Complex excitation patterns in the heart: from phase analysis to phase dynamics

A Data Management Plan created using DMPonline.be

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Project abstract:

The mechanical contraction of the heart is triggered by non-linear waves of electrical depolarization. The electrical signals are generated at the cell membrane level, and their collective behavior at the mesoscale will determine normal or abnormal heart rhythm. The bridging across spatial scales is usually performed by massive numerical simulation of a large set of coupled non-linear PDEs. However, the precise non-linear terms herein will differ between and even within hearts. The exact form and parameters of the classical equations for a given patient are currently impossible to find.

We propose instead a minimal phenomenological model based on the typical excitation cycle and memory effects. A phase-amplitude representation of the state-space manifold produces a Ginzburg-Landau style phase equation, which can be truncated at any desired order. The new model will be fit to in-silico models and recordings of excitation patterns. Symbolic regression is used to validate it against, or extend towards, measured patterns. Difficult regimes such as alternans and afterdepolarizations are considered. Then, I turn to a sparse representation of spatial inhomogeneities (e.g. infarcts) typical for arrhythmogenic regions in the heart. Finally, I address quantitatively fundamental questions such as: which local or collective mechanism is driving a given recorded arrhythmia? What is the maximal prediction time in a simulation? How far is a measured sample away from an arrhythmic event?

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1. Research Data Summary

List and describe all datasets or research materials that you plan to generate/collect or reuse during your research project. For each dataset or data type (observational, experimental etc.), provide a short name & description (sufficient for yourself to know what data it is about), indicate whether the data are newly generated/collected or reused, digital or physical, also indicate the type of the data (the kind of content), its technical format (file extension), and an estimate of the upper limit of the volume of the data.

				Only for digital data	Only for digital data	Only for digital data	Only for physical data
Dataset Name	Description	New or reused	Digital or Physical	Digital Data Type	Digital Data format	Digital data volume (MB/GB/TB)	Physical volume
		Please choose from the following options: • Generate new data • Reuse existing data	*Please choose from the following options:* • Digital • Physical	*Please choose from the following options:* • Observational • Experimental • Compiled/aggregated data • Simulation data • Software • Other • NA	*Please choose from the following options:* • .por, .xml, .tab, .csv,.pdf, .txt, .rtf, .dwg, .gml, … • NA	*Please choose from the following options:* • <100MB • <1GB • <100GB • <1TB • <5TB • <10TB • <50TB • >50TB • NA	
ithildin data	Simulation data for numerical confirmation of theoretical derivations, using own software ithildin	Generate new data	Digital	Simulation data	.npy .yaml .csv	<10 GB	/
openCARP data	Simulation data for numerical confirmation of theoretical derivation, using open source library openCARP	Generate new data	Digital	Simulation data	Custom data types for library	1 mesh = +- 300 MB 1 simulation = +- 13GB So in total < 10 TB	/
Leiden data	Experimental data from Pijnappel's lab: optical voltage mapping of human immortalized cardiac cells	Reuse existing data	Digital	Experimental	binary data	1 file = up to 200 MB So in total < 5 TB	/
Leuven data	Experimental data from Piet Claus lab (cardiovascular dynamics and imaging): meshes of pig hearts and EP mapping data	Reuse existing data	Digital	Experimental	TODO	TODO	/
Minneapolis data	Experimental data from Tolkacheva lab (Minneapolis): optical voltage mapping of rabbit hearts	Reuse existing data	Digital	Experimental	.mat	1 file = +- 130 MB 8 files gives < 100 GB	/

If you reuse existing data, please specify the source, preferably by using a persistent identifier (e.g. DOI, Handle, URL etc.) per dataset or data type:

Leiden data:
The data is similar to the one used in DOI:10.1371/journal.pone.0271351 and DOI:10.1038/s41551-021-00827-5.
Leuven data:
The data is similar to the one used in DOI: 10.1038/s41598-018-20450-w
Also data can be used from the C1 project (C14/18/079) and FWO project (G097021N) of which PC is co-PI.
Minneapolis data:
The data is similar to the one used in DOI:10.3389/fphys.2021.690453, DOI:10.1111/jce.14948

Are there any ethical issues concerning the creation and/or use of the data (e.g. experiments on humans or animals, dual use)? Describe these issues in the comment section. Please refer to specific datasets or data types when appropriate.

- Yes, animal data

Will you process personal data? If so, briefly describe the kind of personal data you will use in the comment section. Please refer to specific datasets or data types when appropriate.

- No

No personal data will be processed, within this project we only work with in silico data and animal experiments.

Does your work have potential for commercial valorization (e.g. tech transfer, for example spin-offs, commercial exploitation, …)? If so, please comment per dataset or data type where appropriate.

- No

Within the scope of this project, the research is fundamental, and no commercial exploitation is foreseen.

Do existing 3rd party agreements restrict exploitation or dissemination of the data you (re)use (e.g. Material/Data transfer agreements/ research collaboration agreements)? If so, please explain in the comment section to what data they relate and what restrictions are in place.

- No

Are there any other legal issues, such as intellectual property rights and ownership, to be managed related to the data you (re)use? If so, please explain in the comment section to what data they relate and which restrictions will be asserted.

- No

2. Documentation and Metadata

Clearly describe what approach will be followed to capture the accompanying information necessary to keep data understandable and usable, for yourself and others, now and in the future (e.g., in terms of documentation levels and types required, procedures used, Electronic Lab

Notebooks, README.txt files, Codebook.tsv etc. where this information is recorded).

For simulations, there are standardized log-files, whose description is provided at the wiki page of the software. See https://gitlab.kuleuven.be/heartkor/ithildin (internal page) and https://opencarp.org/documentation. These logfiles are kept together with the simulation output. For ithildin, a git hash is given referring to the software version (commit).

For the medical images of animal hearts, a standardized headerfile contains the details of the acquisition. A manual comment is added to describe the subject and reason for imaging.

Will a metadata standard be used to make it easier to find and reuse the data? If so, please specify (where appropriate per dataset or data type) which metadata standard will be used. If not, please specify (where appropriate per dataset or data type) which metadata will be created to make the data easier to find and reuse.

- Yes

For the experiments, metadata standards are provided by the hardware.
For our own software (ithildin), we implement automatic upload to the KU Leuven ManGO platform. A *json template file has been created and is distributed among the groups at KU Leuven using the software.
For openCARP, the bundle feature allows to use standardized metadata and upload the simulation in a way that it is reproducible. See also the openCARP website.

3. Data storage & back-up during the research project

Where will the data be stored?

- Python scripts and source code are stored at the GitLab repository: gitlab.kuleuven.be. This includes both the ithildin source files and the pre- and post-processing scripts, as well as any notes taken while conducting computational experiments during the project.
- The output of simulations is stored in ManGO.
- The experimental recordings and images are stored at and shared from internal servers of UZ Leuven. If relevant, a copy can be stored in ManGO as well.
- Project documents, postprocessing images and videofiles are stored in the SharePoint folder of the HeartKOR group and a personal OneDrive provided by KU Leuven.

How will the data be backed up?

All the repositories above are equipped with a back-up system.

Is there currently sufficient storage & backup capacity during the project? If yes, specify concisely.
If no or insufficient storage or backup capacities are available, then explain how this will be taken care of.

- No

The only concern is the possible 10 TB of simulation data in ManGO. My research team is in contact with the support team, who is currently implementing the upload of large files (of 5-10 GB each). When that is successful, we will discuss which storage capacity can be acquired for this project.

How will you ensure that the data are securely stored and not accessed or modified by unauthorized persons?

The servers (GitLab, ManGO, SharePoint) are protected via an authentication procedure.

What are the expected costs for data storage and backup during the research project? How will these costs be covered?

The servers I use are all provided and financially covered within my research team.

4. Data preservation after the end of the research project

Which data will be retained for at least five years (or longer, in agreement with other retention policies that are applicable) after the end of the project? In case some data cannot be preserved, clearly state the reasons for this (e.g. legal or contractual restrictions, storage/budget issues, institutional policies...).

Long term storage of data provided by groups from Leuven, Leiden, Bordeaux and Minneapolis is already secured by them.
At the end of the project, we will select which datasets created by the researcher during the project should be kept for a longer period. It is estimated that about 50% needs to be kept. This will be stored via a central backup in my research group.

Where will these data be archived (stored and curated for the long-term)?

After the project, the 'cold' data that is not published (yet) will be transferred from ManGO to appropriate servers, via cold storage at KU Leuven data centers.
Parts of the results will be shared together with the publications (e.g., via Zenodo or journal supplements). In case of a standalone data set or software, it will be published via KU Leuven RDR.

What are the expected costs for data preservation during the expected retention period? How will these costs be covered?

Publishing data sets in KU Leuven RDR is free, yet has a limit of 50GB per year along with a max. file size of 5GB. If data is published along with a publication, the costs are covered within the publication costs.
Publishing data or code via Zenodo is free of cost and comes with a maximum size per record of 50GB.

5. Data sharing and reuse

Will the data (or part of the data) be made available for reuse after/during the project? In the comment section please explain per dataset or data type which data will be made available.

- Yes, in an Open Access repository
- Yes, in a restricted access repository (after approval, institutional access only, …)

The data that is involved in a publication will be shared according to Open Access principles.
Data that was generated, but not used for publication, will be stored on internal servers, such as ManGO.

If access is restricted, please specify who will be able to access the data and under what conditions.

The data will be available for the respective research groups of my (co-)promotors.

Are there any factors that restrict or prevent the sharing of (some of) the data (e.g. as defined in an agreement with a 3rd party, legal restrictions)? Please explain in the comment section per dataset or data type where appropriate.

- No

Where will the data be made available? If already known, please provide a repository per dataset or data type.

See above, on data sharing platforms.

When will the data be made available?

At the time of publication of the accompanying paper.
If relevant, additional data will be made available at the end of the project.

Which data usage licenses are you going to provide? If none, please explain why.

- For the experimental data: I only plan to postprocess existing experimental data. It is not up to me to publish it separately.
- For the software development: GNU General Public Licence 3.0 (further use possible, remains free software).

Do you intend to add a PID/DOI/accession number to your dataset(s)? If already available, you have the option to provide it in the comment section.

- Yes

This will be done for datasets linked to publications.

What are the expected costs for data sharing? How will these costs be covered?

Currently, gitlab.kuleuven.be, gitlab.com and zenodo.org are free services to the user.
The sharing via journal's servers is paid at the time of submitting the paper.

6. Responsibilities

Who will manage data documentation and metadata during the research project?

Marie Cloet

Who will manage data storage and backup during the research project?

Marie Cloet

Who will manage data preservation and sharing?

Main promotor H. Dierckx

Who will update and implement this DMP?

Marie Cloet