

## Validation of a sequential data assimilation method applied to cardiac electrophysiology

Antoine Gérard, Annabelle Collin, Yves Coudière

### ▶ To cite this version:

Antoine Gérard, Annabelle Collin, Yves Coudière. Validation of a sequential data assimilation method applied to cardiac electrophysiology. Virtual Physiological Human conference, Sep 2018, Saragosse, Spain. hal-01955627

## HAL Id: hal-01955627 https://hal.inria.fr/hal-01955627

Submitted on 14 Dec 2018

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers. L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

# Validation of a sequential data assimilation method applied to cardiac electrophysiology

A. Gérard<sup>1,2,3\*</sup>, Y. Coudière<sup>1,2,3</sup>, Annabelle Collin<sup>1,4</sup>
<sup>1</sup>Univ. Bordeaux, IMB IMR 5251, Talence, F
<sup>2</sup>IHU Liryc, Fondation Bordeaux Université, Pessac, F
<sup>3</sup>Carmen Research team, Inria BSO, Talence, F
<sup>4</sup>Monc Research team, Inria BSO, Talence, F

\*Correspondence: antoine.gerard@inria.fr, 200 Avenue de la Vieille Tour, 33405 Talence

Improved electroanatomical recordings and imaging capabilities prompts for trying to personalize cardiac electrical models. Though it is challenging, data assimilation is a family of methods relevant to this problem. It consists in estimating the state of the system thanks to observations. Among the two main approaches, variationnal and sequential, we choose to investigate the possibilities of a sequential method based on an atrial model and atrial electroanatomical maps. The method combines a state observer and a Kalman filter to estimate some parameters in the model.

First, we simulate a sinus rythm coupled to different pacing scenarios using a validated realistic atria model, see [3], summarized as :

$$\begin{cases} A_m \left( C_m \frac{\partial u}{\partial t}^{(k)} + f(u^{(k)}, t) \right) - \operatorname{div}(\sigma^{(k)} u^{(k)}) \\ &= (-1)^k \gamma(u^{(1)} - u^{(2)}) \qquad (1) \\ \frac{\partial w}{\partial t}^{(k)} &= g_{CRN}(u^{(k)}, w^{(k)}) \end{cases}$$

The anatomical geometry was segmented from clinical MRI, while the electrophysiology is based on the Courtemanche ionic model and monodomain equations on coupled surfaces (endo and epicardum, labeled k = 1, 2) so as to efficiently represent transmural effects. Activation times were then recorded in the left atria, and provide a number of *in silico* electroanatomical maps.

For the data assimilation work, these maps are projected on a coarser mesh of the left atria only. We applied to a simpler monodomain model the Luenberger observer devised by A. Collin & al. [2]. In addition the conductivity parameters were estimated using a Reduced-order-Unscented-Kalman-Filter (RoUKF) [4] in order for the simplified model to fit the recorder maps. Eq. 2 states both the observer and the filter :

$$\begin{cases} A_m \left( C_m \frac{\partial \tilde{u}}{\partial t} + f(\tilde{u}, t) \right) - \operatorname{div}(\sigma \nabla \tilde{u}) = \mathscr{G}_L(z, \tilde{u}) \\ \frac{\partial w}{\partial t} + g_{MS}(\tilde{u}, w) = 0 \\ \dot{\theta}(t) = G_{\theta}(D(z, \tilde{u})) \end{cases}$$
(2)

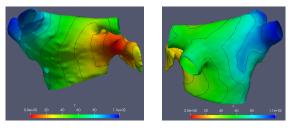


FIGURE 1 - Reconstructed activation map

Firstly, we tried to estimate a unique parameter  $\alpha$  such that the conductivity tensor  $\sigma = \alpha$  Id is isotropic. Secondly, we tried to estimate two conductivities parameters  $g_l$  and  $g_t$  such that the conductivity tensor is  $\sigma(x) = g_t \operatorname{Id} + (g_l - g_t) f(x) \otimes f(x)$ , where the unit vector f(x) points towards the fiber direction.

In order to validate the data assimilation technique, we compared the activation maps coming from a monodomain simulation with estimated parameters, to the originally recorder activations maps.

All simulations were done using Verdandi library [1] developed by M3DISIM Research team and the software CEPS developed by Carmen Research team.

### Références

- 1. D. Chapelle, M. Fragu, V. Mallet, and P. Moireau. *Medical & Biological Eng & Computing*, pages 1–13, 2012.
- A. Collin, D. Chapelle, and P. Moireau. Journal of Computational Physics, 300 :288–307, 2015.
- Simon Labarthe, Jason Bayer, Yves Coudière, Jacques Henry, Hubert Cochet, Pierre Jaïs, and Edward Vigmond. *Europace*, 16(suppl 4) :iv21–iv29, 2014.
- P. Moireau and D. Chapelle. ESAIM : Control, Optimisation and Calculus of Variations, 17(2):380– 405, 2011.

#### **Aknowledgments :**

The authors would like to thanks Inria research team M3DISIM for their help with Verdandi software. This study recieved financial support from the French program managed by the ANR, Grant reference ANR-10-IAHU-04.

Proceedings of the V Virtual Physiological Human conference: 5-7 September 2018, Zaragoza, Spain