Advancing Personalized Healthcare with High-Performance Cloud Computing for the Living Heart Project

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1. Introduction

Major factors contributing to the acceleration of personalized healthcare in recent years come from advances in high-performance computing (HPC), data analytics, machine learning, and artificial intelligence, enabling scientists now to perform the most sophisticated simulations, in genomics, proteomics, and many other fields, using methods like genome analysis, molecular dynamics, and more general computer aided analysis methods widely applied and proven in other areas of scientific and engineering modelling.

To just select one, we demonstrate the impact of computer simulations on personalized health care and present a research project aiming at living heart simulations, which has recently been rewarded with several prestigious international awards.

"The Living Heart Project community has demonstrated the profound impact computational modeling will have on personalized medicine. HPC is essential to efficiently delivering on these benefits, as shown from the recent heart and brain simulations performed by Stanford University and the NIMHANS National Institute of Mental Health. While still at the R&D level, these projects provide a glimpse into what will be clinically possible in the near future."

Dr. Steve Levine, Sr. Director Life Sciences, Dassault Systèmes

2. Studying Personalized Drug-induced Arrhythmias of a Human Heart

Two years ago, during the Supercomputing Conference SC'17 in November in Denver, UberCloud – together with the Stanford Living Heart Project – won the Hyperion Research Award for Innovation Excellence, elected by the HPC User Forum Steering Committee. The Living Heart Project (LHP) team consisted of researchers from the Living Matter Laboratory at Stanford University, Hewlett Packard Enterprise and Intel (the sponsors), Dassault Systemes SIMULIA (for Abaqus 2017), Advania (providing HPC Cloud resources), and the UberCloud tech team for developing the Abaqus high-performance software container and integrating all software and hardware components into one seamless automated self-service cloud solution stack.

The Living Heart Project is uniting leading cardiovascular researchers, educators, medical device developers, regulatory agencies, and practicing cardiologists around the world on a shared mission to develop and validate highly accurate personalized digital human heart models. These models will establish a unified foundation for cardiovascular in silico medicine and serve as a common technology base for education and training, medical device design, testing, clinical diagnosis and regulatory science —creating an effective path for rapidly translating current and future cutting-edge innovations directly into improved patient care.

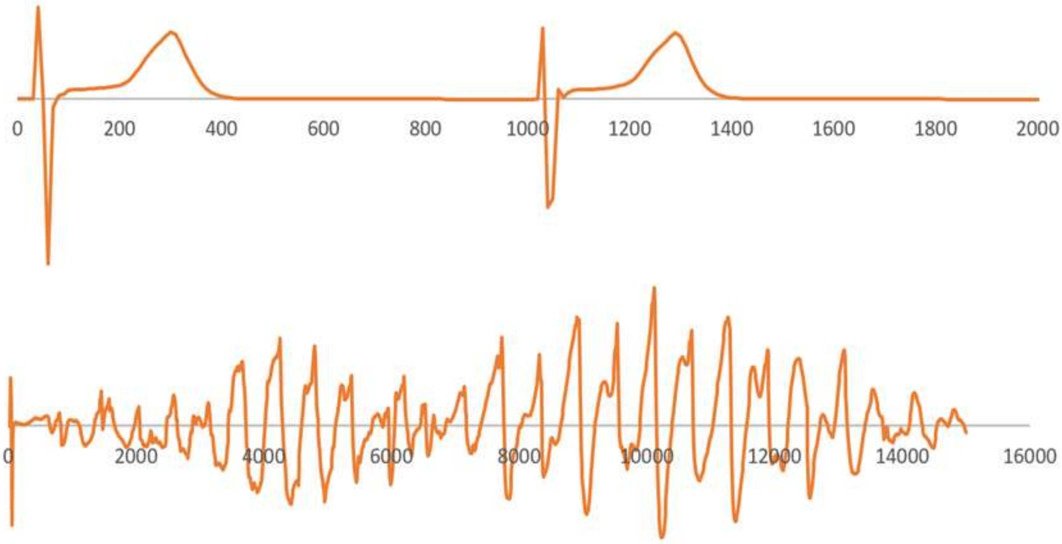

Figure 1 Electrocardiograms: tracing for a healthy, baseline case, versus the arrhythmic development after applying the drug Sotalol

This Stanford LHP project dealt with simulating cardiac arrhythmia which can be an undesirable and potentially lethal side effect of drugs. During this condition, the electrical activity of the heart turns chaotic, decimating its pumping function, thus diminishing the circulation of blood through the body. Some kind of cardiac arrhythmia, if not treated with a defibrillator, will cause death within minutes.

Before a new drug reaches the market, pharmaceutical companies need to check for the risk of inducing arrhythmias. Currently, this process takes years and involves costly animal and human studies. In this project, the Living Matter Laboratory of Stanford University developed a new software tool enabling drug developers to quickly assess the viability of a new compound. This means better and safer drugs reaching the market to improve patients' lives.

"The Living Heart Project has allowed us to perform virtual drug testing using realistic human heart models. For us, high-performance cloud computing and the close collaboration with UberCloud, HPE, Dassault Systèmes, and Advania, were critical to speed-up our simulations to identify the arrhythmic risk of existing and new drugs in the benefit of human health."

Prof. Ellen Kuhl, Head of Living Matter Laboratory at Stanford University

A computational model that is able to assess the response of new drug compounds rapidly and inexpensively is of great interest for pharmaceutical companies, doctors, and patients. Such a tool will increase the number of successful drugs that reach the market, while decreasing cost and time to develop them, and thus help hundreds of thousands of patients in the future. However, the creation of a suitable model requires taking a multiscale approach that is computationally expensive: the electrical activity of cells is modelled in high detail and resolved simultaneously in the entire heart. Due to the fast dynamics that occur in this problem, the spatial and temporal resolutions are highly demanding.

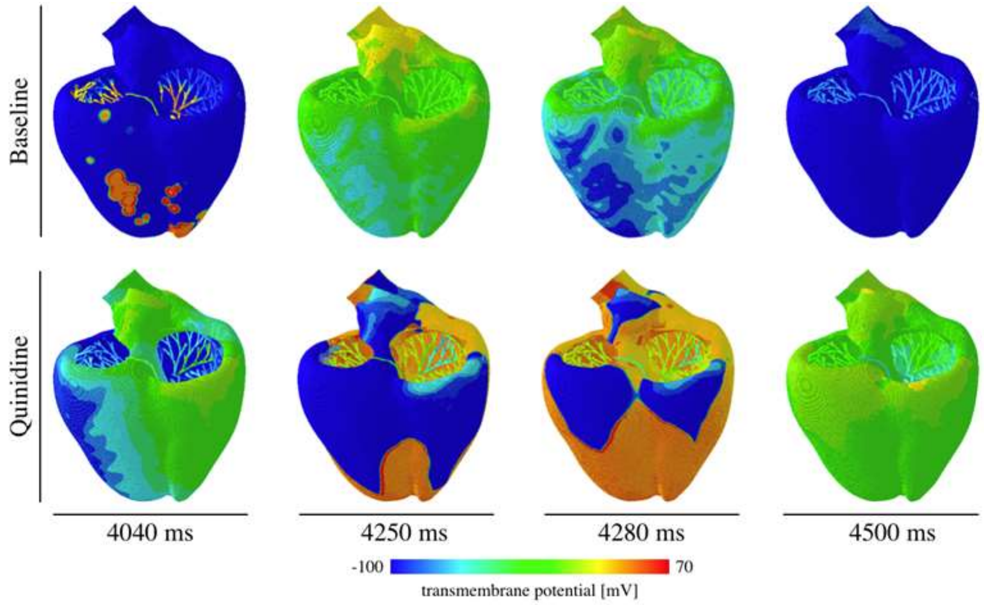

***Figure 2** Evolution of the electrical activity for the baseline case (no drug) and after the application of the drug Quinidine. The electrical propagation turns chaotic after the drug is applied, showing the high risk of Quinidine to produce arrhythmias*

3. Other Case Studies About Personalized Healthcare with High-Performance Cloud Computing

Over the last two years, we have been involved in additional projects concerning personalized healthcare, together with Dassault Systemes, demonstrating the great benefit of cloud and container technology. In addition to the one presented above (i.e. Studying Drug-induced Arrhythmias of a Human Heart with Abaqus), we have completed the following projects:
- HPC Cloud Simulation of Neuromodulation in Schizophrenia (NIMHANS)
- Simulation of a Personalized Left Atrial Appendage Occluder (PLAAO) Device (Admedes)
- Transcatheter Aortic Valve Implantation - Novel cloud computing simulations provide powerful decision support for developers and clinicians (Enmodes)

All four projects benefited from the availability of powerful high-performance cloud computing resources. Simulation times in all cases were drastically reduced, some from months to days, others from days to a few hours. Some of the problems were so large that they didn't fit into the users in-house computing system, thus being impossible to be solved in-house. Still, intentionally, we didn't use large supercomputers, but moderate HPC clusters (4 – 8 compute nodes) to realistically model the real scenarios for e.g. cardiovascular researchers, educators, medical device developers, and practicing cardiologists.

Please contact Wolfgang.Gentzsch@TheUberCloud.com if you are interested in the case studies.