanced-learn` toolbox part of `scikit-learn-contrib` project `https://github.com/scikit-learn-contrib/imbalanced-learn`

4.11 PUBLICATIONS

Peer-Review Journals Papers (8):

1. **K. Alsaih, G. Lemaitre, J. Massich, M. Rastgoo, D. Sidibe, and F. Meriaudeau**, "Machine Learning Techniques for DME Classification on SD-OCT images", *BioMedical Engineering OnLine*, Submitted.
2. **G. Lemaitre, R. Marti, M. Rastgoo, J. Massich, F. Freixenet, J. C. Vilanova, and F. Meriaudeau**, "Automatic prostate cancer detection through DCE-MRI images: all you need is a good normalization", *Medical Image Analysis*, Submitted.
3. **I. P. Houben, P. Van de Voorde, C. R. Jeukens, J. E. Wildberger, G. Lemaitre, I. A. Illan, A. Meyer-Baese, L. F. Kooreman, M. L. Smidt, and M. B. Lobbes**, "Contrast-enhanced spectral mammography as work-up tool in patients recalled from breast cancer screening: risks versus benefits", *European Radiology*, Submitted.
4. **G. Lemaitre, F. Nogueira, and C. Aridas**, "Imbalanced-learn: A Python Toolbox to Tackle the Curse of Imbalanced Datasets in Machine Learning", *Journal of Machine Learning Research*, Submitted.
5. **D. Sidibe, S. Sankar, G. Lemaitre, M. Rastgoo, J. Massich, C. Y. Cheung, G. S. Tan, D. Milea, E. Lamoureux, T. Y. Wong, and F. Meriaudeau**, "An anomaly detection approach for the identification of DME patients using spectral domain optical coherence tomography images", *Computer Methods and Programs in Biomedicine*, Submitted.
6. **G. Lemaitre, M. Rastgoo, J. Massich, C. Y. Cheung, T. Y. Wong, E. Lamoureux, D. Milea, F. Meriaudeau, and D. Sidibe**, "Classification of SD-OCT Volumes using Local Binary Patterns: Experimental Validation for DME detection", *Journal of Ophthalmology*, vol. 2016, Mai 2016.
7. **M. Belkacemi, C. Stolz, A. Mathieu, G. Lemaitre, J. Massich, and O. Aubreton**, "Non Destructive Testing based on a Scanning-From-Heating approach: Application to non-through Defect Detection and Fiber Orientation Assessment", *Journal of Electronic Imaging*, vol. 24(6), pp 1-8, Nov/Dec 2015.
8. **G. Lemaitre, R. Marti, J. Freixenet, J. C. Vilanova, P. M. Walker, and F. Meriaudeau**, "Computer-Aided Detection and Diagnosis for prostate cancer based on mono and multi-parametric MRI: A Review", *Computer in Biology and Medicine*, vol. 60, pp 8 - 31, 2015.

Peer-Review International Conferences Papers (18):

1. **J. Massich, M. Rastgoo, G. Lemaitre, C. Cheung, T. Y. Wong, D. Sidibe, and F. Meriaudeau**, "Classifying DME vs normal SD-OCT volumes: A review", *23rd International Conference on Pattern Recognition (ICPR) 2016*. Cancun: Mexico (December 2016).

2. **K. Alsaih, G. Lemaitre, J. Massich, M. Rastgoo, D. Sidibe, T. Y. Wong, E. Lamoureux, D. Milea, C. Leung, and F. Meriaudeau**, "Classification of SD-OCT volumes with multi-pyramids, LBP and HoG descriptors: Application to DME detection", *38th International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC) 2016*. Orlando: USA (August 2016).

3. **A. Pampouchidou, K. Marias, M. Tsiknakis, P. Simos, F. Yang, G. Lemaitre, and F. Meriaudeau**, "Video-based depression detection using local curvelet binary patterns in pairwise orthogonal planes", *38th International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC) 2016*. Orlando: USA (August 2016).

4. **S. Hoffmann, M. Lobbes, I. Houben, K. Pinker-Domenig, G. Wengert, B. Burgeth, U. Meyer-Baese, G. Lemaitre, and A. Meyer-Baese**, "Computer-aided diagnosis of diagnostically challenging lesions in breast MRI: a comparison between a radiomics and a feature-selective approach", *SPIE Commercial+ Scientific Sensing and Imaging*. Baltimore: USA (July 2016).

5. **M. Belkacemi, C. Stolz, A. Mathieu, G. Lemaitre, and O. Aubreton**, "A combined three-dimensional digitisation and subsurface defect detection data using active infrared thermography", *13th Quantitative Infrared Thermography Conference (QIRT)*. Gdansk: Poland (July 2016).

6. **M. Belkacemi, J. Massich, G. Lemaitre, C. Stolz, V. Daval, G. Pot, O. Aubreton, R. Collet, and F. Meriaudeau**, "Wood fiber orientation assessment based on punctual laser beam excitation: A preliminary study", *13th Quantitative Infrared Thermography Conference (QIRT)*. Gdansk: Poland (July 2016).

7. **M. Rastgoo, G. Lemaitre, J. Massich, O. Morel, F. Marzani, R. Garcia, and F. Meriaudeau**, "Study of Data Imbalancing for Melanoma Classification", *3rd International Conference on BIOIMAGING*. Rome: Italy (February 2016).

8. **G. Lemaitre, M. Rastgoo, J. Massich, J. C. Vilanova, P. M. Walker, J. Freixenet, A. Meyer-Baese, F. Meriaudeau, and R. Marti**, "Normalization of T2W-MRI prostate images using Rician a priori", *SPIE Medical Imaging 2016*. San Diego: USA (February 2016).

9. **M. Rastgoo, G. Lemaitre, O. Morel, J. Massich, F. Marzani, R. Garcia, and D. Sidibe**, "Classification of melanoma lesions using sparse coded features and random forests", *SPIE Medical Imaging 2016*. San Diego: USA (February 2016).

10. **A. Meyer-Baese, J. Massich, G. Lemaitre, and M. Rastgoo**, "Real-Time Optical Flow with Theoretically Justified Warping Applied to Medical Imaging", *Breast Image Analysis Workshop (BIA), Medical Image Computing and Computer Assisted Interventions (MICCAI) 2015*. Munich: Germany (Oct. 2015).

11. **J. Massich, G. Lemaitre, J. Marti and F. Meriaudeau**, "An Optimization Approach to Segment Breast Lesions in Ultra-Sound Images using Clinically Validated Visual Cues", *Breast Image Analysis Workshop (BIA), Medical Image Computing and Computer Assisted Interventions (MICCAI) 2015*. Munich: Germany (Oct. 2015).

12. **G. Lemaitre, M. Rastgoo, J. Massich, S. Sankar, F. Meriaudeau, and D. Sidibe**, "Classification of SD-OCT volumes with LBP: Application to DME detection", *Ophthalmic Medical Image Analysis Workshop (OMIA), Medical Image Computing and Computer Assisted Interventions (MICCAI) 2015*. Munich: Germany (Oct. 2015).

13. **J. Massich, G. Lemaitre, J. Marti, and F. Meriaudeau**, "Brest Ultra-Sound image Segmentation: an Optimization approach based on super-pixels and high-level descriptors", *International Conference on Quality Control and Artificial Vision (QCAV) 2015*. Le Creusot: France (Jun. 2015).

14. **G. Lemaitre, J. Massich, R. Marti, J. Freixenet, J. C. Vilanova, P. M. Walker, D. Sidibe, and F. Meriaudeau**, "A Boosting Approach for Prostate Cancer Detection using Multi-parametric MRI", *International Conference on Quality Control and Artificial Vision (QCAV) 2015*. Le Creusot: France (Jun. 2015).

15. **G. Lemaitre, A. Bikfalvi, J. Llach, J. Massich, and F. Julian**, "Business Model Design for University Technology Valorisation", *International Technology, Education and Development Conference (INTED) 2015*. Madrid: Spain (Mar. 2015).

16. **M. Rastgoo, G. Lemaitre, X. Rafael, F. Miralles, and P. Casale**, "Pruning AdaBoost for Continuous Sensors Mining Applications", *Ubiquitous Data Mining Workshop, 20th European Conference in Artificial Intelligence 2012*. Montpellier: France (Aug. 2012).

17. **G. Lemaitre, E. Vargiu, J.A. Lorenzo Fernandez, and F. Miralles**, "Real-Time 2D Face Detection and Features-based Tracking in Video", *IADIS Multi Conference in Computer Science in Computer Graphics, Visualization, Computer Vision and Image Processing 2012*. Lisbon: Portugal (Jul. 2012), 2012.

18. **J. Cartwright, N. Johnson, B. Davis, Z. Qiang, T.L. Bravo, A. Enoch, G. Lemaitre, H. Roth, and Y. Petillot**, "Nessie III Autonomous Underwater Vehicle for SAUC-E 2008", *The Unmanned Underwater Vehicle Showcase (UUVS)*, 2008.

Thesis (2):

1. **G. Lemaitre and P.M. Walker**, "Absolute Quantification in 1H MRSI of the Prostate at 3T", *Thesis for Master in Science Vision and roBOTic (ViBOT)*, 2011.

2. **G. Lemaitre, A. Bikfalvi, and J. Llach**, "Valorisation of Computerized Technology in the Health Care Sector", *Thesis for Master in Science Business Innovation and Technology Management (BITM)*, 2014.

5 CAPACITIES OF THE PARTICIPATING ORGANISATIONS

Beneficiary ViCOROB research institute (Universitat de Girona)

General Description	ViCOROB research institute belongs to the Department d'Aquitectura i Technologia de Computadors at the Universitat de Girona, a public university in Girona since 1992. ViCOROB is a research institute specialized in computer vision and robotics at UdG. In 2013, the UdG has rewarded ViCOROB by promoting the group into a Research Institute funded by the university itself. VICOROB has been always highly motivated to solve different and challenging societal problems and succeeded to obtain outside funding for solving them. The scientific results have been disseminated not only in form of peer-reviewed articles but also to the broad public audience by participating in several media events, speeches and published material. Three spin-off companies emerged: Coronis Computing SL, AQSENSE and BonesNotes.
Role and Commitment of key persons (supervisor)	Dr. Robert Martí, PhD, is associate professor in the Image Analysis Lab within ViCOROB. His main research interests are in the field of medical image analysis, specially focusing on feature extraction, pattern-recognition and image registration and its application to mammographic and prostate image analysis and CAD system.
Key Research Facilities, Infrastructure and Equipment	The laboratories of ViCOROB are well-equipped with computers, servers, and specific software required for processing clinically data acquired. The Image Analysis Lab has recently been equipped with 2 high-performance servers (featuring 4 quad-core processors and 128 GB of RAM), a Totoku MS31i2 Diagnostic Displays system, and access to the use of CESCA facilities (the Supercomputing research center in Barcelona) which offers supercomputing shared-memory and distributed-memory machines suitable when dealing with such huge amount of data.
Independent research premises?	Yes — 2 clusters with 32 nuclei for massive and parallel computing
Previous Involvement in Research and Training Programmes	During the last 3 years, UdG has coordinated 6 individual MCA and 2 Research Networks (RESKITCHLAB and CHEMEVE). In the last decade, the UdG has participated in more than 160 European projects. The following most noticeable research projects related to medical imaging have been developed at ViCOROB: Proscan (Help with location of prostate cancer) and M3CAD (Multi-modality and Multi-view Mammographic Computer Aided Diagnosis System)
Current involvement in Research and Training Programmes	UdG is currently coordinating an ITN action, SANITAS, and is participating as a full partner in ENDURE and ROBOACADEMY. Also, UdG is coordinating 3 IRSES actions (CANIOC, CLIMSEAS, and IREBD) and participating in one IAPP (PEP2BRAIN). Moreover, it is the main beneficiary of 8 individual Marie Curie actions. UdG is coordinating two Starting Grant projects (ERC) one Proof of Concept (ERC) and one COST action, among other participation, both as a partner and coordinator, in R&D European and national funded projects. Current projects under development in ViCOROB include: ASSURE (Adapting Breast Cancer Screening Strategy Using Personalised Risk Estimation), IA-BioBreast (temporal analysis and automatic detection of lesions in multimodal images). Furthermore, ViCOROB organises the Erasmus Mundus Master in Computer Vision and Robotics (Vibot) and the Erasmus+ Joint Master in Medical Imaging and Applications (MaIA).
Relevant Publications and/or research/innovation products	• **R. Martí et al.**, "Computer-Aided Detection and Diagnosis for prostate cancer based on mono and multi-parametric MRI: A review", *Computers in Biology and Medicine*, vol. 60, pp 8 - 31, 2015). [IF 1.475, Q2(41/85) B] • **R. Martí et al.**, "A supervised learning framework of statistical shape and probability priors for automatic prostate segmentation in ultrasound images", *Medical Image Analyis*, 7(6), pp 587-600, 2013. [IF 4.087, Q1(7/115) CSAI] • **R. Martí et al.**, "A spline-based diffeomorphism for prostate multimodal registration", *Medical Image Analyis*, 16(6), pp 1259-1279. 2012. [IF 4.087, Q1(7/115) CSAI] • **R. Martí et al.**, "A survey of prostate segmentation methodologies in ultrasound, magnetic resonance, and computed tomography images", *Computer Methods and Programs in Biomedicine*, 108(1), pp 262-287. 2012. [IF 1.555, Q1(21/100) CSTM] • **R. Martí et al.**, "Statistical shape and texture model of quadrature phase information for prostate segmentation", *International Journal of Computer Assisted Radiology and Surgery*, 7(1), pp 43-55, 2012. [IF 1.364, Q3(76/120) RNMMI]

Partner Organisation Florida State University

General Description	Florida State University (FSU)
Key Persons and Expertise (supervisor)	Anke Meyer-Baese, PhD, Professor at the Department of Scientific Computing in the FSU
Key Research facilities, infrastructure and equipment	National high magnetic field laboratory. FSU research foundation, multi-parametric MRI, MR scanners. Clinical resources, clusters for intensive computing.
Previous and Current Involvement in Research and Training Programmes	Prof. Anke Meyer-Baese led over twenty funded research projects (NSF, NIH) in her field with a total volume of six million dollars. Currently, she directs among others, a research project on CAD for breast cancer with NIH funding. Her interaction with students is exemplary: she directed 2 research professors, 1 Marie-Curie Fellow, 6 post-docs, over 35 graduated students, achieving teaching evaluations among the best at FSU, and attaining one of the highest students' retentions. Many of her former doctoral and postdoctoral students have obtained positions in academia.
Relevant Publications and/or research/innovation product	• **A. Meyer-Baese, V. J. Schmid**, "Pattern Recognition and Signal Analysis in Medical Imaging", *Elsevier* • **A. Meyer-Baese et al.**, "Global exponential stability of competitive neural networks with different time scales", *Neural Networks, IEEE Transactions on*, 14(3), pp 716-719 • **A. Meyer-Baese et al.**, "Comparison of two exploratory data analysis methods for fMRI: unsupervised clustering versus independent component analysis", *Information Technology in Biomedicine, IEEE Transactions on*, 9(3), pp 387-398

6 ETHICS ASPECTS

According to the article 8 of the Charter of Fundamental Rights of the European Union: "Everyone has the right to the protection of personal data concerning him or her". Concerning this fact, the present project has a potentially sensitive issue, as the collected data comes from real patients suffering prostate cancer. It is important to stress that the participants of the database are fully informed of the aims and uses of the MRI images, and a signature is required for consent. But more importantly, *no personal data is used or available* in this project, as every image is thoroughly anonymized before the data is transferred to processing for research.

7 LETTER OF COMMITMENT OF PARTNER ORGANISATION

FLORIDA STATE UNIVERSITY | *The* FSU RESEARCH FOUNDATION

2000 Levy Avenue, Suite 351
Tallahassee, Florida 32310
850.644.8650 • Fax 850.644.3658

September 9, 2015

The Marie Sklodowska-Curie Actions
in Horizon 2020

RE: H2020-MSCA-IF-2015
Project: "Deep-learning based multi-parametric MRI computer-aided diagnosis for prostate cancer (ProDeepCAD)"
Principal Investigator: Guillaume Lemaitre

This letter is to advise that the above-referenced project will be administered by the Florida State University Research Foundation, Inc., a direct support organization of Florida State University. The Research Foundation is a non-profit, educational corporation with an IRS 501(c) (3) designation.

Checks should be made payable to the FSU Research Foundation Inc. and sent to the following address:

The Florida State University Research Foundation, Inc.
2000 Levy Avenue, Suite 351
Tallahassee, FL 32310

Questions concerning administrative matters should be directed to Cathy Flynn, Grants Compliance Analyst, at (850) 644-2130 or via email at cflynn@fsu.edu.

Sincerely,

Cathy Flynn
Grant Compliance Analyst
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ENDPAGE

MARIE SKŁODOWSKA-CURIE ACTIONS

Individual Fellowships (IF)
Call: H2020-MSCA-IF-2016

PART B

"PREDICATE"

"comPuteR-aidEd diagnosis using Deep learning and radIomiCs for prostATE cancer"

This proposal is to be evaluated as:

[Standard GF]