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Calibration of an Electrophysiological Model of the Heart

Damien Lepiller

Projet ASCLEPIOS, INRIA Sophia-Antipolis, France
damien.lepiller@sophia.inria.fr

Abstract. This research work presents a 3D electrophysiological model of the heart ventricles and a simple method to calibrate it. The action potential propagation is simulated using Aliev & Panfilov on a realistic mesh provided by ECGSIM. The model is calibrated by browsing the parameters space and matching simulated action potential duration and depolarization speed with reference ones also measured thanks to ECGSIM activation times. The calibration makes it then possible to help medical diagnosis.

1 Introduction

The computational modeling of the human body has been of increasing interest in the last decades [1], as it has benefited from progresses in biology, physics and computer science. It is now possible to combine *in vivo* observations, *in vitro* experiments and *in silico* simulations.

Recent developments of medical imaging and electrophysiological measures in cardiology allow the realisation of realistic models of the heart which can be used to help diagnosis. There is an important litterature on the functional imaging and modeling of the heart [2, 3], and numerous models of electric propagation through the myocard have been developed [4–10]. However, only a few calibration methods have been proposed.

In this presentation, we describe a method to adjust the parameters of an integrated 3D model of the left and right ventricles of a patient heart. The model can then be used to detect a number of pathologies such as ischemia [11] or arythmia and to simulate the effects of therapeutic actions.

2 Model

Many of the functional models of the heart are designed to reproduce realistically manner the cardiac activity (especially ionic gates and concentrations), often leading to high computational costs and the manual tuning of a very large set of parameters. In our approach, we had rather select a model involving a limited number of parameters, based on Aliev & Panfilov [9]. Thus allowing the identification of the model parameters from clinical measurements on a specific patient by solving the inverse problem.

$$\begin{cases} \partial_t u = div(\mathbf{D}\nabla u) + \mathbf{k}u(1-u)(u-\mathbf{a}) - uz \\ \partial_t z = -\epsilon(\mathbf{k}u(u-\mathbf{a}-1) + z) \end{cases} \quad (1)$$

Whereas synthetic geometry of the heart are commonly used to compute the propagation of the depolarization wave, we choosed to use the mesh provided by ECGSIM, a program originaly designed to simulate ECG from depolarization and repolarization instants (activation times) on epicardium and endocardium [12]. Though this mesh is inapropriate for the finite elements calculations involved with our model (we had to refine and transform it from triangulation to tetrahedrization), it provides also activation times we use as reference for calibration.

3 Method

PDE (1) shows 3 parameters to adjust (in bold). Since we only have activation times at our disposal, not all three of them can be adjusted. We choose to calibrate a and k because they have an influence respectively on the action potential duration (apd) and on the depolarization speed (c), both measurable, and because k and scalar D cannot be adjusted at the same time due to observability considerations. Moreover, we are able to set D as a diffusion tensor.

It is well known that muscle fiber orientations vary across the myocardial wall from $+70°$ on the endocardium to $-70°$ on the epicardium. Fibre have an important impact on the behaviour of the depolarization wave as the action potential shifting is around 3 times faster in fiber direction than in radial directions. Therefore, we defined an analytical linear fiber model to set the diffusion tensor D on each vertex.

To adjust a, respectively k, we browse the parameter space (solving the direct problem with a different parameter value each time) to match reference apd, respectively c, measured thanks to ECGSIM activation times. The relation between a and apd, respectively k and c, is then approximated with a rational model and least square resolution. This method can be used one time for the entire mesh or one zone at a time (segmentation provided by AHA [13]) or on each vertex.

4 Results

We obtain very promising results on simulated apd (figure 1). But before getting the same quality on matching depolarization speed, several difficulties have to be tackled. The stability of the model with regard to its parameters in particular has to be studied precisely.

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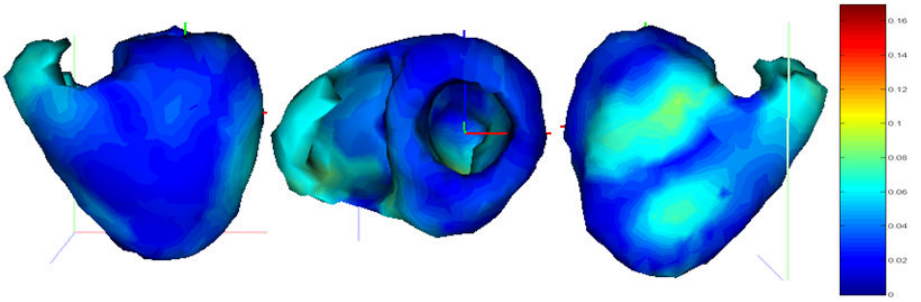

Fig. 1. Error map between simulated and reference apd (in seconds)

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Needs and Specification of a Meta-Protocol for Electronic Document Exchange

Nicolas Nobelis

Laboratoire I3S, Université de Nice - Sophia Antipolis et CNRS, France
nobelis@polytech.unice.fr

Abstract. With the expansion of the Information Society, we are coping everyday with electronic document transfer issues. Various *ad hoc* protocols have been developed for specific transfer properties or constraints. However, for a given electronic document transfer specification, how can users choose the most suitable protocol? We present a new architecture for electronic document transfer, where the system is able to select the best protocol among a protocols database.

1 Problem Statement

One of the most sensitive issues of our networked society is the transfer of electronic documents, which concerns everyone: individuals, corporations and public institutions. Individuals want, for instance, to exchange multimedia files, while a corporation may want to transfer a sensitive document between two departments and the public institution may be sending new procedures to its employees.

2 Various Needs, Several Protocols

People have various needs, which lead to several protocols designs. In order to design such a protocol, one has to answer many questions: how to be sure that only the recipient of the document will be able to open it? How to check the identity of this person? Should we receive something in exchange? If we are the recipient, should we accept a document from anyone? These questions can be summed up into several properties, such as Authenticity, Confidentiality, Non-repudiation, and so forth [1]. Much work has been done to develop protocols that suit the needs of different parties willing to exchange a document. For instance, several peer to peer (P2P) protocols have been developed for the needs of individuals, various others to cope with secure document transfer in corporate environments and multiple ones to deal with mass mailing in a public institution's Intranet.

Generally speaking, these protocols are dedicated to a single task: almost no one will use P2P software to exchange sensitive documents, and an individual usually doesn't need strong encryption and proof of receipt when sharing his holiday pictures. Users work in various environments (*e.g.* at home, at work, in an airport), use severals of these protocols, and thus choosing the most suitable one for a specific case isn't a simple task. Another issue is the fact that all these protocols have their own ways to manage identity, trust, and credentials.

3 Our Proposal: a Meta-Protocol for Electronic Document Exchange

The goal of our work is to design an exchange meta-protocol which is adaptive enough to choose the best solution for the needs of the entities involved in the transaction. This meta-protocol should be driven by policies and integrate a trust management engine [2]: indeed, in order to choose the best way to exchange an electronic document, one has to evaluate the amount of trust in each of the entities present in the system. Besides, the policy system allow us to specify Global Policies (which will be applied to each transfer) and Exchange-Specific Policies.

With these policies and with the quantification of the trust at a given time, one can weigh the pros and cons of the different protocols and select the transaction that best satisfies several properties simultaneously.

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Embedded System Design

Sébastien Bilavarn

Laboratoire I3S, Université de Nice - Sophia Antipolis, France
bilavarn@unice.fr

Abstract. This talk exposes research related to the design of embedded systems. It will first address a methodology that has been defined for the early design space exploration of HW/SW implementations. Second, an application study considering the constraints of media processing will be presented along with their impacts on embedded processor architectures.

1 Introduction

Consumer electronics evolves continuously towards increasingly complex system on chips. In a few years from now tens of programmable processors will be embedded in an IC with together over 100M transistors adding to the complexity of the problem of architecting such systems.The emerging complex and integrated heterogeneous embedded system platforms require adequate design methods able to efficiently model, explore, analyze and design the ever complex SW and HW architectures. Current design methodologies provide quite low-level abstraction capabilities. Future Embedded Systems design will need to adopt new methods and flows able to keep pace with the increasing complexity of design problems, in order to meet rapidly increasing performance requirements linked with a pressure to lower development cost and shorten time-to market. This talk presents an approach defined for the design of embedded systems and the corresponding framework developped. It will also present an application study to the enhancement of processor architectures for embedded multimedia.

2 Design Space Exploration

Until now, system level design flows still require many modifications of a specification before an actual implementation of a constraint compliant solution can be met (delay, power, throughput). Because of the diversity of implementation solutions and tools, it is difficult to predict a priori performance and space characteristics of the final design. For this reason, the refinement cycle is iterative and requires at each step manual application of transformations, synthesis, result analysis, and code re-writing to trade-off performance and space. This process is called design space exploration (DSE).

Assistance at this level can bring significant time savings. Methods have been studied and developed with this concern in a way to decorrelate exploration from implementation, at the beginning of the design process. A key element of this

methodology is the definition of abstraction layers that allow the systematic reuse of components at the system level driven by performance estimation and analysis. Investigations have already tackled the problem of hardware exploration and led to define a method that is able to target several FPGA families. The estimation methods combined with the design space exploration techniques are still under developement to allow the design process to consider complete HW/SW architectures in order to find out the optimal implementation in a shorter design time and at a lower global cost.

3 Processor Enhancements for Media Streaming

Multimedia is representative of the evolution of the design constraints. The generalisation of mobile terminals and telecommunication networks have led to the developement of applications and standards that require new embedded processor capabilities to cope with real time and low power execution (e.g. video coding). An aspect of the research conducted have tackled this and investigated the use of reconfigurable computing. Two directions have been explored. The first one is based on the design of a reconfigurable coprocessing unit dedicated to the acceleration of media applications. It defines a way to handle high parallelism instructions based on a concept of run time configurable instructions. The second one adresses the compilation problem considering the use of reconfigurable hardware to speed up high computing loop execution in multimedia algorithms. Issues are based on previous design space exploration techniques to automate an efficient parallelizaion of C/C++ code onto FPGA-like accelerators.

Notes

Les séminaires doctorants

Les séminaires des doctorants STIC permettent aux futurs docteurs d'échanger leurs expériences dans leur travail de thèse, tant sur le plan scientifique que sur le plan professionnel et éducatif. Ces rencontres ont lieu mensuellement dans l'un des laboratoires STIC de Sophia Antipolis.

Un séminaire est l'occasion de trois à quatre interventions, dont une effectuée par un jeune permanent. Chaque intervention comporte un exposé technique d'une vingtaine de minutes et une période d'échanges et de retours d'expérience d'une dizaine de minutes.

Ces actes compilent les résumés en anglais des exposés techniques du séminaire doctorant du 15 novembre 2006.

L'ADSTIC

L'ADSTIC est l'association des doctorants du campus sciences et techniques de l'information et de la communication de l'université de Nice Sophia Antipolis. Créée en 2004, l'ADSTIC est une association loi 1901.

Notre but essentiel est de faciliter les contacts entre les doctorants des différentes disciplines présentes sur le campus STIC, de les informer et de valoriser leur formation doctorale. L'ADSTIC se veut aussi un lien entre les doctorants passés, actuels et futurs...

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