MeDiTATe project
Newsletter N°3 – July 2023

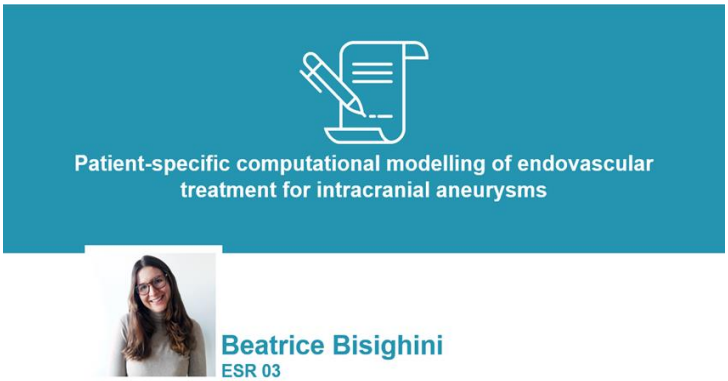
The MeDiTATe project aims to deliver new technologies targeted at industrial and clinical translation to accelerate the process of personalized cardiovascular medical procedures, validated through an integrated experimental programme to improve patient care.

This issue of the newsletter focuses on the main advancements of the MeDiTATe project achieved during the second trimester months of the 2023 where relevant research contributions with respect to the state of the art have been finalised by our 14 Early Stage Researchers in all the topics of the MeDiTATe project: 3D printing, advanced computational modelling, experimental activities and artificial intelligence. Several papers are already published, other are incoming in the second quarter of 2023. Some of our ESRs are concluding their PhD period and they are finalising their PhD Thesis. Please enjoy reading about the latest activities of our ESRs!

Scientific publications

"Patient-specific computational modelling of endovascular treatment for intracranial aneurysms"

Beatrice Bisighini (ESR 03), published the paper titled ***Patient-specific computational modelling of endovascular treatment for intracranial aneurysms*** in the **Brain Multiphysics Journal**.
The work was developed in collaboration with other authors including Stéphane Avril from **Mines Saint-Étienne** Research Coordinator of MeDiTATe project and PhD Supervisor of Beatrice Bisighini.
The paper, whose abstract is reported in the following lines, is available at this **link**.



Fast strain mapping in abdominal aortic aneurysm wall reveals heterogeneous patterns"

Marta Bracco (ESR 13) of the MeDiTATe project, published the paper ***"Fast strain mapping in abdominal aortic aneurysm wall reveals heterogeneous patterns"*** in the **Frontiers in Physiology** journal.
This work involved the collaboration of several authors from the MeDiTATe project including **Marco Evangelos Biancolini,** Principal Investigator of the MeDiTATe project, **Stéphane Avril,** Research Coordinator of MeDiTATe project and **Laurence Rouet** (Philips) Industrial Supervisor of the ESR 13.
The full paper is available at this **link**.

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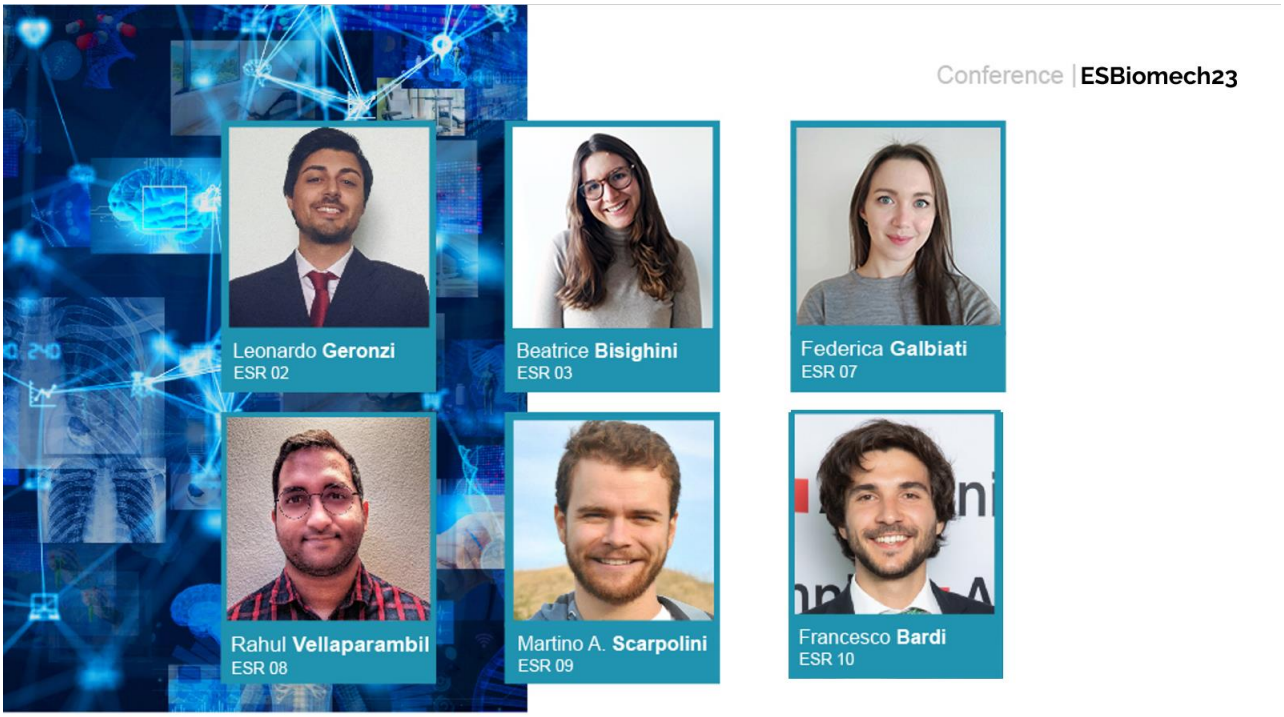
Events

ESBiomech23



The MeDiTATe project were present at the 28th Congress of the European Society of Biomechanics (ESBiomech23). The event took place in Maastricht, The Netherlands July 9 -12, 2023.

In this occasion six of our Early-Stage Researchers (ESRs) presented the results of their activities:

- **Leonardo Geronzi – ESR 02**: "*ASCENDING AORTIC ANEURYSM GROWTH PREDICTION BASED ON MACHINE LEARNING AND SHAPE FEATURES DERIVED FROM 3D SLICER" & "DEVELOPMENT OF DIGITAL TWINS FROM HIGH-FIDELITY SIMULATIONS FOR HEALTHCARE APPLICATIONS"*
- **Beatrice Bisighini – ESR 03**: "*MACHINE LEARNING-BASED REDUCED ORDER MODELLING FOR THE SIMULATION OF BRAIDED STENT DEPLOYMENT"*
- **Federica Galbiati – ESR 07**: "*ASSESSMENT OF THE COMBINED EFFECTS OF VALVE PHENOTYPE AND ANEURYSM PROGRESSION ON ATAA HEMODYNAMICS" & "AORTIC HEMODYNAMICS EVALUATION BASED ON REDUCED ORDER MODELS: EFFECT OF INLET CONDITIONS"*
- **Rahul Sathish Vellaparambil – ESR08**: "*STENT-GRAFTS DERIVED FROM AUXETIC UNIT CELLS: NUMERICAL SIMULATION OF DEPLOYMENT INTO A CURVED ARTERY"*
- **Martino Andrea Scarpolini – ESR 09**: "*DATA-DRIVEN FSI SIMULATION OF VENTRICLE AND AORTA INTEGRATING IN VIVO AND IN SILICO DATA" & "IMPLEMENTING DIGITAL TWINS OF THE CARDIOVASCULAR SYSTEM IN CLINICAL SETTINGS: AN AUTOMATED DEEP LEARNING PIPELINE"*
- **Francesco Bardi – ESR 10**: "*FSI COMPUTATIONAL MODEL OF A PATIENT SPECIFIC AAA VALIDATED BY LED ILLUMINATED PIV"*

More details **here.**

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Acknowledgements and results

Maria Nicole Antonuccio PhD thesis defense

At the end of May, Maria Nicole Antonuccio, ESR 14 of the MeDiTATe project successfully defended her phD thesis for the doctoral program "Engineering ad Biomechanics" at the **École des Mines de Saint-Étienne**. Her PhD thesis "*Hemodynamic characterization of abdominal aortic aneurysms using augmented ultrasound imaging*" was regarding the development of a new ultrasound-based to enrich the knowledge on local hemodynamics in patients with abdominal aortic aneurysm, thus supporting the clinical follow-up.

This is an important achievement for the MeDiTATe project, as she is the very first ESR completing the full path.

An acknowledgement for Leonardo Geronzi, ESR 02 of the MeDiTATe project

During the Summer Biomechanics, Bioengineering, and Biotransport Conference (SB3C) in Vail, Colorado (USA) **Leonardo Geronzi** ESR 02 of the MeDiTATe project was awarded as one of the two Runner-Ups for the talk 'Tuning of the mechanical boundary conditions parameters for a patient-specific thoracic aorta model'

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MeDiTAlks

An interview with Prof. Kyriakos C. Giannakoglou, Training Coordinator of the MeDiTATe project

We had a small talk with Prof. Kyriakos C. Giannakoglou, a member of the Board of the MeDiTATe project. He is a professor at the School of Mechanical Engineering of the National Technical University of Athens (NTUA) and head of the Parallel CFD & Optimization Unit of the same School. His research interests include the development of CFD-based analysis and optimization methods and tools in fluid mechanics, incl. adjoint & evolutionary algorithms, extended to multi-disciplinary applications (aerostructural, aerothermal, aeroacoustic). His research group has developed the publicly available continuous adjoint for shape optimization in the OpenFOAM environment. In MeDiTATe, he is supporting/training ESR 04, ESR 05 and ESR 06 to extend/adapt an existing CFD software on GPUs, coupled with a structural analysis tool, to simulate aneurysm-related flows, at reduced cost, as a part of a digital twin. He has participated in numerous projects funded directly by the industry, as well as the EU, including eight MSCA ITNs. He has supervised 29 PhDs (accomplished) whereas 10 more are in progress.

1. **The MeDiTATe project, a research proposal funded by the European Commission in the framework of Horizon 2020 programme. Can you tell us more about NTUA and its role in the project?**

Founded in 1837, the National Technical University of Athens (NTUA) is the oldest Technical University in Greece. NTUA participates into MeDiTATe through the Parallel CFD & Optimization Unit (PCOpt) of the School of Mechanical Engineering. The PCOpt/NTUA group comprises 15 research engineers developing, among other, CFD methods and software which are also ported onto HPC systems, including clusters of GPUs. For us, MeDiTATe was a great opportunity to see a portfolio of in-house tools being adapted to biomedical flows. The three ESRs associated with the PCOpt/NTUA had to use the in-house CFD code PUMA, written in C++/CUDA and accelerated on NVIDIA GPUs; next to PUMA, the three ESRs had also the chance to familiarize themselves with the open-access CFD software OpenFOAM; having access to two codes makes their life easier and gives them the possibility to make comparisons. Let me say a few things about the work of the three ESRs, one by one.
The objective of ESR 04 was to extend/integrate and use the CFD model to simulate the flow in aneurysms, assuming rigid walls, Newtonian and non-Newtonian fluids and variable viscosity. Flow computations using PUMA running on GPU clusters are fast, and this is challenging in the context of a digital twin. Studies are expected to lead to estimates of the aneurysm rupture risk, occurring when the

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stresses acting on the arterial wall exceed its failure strength. Next to them, Deep Neural Networks (DNNs) predict the failure points of the arterial wall, the origin and the progress of the aneurysms. ESR 05 extends the same background code to cope with moving walls, by incorporating a generic wall thickness model and Fluid-Structure Interaction (FSI) techniques. The structural problem within the solid region is solved using Finite Element Method (FEM) tools. A DNN is trained based on available real data to predict the cerebral aneurysm evolution and validate existing Fluid-Solid-Growth models of cerebral aneurysm evolution. Finally, the main objective of ESR 06 is to identify hemodynamic variables which are of greatest importance in aneurysm stabilization or rupture, through sensitivity studies. Uncertainty quantification (UQ) techniques are used for quantities of interest, such as the asymmetry metric, the saccular index, etc. The sensitivity of the simulation results changes in the input variable values are investigated. Shape imperfections and wall movement are realized by CAD-free techniques and a morphing/smoothing tool that adapts meshes to new boundary shapes.

2. **Let's talk about the idea behind MeDiTATe. The project received funding from the EU in the Framework of Horizon 2020 programme, therefore it is clear that the proposed approach meets the EU's ambition to exploit scientific research to improve the treatment of the cardiovascular diseases and patient care. In particular, how can the scientific community benefit from your work?**

The ultimate goal of the MeDiTATe network is the creation of Medical Digital Twins; to do so, several partners, from universities, research centres, hospitals and companies, with experience in the treatment of the cardiovascular diseases and patient care and numerical methods performing the solution of fluid problems interacting with the structural analysis of their vessels should join efforts; making these people work together was the first success of MeDiTATe. It is expected that the work done by the MeDiTATe ESRs will firstly lead to new findings in pure research and, then, will find its way in practical applications. The latter will be used to help scientists working for the treatment of cardiovascular diseases by offering state of the art tools for fast and accurate predictions, using simulations. Recall that the ultimate goal is to build a Medical Digital Twin.

3. **Is it really doable to adapt methods developed for different applications and use them for the MeDiTATe applications?**

The answer is definitely yes! For instance, the numerical simulation of the flow in blood vessels, including the more specific aneurysm studies, requires the availability of three tools: a CFD software for the analysis of flow patterns, a software for the structural analysis of the blood vessels walls (a FEM code) and, of course, a technique to make them cooperate by exchanging data, which is the so-called Fluid-Solid Interaction (FSI) technique. The literature is full of methods and tools developed for the accurate and efficient solution of all the above, developed in quite different application domains. As an example, FSI methods for use in aircraft applications are quite mature right now. With some add-ons that are really necessary if these methods are to be used in simulations, for instance, in aorta flows', such as the use of a non-Newtonian fluid, these methods can readily be ported in the field of biomedical flows. We should also keep in mind that the majority of software developed for other engineering applications is already adequately parallelized and runs on HPC systems including clusters of GPUs. It is obvious that the type of applications MeDiTATe is dealing with can readily profit of all previous developments and achievements. This is where the three ESRs associated with the PCOpt/NTUA contributed to.

4. **Professor Giannakoglou, the MeDiTATe project has almost reached the end. What are your thoughts on the achievements at this final stage of the project? Which skills do you think that the fellows will acquire at the end of this journey?**

It is much easier for me to talk about the ESRs who worked with me in this project and spent 50% of their time in the PCOpt/NTUA. Having already exposed themselves in both the academic and industrial environment, they have already seen both sides; this is valuable piece of information that might help them, in the near future, to made decisions about the future steps in their career. While approaching the end of their involvement in MeDiTATe, I feel they have already learned a lot about the tools needed for these applications; they became familiar with CFD methods for the analysis of fluid flows, with FEM for the structural analysis and their interaction; they have extensively used them in an HPC environment, got results and know how to interpret them. They became ready to use these tools, but also any other

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similar tool they might have access to, for application regarding studies of aneurysms in an effort to build a digital twin, absolutely useful to people involved in the health sector. It is important that the three ESRs of PCOpt/NTUA were Mechanical Engineers and MeDiTATe managed to bridge the gap between the way engineers and medical scientists are facing this kind of problems.

5. **Any message for our readers?**

If you are looking for a way to expose yourself simultaneously to the academic and non-academic sectors, if you wish to get high quality training on scientific/technical topics as well as transferable skills, if you are strongly interested in innovation and long-term employability, apply to a Marie Skłodowska-Curie Actions (MSCA) Innovative Training Network.

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