Cardiofunxion

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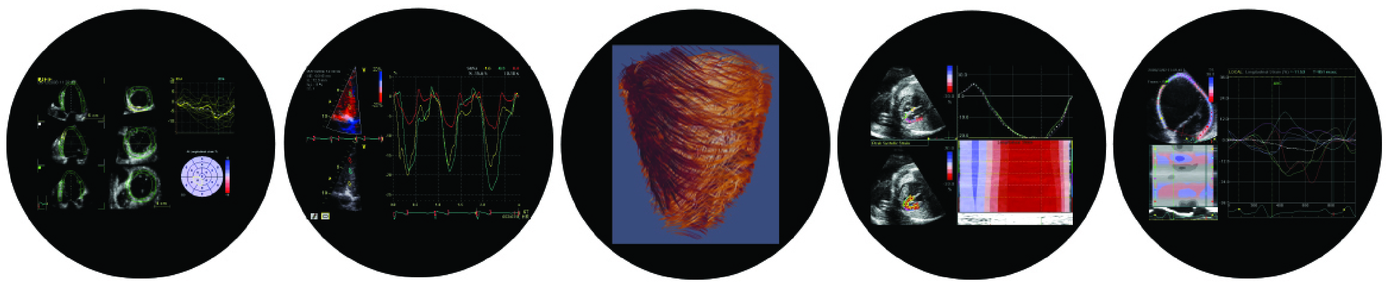
The project

Cardiovascular diseases remain the major cause of death, morbidity and loss of quality of life, and thus represent a top priority for EU research and innovation efforts.

In clinical routine, patients are examined with imaging modalities, whose output is transferred to proprietary workstations for extraction of clinical parameters, such as volumes, sizes and blood velocities. Findings are then summarized in free text to produce a final report for follow-up. Only the trained cardiologist is able to integrate clinical guidelines and physiological knowledge to support decision-making. On the other hand, the measurements taken into consideration depend on the workstation, raising the responsibility of the manufacturers as to include the latest technologies. Such developments are however often motivated by marketing.

Alternatively, an approach combining knowledge from **clinic, industry and academia** is necessary for the improvement of tool validation and result interpretation. Cardiofunxion establishes such a collaboration, with the aim of developing a framework for the assessment of cardiovascular diseases, combining imaging insights with physiological knowledge. For industrial, academic and clinical partners, this respectively entails the creation of workstations, contribution to the relevant algorithms and clinical validation.

Cardiofunxion is a Marie Curie industrial doctorate that offers 4 early-stage researchers the opportunity to contribute to the development of advanced techniques for the assessment of cardiovascular disorders.



Partners

PhySense, DTIC, UPF

UPF is the most productive university in Spain in research outcome and attraction of funds (THE2013) and 12th worldwide among young universities (THE2014, 100 under 50). DTIC conducts research in a broad range of fields, with participation in international programs (66 projects in FP7, including 9 ERC grants).

Philips Research France

PHILIPS Research Lab in Paris is an image processing competence centre with strong focus on clinical applications. PHILIPS pioneers 3D Ultrasound, being first to introduce a matrix probe. PHILIPS Research Medisys provided the first quantification tools for analyzing cardiac function on those images.

Institut de Investigacions Biomediques Agusti Pi i Sunyer

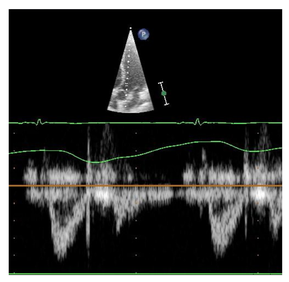
The research group on Cardiac Diseases at IDIBAPS envisages a multidisciplinary approach, including cardiologists specializing in electrophysiology, cardiac imaging, radiologists, bioengineers and biologists. It covers the entire spectrum of cardiovascular pathology, from basic studies to clinical research and therapy.

Centre Hospitalier et Universitaire de Caen

Caen university hospital is an academic hospital that reaches regional, national and international populations, with all medical and surgical activities, and affiliated to the University of South Normandy. In the field of cardiac care, it is a secondary and tertiary center for heart failure, cardiac surgery, cardiac resynchronisation therapy and heart transplantation since 1973.

ESR1 Longitudinal assessment of cardiac function

Cardiac stress is known to induce changes in hemodynamic parameters (e.g. blood pressure and flow) as well as mechanical changes in the left-ventricular wall dynamics (e.g. in motion and deformation). The nature and magnitude of such changes are expected to follow certain patterns for different types of stress and patient characteristics (e.g. age, sex). In the presence of cardiovascular pathologies, under-stress deviations from the typical stress-induced change patterns are expected.



In this context, we propose the implementation of a framework for cardiac function assessment, based on the quantification and integration of relevant variables (e.g. strain, velocities, volumes, heart rate, pressures) extracted from different channels of information – echocardiography, Doppler, electrocardiogram and pulse signals – and patient data, both at rest and under stress.

Current status: Initial phase of framework implementation.

ESR2 Fusion of heterogeneous measurements into a physiologically plausible patient representation

The aim of this project is the development of a consistent framework and representation of an individual heart, explicitly integrating measurement data, respective uncertainty and physiological knowledge, including mathematical models of the complete circulation. Such framework will allow not only for the description of individual patients but also for the detection of pathological patterns, by splitting measurement-based uncertainty from pathology induced variability. The tool will then be validated through the study of the influence of changes in ventricular size and contractility in hemodynamics.

ESR4 Novel approach for evidence based classification of heart failure etiologies

When deliberating a diagnosis or a therapeutic option, clinicians follow recommendations expressed in the form of sequences of decisions, or decision trees (DTs). Given the success of automated learning, can DTs algorithms help clinicians make decisions? What insights can be extracted in an clinically interpretable format?

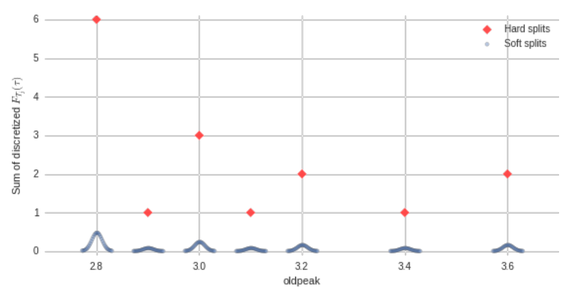
DTs are interpretability, handle all kinds of data and have low complexity. However, clinical data poses challenges such as little or missing data and uncertainty. E.g. left-ventricular ejection fraction measured through MR or ECG resulted in 28% of opposing eligibility outcomes for cardiac device therapy[1].

Decision trees for uncertain data

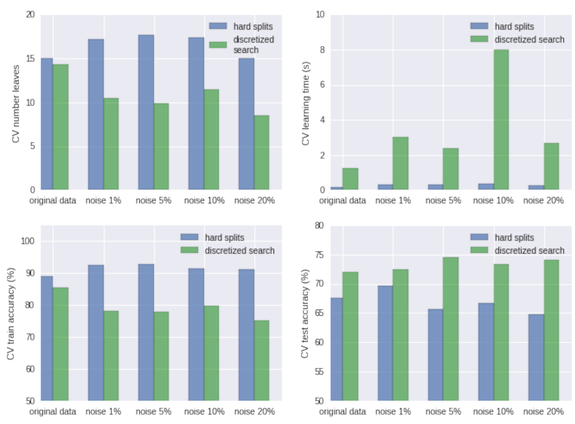
A soft-split DT was developed which accounts for data variability. An input variable X_j has uncertainty represented by normally-distributed variable $\mathcal{T}_j$, whose std $\sigma_{\mathcal{T}_j}$ represents the uncertainty. We set $\sigma_{\mathcal{T}_j} = u \times \bar{x}_j$, with u the **uncertainty factor** subject to investigation.

- The algorithm **improved accuracy** in heart-disease classification data, noisified with 1%, 5%, 10% and 20% noise factors.
- The optimal **u grew with the noise**: 0.02, 0.07, 0.08, 0.12 and 0.2.
- This was accompanied by a decrease in training accuracy, suggesting improved **generalizability**.

Ongoing work includes investigating the role of the model parameters, testing with more data, and applying the method to a clinical decision problem, such as the prediction of CRT response.



Uncertainty distribution computed by the DT.



Results: accuracy, tree size and learning time.

ESR3 Open reference database and tools for the multimodal validation of strain

Currently, few reference data has been disseminated to standardize heart motion and deformation algorithms. Segmentation is not trivial, synthetic or phantom data are currently of limited realism and in vivo techniques such as sonomicrometry are invasive procedures.

In this context, a new approach was recently proposed by Philips for the generation of ultrarealistic in silico data in 3D ultrasound. In this project, we will extend the current ultrasound approach to tagged MR. Both simulators will be integrated into a reference database and enriched with curated clinical data. Additionally, tools for the quantitative comparison of results from different cardiac motion and strain tools will be made available.

MARIE CURIE ACTIONS
THE FRAMEWORK PROGRAMME FOR RESEARCH AND INNOVATION HORIZON 2020