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Registration and query of biophysical parameters using the MyocyteDB platform

Cadastro e consulta de parâmetros biofísicos utilizando a plataforma MyocyteDB

Registro y consulta de parámetros biofísicos utilizando la plataforma MyocyteDB

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Abstract
Currently, the research related to the computational modeling of myocytes has been standing out substantially regarding the knowledge of the complex process of cardiac excitation-contraction. In this context, the availability of a data repository of electrophysiological parameters for the development of mathematical models becomes a growing need. The objective of this article is to present the MyocyteDB web platform that's focused on the inclusion and consultation of biophysical parameters and statistical data for computational modeling of the ventricular myocyte. For the development of this platform, cloud computing technologies (Azure) were used. A careful review of the literature in the search for mathematical models of cardiac electrophysiology was carried out on the conductance values of the main ion channels to compose the initial set of data to be inserted into the platform. From the set of collected values available on this platform, it becomes possible to produce statistical data of a descriptive nature, export data in spreadsheet format, and access the dataset via API. It is expected this platform could be a tool capable of helping future modelers in the research and adjustments of biophysical parameters used in the cardiac electrophysiological modeling process. Thus, providing greater dynamics in the search for values of biophysical parameters used in mathematical modeling of myocytes.
Keywords: Web platform; Database; Ventricular myocyte; Mathematical modeling; Biophysical parameters.

Resumo
Atualmente as pesquisas relacionadas à modelagem computacional de miócitos vem se destacando substancialmente no que tange o conhecimento do complexo processo de excitação-contração cardíaca. Neste contexto, a disponibilidade de um repositório de dados de parâmetros eletrofisiológicos para desenvolvimento de modelos matemáticos torna-se uma necessidade crescente. O objetivo deste artigo é apresentar a plataforma web MyocyteDB focada na inclusão e consulta de parâmetros biofísicos e dados estatísticos para modelagem computacional do miócito ventricular. Para o desenvolvimento desta plataforma, foram empregadas as tecnologias de computação em nuvem (Azure). Uma criteriosa revisão da literatura na busca de modelos matemáticos da eletrofisiologia cardíaca, foi realizada sobre os valores de condutância dos principais canais iônicos para compor o conjunto inicial de dados a ser inserido na plataforma. A partir do conjunto de valores coletados à disposição nesta plataforma, foi possível apresentar dados estatísticos de natureza descritiva, a exportação de dados em formato de planilha e o acesso via API do conjunto de dados. Espera-se que esta plataforma seja uma ferramenta capaz de auxiliar futuros modeladores na pesquisa e ajustes de parâmetros biofísicos utilizados no processo de modelagem eletrofisiológica cardíaca. Deste

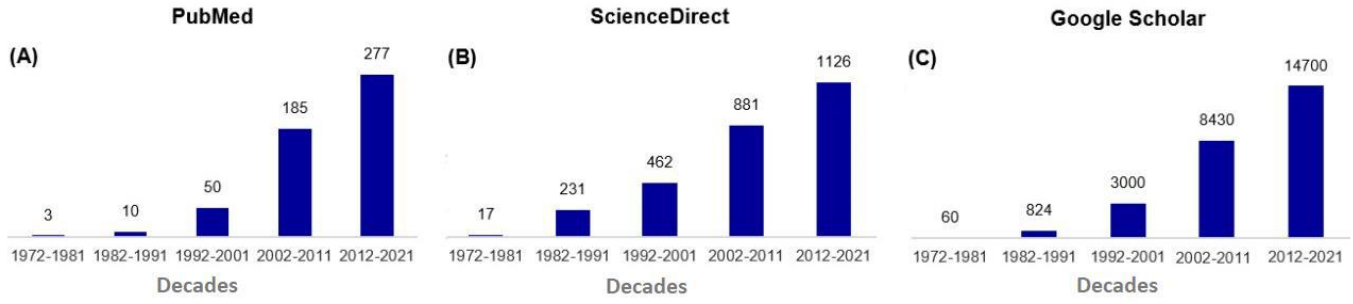
modo, proporcionando uma maior dinâmica na busca de valores de parâmetros biofísicos utilizados na modelagem matemática de miócitos.
Palavras-chave: Banco de dados; Miócito ventricular; Modelagem matemática; Parâmetros biofísicos.

Resumen
Actualmente, la investigación relacionada con el modelado computacional de miocitos ha venido destacándose sustancialmente en cuanto al conocimiento del complejo proceso de excitación-contracción cardiaca. En este contexto, la disponibilidad de un repositorio de datos de parámetros electrofisiológicos para el desarrollo de modelos matemáticos se convierte en una necesidad creciente. El objetivo de este artículo es presentar la plataforma web MyocyteDB que se centra en la inclusión y consulta de parámetros biofísicos y datos estadísticos para el modelado computacional del miocito ventricular. Para el desarrollo de esta plataforma se utilizaron tecnologías de computación en la nube (Azure). Se realizó una cuidadosa revisión de la literatura en la búsqueda de modelos matemáticos de electrofisiología cardíaca sobre los valores de conductancia de los principales canales iónicos para componer el conjunto inicial de datos a serem insertados en la plataforma. A partir del conjunto de valores recopilados disponibles en esta plataforma, es posible producir datos estadísticos de carácter descriptivo, exportar datos en formato de hoja de cálculo y acceder al conjunto de datos a través de API. Se espera que esta plataforma sea una herramienta capaz de ayudar a los futuros modeladores en la investigación y ajustes de parámetros biofísicos utilizados en el proceso de modelado electrofisiológico cardíaco. Aportando así una mayor dinámica en la búsqueda de valores de parámetros biofísicos utilizados en el modelado matemático de miocitos.
Palabras clave: Plataforma web; Banco de datos; Miocito ventricular; Modelo matematico; Parámetros biofísicos.

1. Introduction

Considering the advances in computing capacity available over the last few years, there is a large-scale increase in the number of mathematical models that describe cardiac electrophysiology (Noble et al., 2012). As an example, Figure 1 illustrates the upward growth of publications on mathematical and computational modeling of the ventricular myocyte in recent decades. The research was carried out on different search platforms for works related to the keywords: *ventricular* AND *myocyte* AND *mathematical model*.

Figure 1 - Number of publications involving the mathematical modeling of the ventricular myocyte located in different databases: (A) PubMed; (B) ScienceDirect; (C) Academic Google.



Source: Authors (2022).

Based on these models, the scientific community has expanded its knowledge about the complex process of cardiac excitation-contraction (EC) coupling, becoming a field of study in full expansion for both biomedical and mathematicians. It is observed that, over time, new specific repositories of mathematical models for the study of cardiac electrophysiology have emerged, such as the Project CellML (https://www.cellml.org/), Virtual Project Physiological Rat (http://vpr.sites.uofmhosting.net/) and the Virtual Simulation Environment Cardiac Electrophysiology Web Lab (https://travis.cs.ox.ac.uk/FunctionalCuration/index.html). However, despite this growing number of repositories that become available, there are no specific tools to search for biophysical parameters used in the mathematical modeling of the cardiac

myocyte. Allied to this fact, with the growth in the number of published mathematical models, the availability of means that will allow greater dynamics in the search for these parameters to be used by modelers, it becomes of great importance.

In this sense, this work has as its main objective the development and availability to the scientific community, of an online database platform, for registration, consultation, and statistical analysis of biophysical parameters used in the area of cardiac electrophysiology modeling.

2. Methodology

2.1 Research on the main biophysical parameters used in the mathematical modeling of the ventricular myocyte

This section details the methodology used in the search for potentially more relevant publications to obtain values of parameters of cardiac electrophysiology of the ventricular myocyte. For the initial composition of the dataset of biophysical parameters to be inserted in the platform, the literature searched was the works cited in the review article by Noble et al. (2012). From this set, the works that specifically mentioned the mathematical and computational modeling of the electrophysiology of ventricular myocytes of the most common animal species in this field of study were selected. Then, the works by Morotti et al. (2014) for mice and Gattoni et al. (2016) for rats were also added.

Table 1 displays the main characteristics and the initial set of articles used in the collection of the parameters contemplated in this work.

Table 1 - Set of references used in this work highlighting the species, number of Ordinary Differential Equations (ODE) and the main characteristics of each model.

Species	Model	ODEs	Main features
Mouse	Morotti et al., 2014	48	Development of a computational model that includes the Ca^{2+} and CaMKII signals.
	Li et al., 2011	36	Ventricular model using mouse data.
	Wang & Sobie, 2008	35	Mathematical modeling of action potential for neonatal mice.
	Bondarenko et al., 2004	41	First mouse ventricular model.
Rat	Gattoni et al., 2016	32	Experimental and modeling study of cardiac response based on calcium levels.
	Pasek et al., 2006	41	Study of the functional role of cardiac T tubules.
	Coutu & Metzger, 2005	31	Genetic manipulation of calcium influencing proteins in myocytes.
	Pandit et al., 2001	28	Mathematical modeling of action potential heterogeneity.
Rabbit	Mahajan et al., 2008	26	Markov formulation for the L-type Ca^{2+} channel
	Shannon et al., 2004	46	New Ca^{2+} dynamics with the inclusion of 4 compartments.
Human	Grandi et al., 2010	38	Mathematical modeling for manipulation of Ca^{2+} and ionic currents in the human ventricular myocyte.
	Ten Tusscher & Panfilov, 2006	18	Study of Alternates in a human ventricular tissue model.
	Iyer et al., 2004	67	First human ventricular model using stochastic modeling.

Source: Authors (2022).

Initially, to register the first biophysical parameters on the MyocyteDB platform, from the selected articles, the conductance values of the main ion channels (sodium, potassium and calcium channels) were obtained, which are normally available as supplementary materials for these articles.

The initial choice for sodium, potassium and calcium ion channels is due to the fact that they are well highlighted in the literature for the study of cardiac cycle dynamics.

2.2 MyocyteDB Plataform

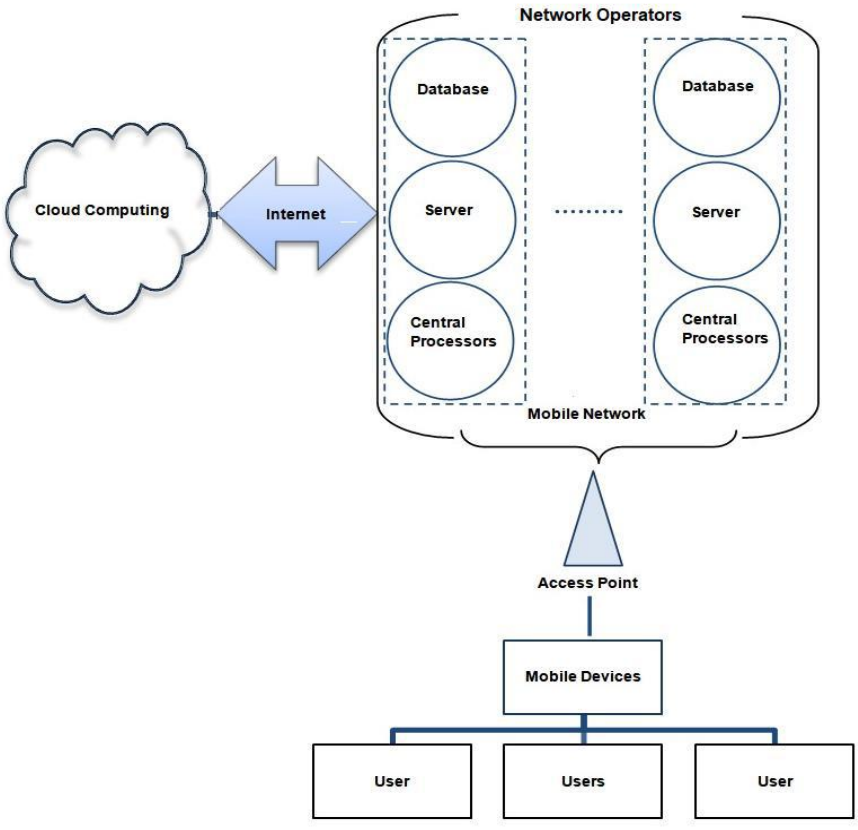
Based on the objectives described above, this platform aims at the entire process of registration and consultation of biophysical parameters applicable to the mathematical modeling of cardiac myocytes and the main statistics involved.

2.2.1 Cloud computing

Currently, having seen increasing popularization of services available in the internet environment, the use of technologies based on cloud computing has spread in several areas. In this way, providing a comprehensive number of applications, services, storage and computing power for the internet, especially in the health area (Shabbir et al., 2021) (Miguel et al.,2021).

Figure 2 presents a typical structure of the use of Cloud Computing for mobile internet networks. In this type of structure, users of mobile devices are connected to the network through access points, where information and user application requests are sent and processed by central servers. Over the Internet, customer requests are sent to the cloud, which provides the necessary services according to the request.

Figure 2 – Cloud computing structure for mobile internet applications.



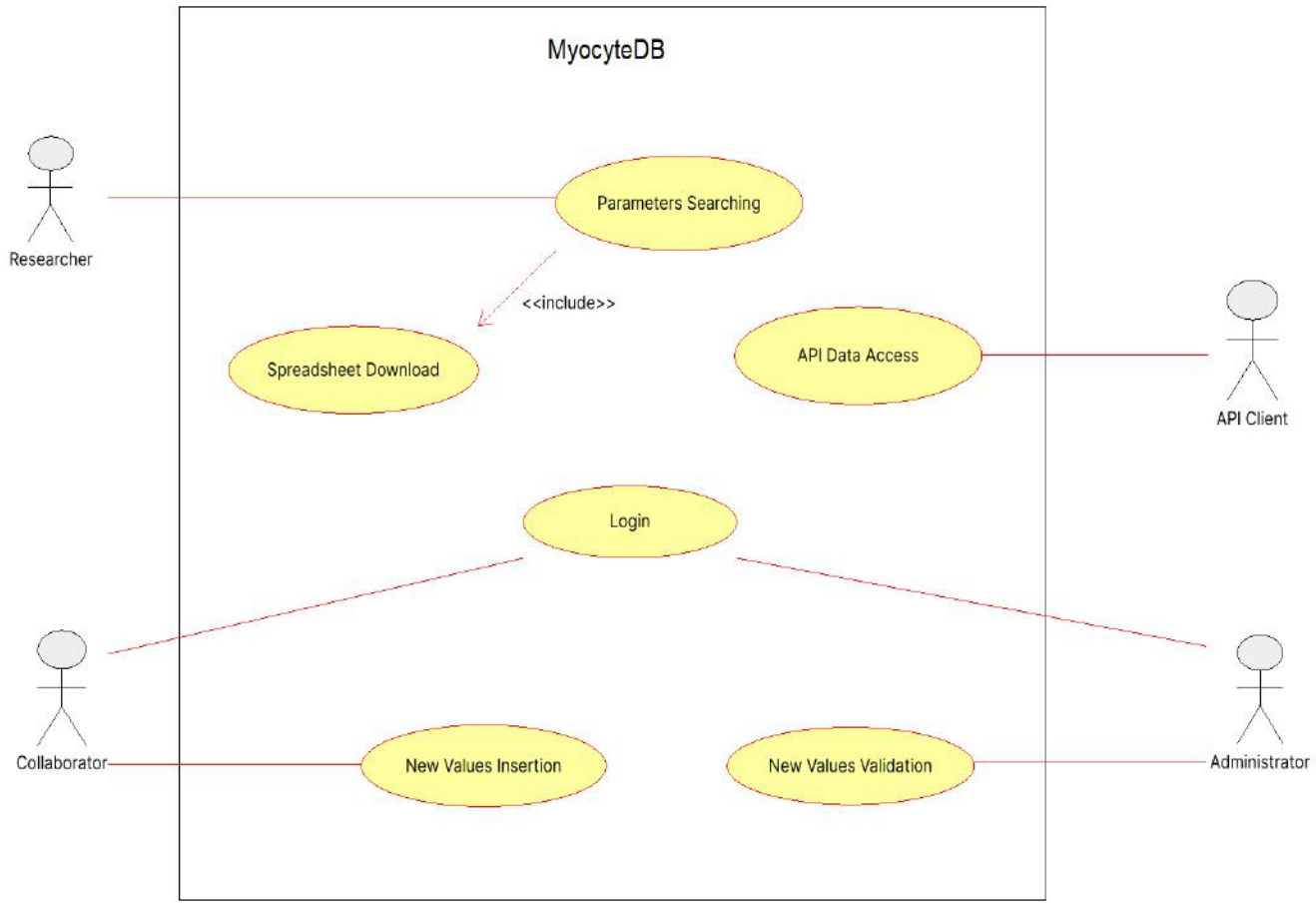
Source: Authors (2022).

Among the available cloud computing options, Microsoft Azure was adopted for this project. Among the programming languages available in this technology, the one used was C# (C Sharp).

2.2.2 Definition of Use Cases

The Use Case diagram, represented in Figure 3, illustrates the main users of the system: Researcher, Collaborator and Administrator. In addition to this, the API Client also stands out, allowing applications connected to the internet to use the parameter values provided by this platform via API (Application Programing Interface).

Figure 3 - Use Case Diagram.



Source: Authors (2022).

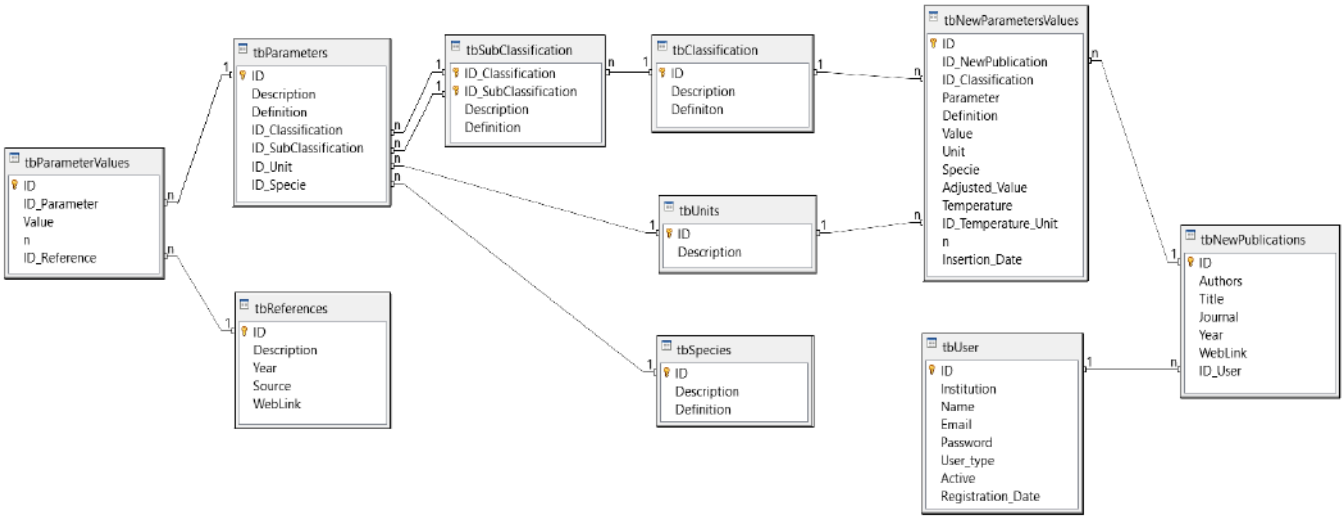
The Researcher user has free access to search parameters through the search categorized by animal species. The resource to download files in a data sheet with the set of parameter values related to each animal species is also available.

The Contributor user, through an authenticated account, will be able to enter new works with their respective values of cardiac electrophysiology parameters. The Administrator user, through an authenticated account, will have access to the module responsible for the task of performing the analysis and validation of parameter values that were previously entered by the collaborating users. Finally, API Clients, through specific applications, will be able to directly access parameter values for the purpose of simulations in mathematical models of myocytes.

2.2.3 Database Structure

The development of the database for this project was based on the concept of the Entity-Relationship model. (Chen, 1976) (Frank, 2021). Figure 4 illustrates the diagram of the main structure of the database with the relationships between the tables used in this project.

Figure 4 – Main Entity-Relationship Diagram used in the project.



Source: Authors (2022).

In the diagram, it is possible to see the relationships between the parameter tables and their related tables. Each parameter must have attributes such as description, definition, classification, subclassification, unit and species. The parameter values are recorded in a specific table depending directly on the reference of the academic work that was used as the data source. In this way, the same parameter may be associated with more than one value, depending on the reference of the related source.

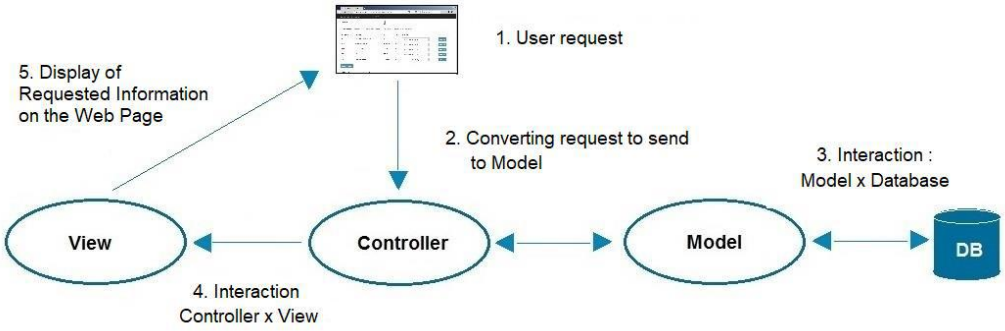
It is observed that the statistical values of a descriptive nature provided by the platform are not represented in this diagram. All information of a statistical nature will always be computed on demand whenever it is required to be displayed to the user.

The tables relating to the registration of new parameters by collaborating users are accessed by the administrator users for the purpose of validating the parameters for the availability of queries on the platform.

2.2.4 MVC Architecture

MVC (Model-View-Controller) is a design pattern proposed for application development for various purposes. Combining technologies to be divided into a set of three layers: data model (Model), display interface (View) and controller (Controller) (Reenskauge, 1979). The latter, controlling the processing mode of the first two components. When a user makes a request to the system, a router identifies which control and method to operate. Then the Controller fetches the appropriate data from the Model to be displayed to the user through the View layer. The overview of the MVC architecture used in the MyocyteDB platform is exemplified in Figure 5.

Figure 5 – MVC components used in the MyocyteDB platform.



Source: Authors (2022).

In this work, the ASP.NET MVC framework was used, due to the fact that it is a consolidated technology and suitable for access environments via the Web.

3. Results

3.1 Maximum Conductance of Ionic Channels

In this section, the results obtained in the literature review are highlighted, according to the criteria mentioned above for the search for parameters. In view of the diverse nature of existing biophysical parameters, this section will specifically address the conductances of ion channels.

3.1.1 Maximum Conductance of Ionic Channels in Mice

Table 2 shows the maximum conductances of the ion channels of the main ionic currents used in the modeling of the mouse ventricular myocyte. The maximum conductance values of these channels are values widely used in model modeling, being obtained from experimental data.

Table 2 - Maximum conductance values (mS/µF) of the main ion channels used in the mathematical modeling of the mouse ventricular myocyte.

Description		**Models**			
Author		Morotti et al	Li et al	Wang & Sobie	Bondarenko et al
Year		2014	2011	2008	2004
CaL	Specific maximum conductance for the L-type Ca^{2+} channel	-	-	0.055	0.1729
CaB	Maximum conductance of the background Ca^{2+} current (epicardium)	0.000754	0.00022	0.00025	0.000367
Na	Maximum conductance of the Na^{+} current	10	25	10	13
Nab	Maximum conductance of the background Na^{+} current	0.0013	0.0026	0.003	0.0026
Ktof	Maximum conductance of K^{+} transient external current (apex)	0.44	0.535	0.017	0.4067
Ks	Maximum conductance of the K^{+} slow-delay rectifier current	0.3	0.00575	0.046	0.00575

Ktos	Maximum conductance of K^+ transient external current (epicardium)	0.0176	-	-	0.063
Kur	Maximum conductance of the K^+ retard-rectifier ultrafast current (epicardium)	-	0.250	0.005	0.160
Kss	Maximum current conductance in the non-activating steady state of K^+ (apex)	0.015	0.060	0.015	0.0324
Kr	Maximum current conductance of K^+ fast delay rectifier	0.3	0.0165	1.17	0.078
K1	Maximum conductance of the K^+ rectifier current inward	0.9	0.35	0.235	-

Source: Authors (2022).

In the models by Morotti et al. (2014) and Li et al. (2011) the specific conductances for the L-type Ca^{2+} channel (CaL) are not available, considering that their models are based on a modeling that uses membrane permeability.

In the models by Li et al. (2011) and Wang & Sobie (2008) the maximum conductances of the external current of K^+ (Ktos), according to the implementation of these models, are not available. As well as the specific conductance of the epicardial K^+ delayed-rectifier ultrafast current (Kur) is not available in Li et al. (2001).

In the model described by Bondarenko et al. (2004) the maximum conductance of the rectifier current from K^+ to the inside (K1), despite being referenced in the described model, is not available in this work.

3.1.2 Maximum Conductance of Ionic Channels in Rats

Table 3, below, shows the maximum conductances of the ion channels of the main ionic currents of rat ventricular myocytes.

Table 3 - Maximum conductance value of ion channels used in cardiac electrophysiology modeling of rat ventricular myocytes.

Description		**Models**			
Author		Gattoni et al.	Pasek et al.	Coutu & Metzger	Pandit et al.
Year		2016	2006	2005	2001
Unit		µS	µS	µS/mF	µS
CaL	Specific maximum conductance for the L-type Ca^{2+} channel	-	-	-	0.031
CaB	Maximum conductance of the background Ca^{2+} current (epicardium)	-	6.48×10^{-6}	3.2×10^{-4}	3.24×10^{-5}
Na	Maximum conductance of the Na^+ current	0.7	0.8	12.8	0.8
Nab	Maximum conductance of the background Na^+ current	8.02×10^{-5}	8.02×10^{-5}	0.007	8.02×10^{-5}
Kb	Maximum conductance of the background K^+ current	1.38×10^{-4}	1.38×10^{-4}	-	1.38×10^{-4}

K1	Maximum conductance of the K^+ rectifier current inward	0.04	0.24	0.5	0.024
t	Maximum slow current conductance out of transient Ca^{2+} independent of K^+	0.0196	3.5×10^{-4}	0.17	0.035
SS	Maximum current conductance out of K^+ at steady state	0.012	0.007	0.066	0.007
f	Conductance of the maximum inward triggering hyperpolarization current	1.21×10^{-6}	0.00145	0.24	0.00145

Source: Authors (2022).

In the models by Pasek et al. (2006) and Coutu & Metzger (2005) the specific conductances for the L-type Ca^{2+} channel (CaL) are not available, due to the fact that their models approach a modeling based on membrane permeability.

Table 4, below, shows the maximum conductances of the ion channels of the main ionic currents of rabbit ventricular myocytes.

Table 4 - Maximum conductance value (mS/µF) of ion channels used in the cardiac electrophysiology modeling of rabbit ventricular myocytes.

Description		**Models**	
Author		Mahajan et al.	Shannon et al.
Year		2008	2004
CaB	Maximum conductance of the background Ca^{2+} current (epicardium)	-	0.0002513
Na	Maximum conductance of the Na^+ current	12	16
Nab	Maximum conductance of the background Na^+ current	-	0.000297
Ktof	Maximum conductance of K^+ transient external current (apex)	0.11	0.06
Ks	Maximum conductance of the K^+ slow-delay rectifier current	0.1386	-
Ktos	Maximum conductance of K^+ transient external current (epicardium)	0.04	0.02
Kr	Maximum current conductance of K^+ fast delay rectifier	0.0125	-
K1	Maximum conductance of the K^+ rectifier current inward	0.3	-

Source: Authors (2022).

In the model described by Shannon et al. (2004) the maximum conductance values GKs, GKr and GK1 are not made available according to the implementation of the model. In Mahajan et al. (2008) the values of GCaB and GNaB are also not available.

3.1.4 Maximum conductance of ion channels in humans

Table 5, below, shows the maximum ion channel conductances of the main ionic currents of human ventricular myocytes.

Table 5 - Maximum conductance value (mS/µF) of ion channels used in cardiac electrophysiology modeling of human ventricular myocytes.

Description		**Models**		
Author		Grandi et al.	Ten Tusscher & Panfilov,	Iyer et al.
Year		2010	2006	2004
CaB	Maximum conductance of the background Ca^{2+} current (epicardium)	-	0.000592	7.684×10^{-5}
Na	Maximum conductance of the Na^{+} current	23	14.838	56.32
Nab	Maximum conductance of the background Na^{+} current	0.000597	0.00029	0.001
Ktof	Maximum conductance of K^{+} transient external current (apex)	0.1144	-	0.0775
Ks	Maximum conductance of the K^{+} slow-delay rectifier current	0.0035	0.392	0.0035
Ktos	Maximum conductance of K^{+} transient external current (epicardium)	0.0156	0.294	-
Kr	Maximum current conductance of K^{+} fast delay rectifier	-	0.153	0.186
K1	Maximum conductance of the K^{+} rectifier current inward	-	5.405	-

Source: Authors (2022).

In the model described by Grandi et al. (2010) the maximum GCaB conductance is not available. The parameters GK1 and GKr are also not available. In the model of Ten Tusscher and Panfilov (2006) the maximum conductance GCal is available only in $cm.ms^{-1}$. μF^{-1}. The GKtof parameter is not available. In Iyer et al. (2004) parameters referring to GKtos and Gk1 are not available.

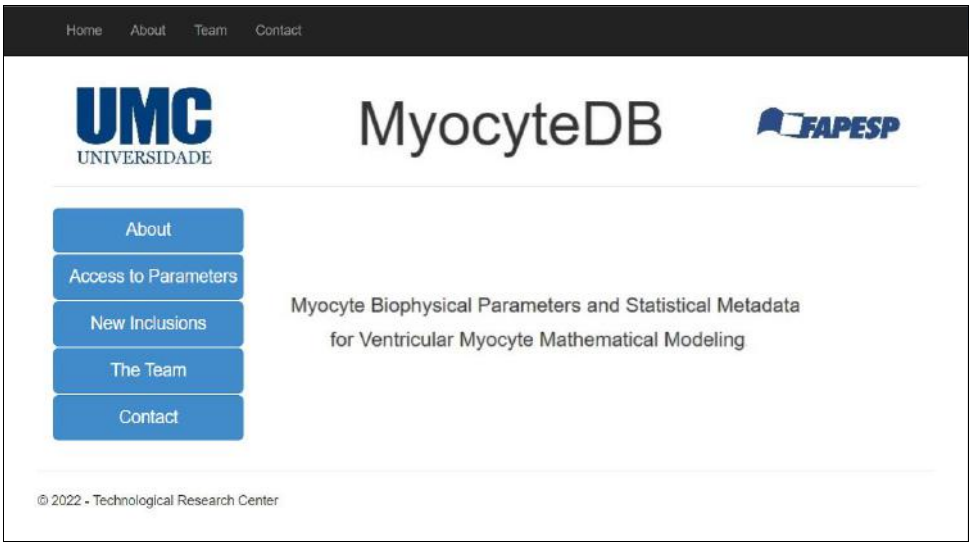
As presented, these parameters constitute the initial set to be fed into the database of the platform described in this work. The set of parameters referring to the other classes of biophysical parameters will be submitted following the same methodological models.

3.2 MyocyteDB Platform

The MyocyteDB platform, available at myocytedb.org, allows access to values of the main parameters of cardiac electrophysiology of ventricular myocytes from different species.

The initial screen of the platform is illustrated in Figure 6, showing the options related to the search for the parameter database, relevant information about the platform and authenticated access to the module for registering new values.

Figure 6 - MyocyteDB Platform Home Screen.

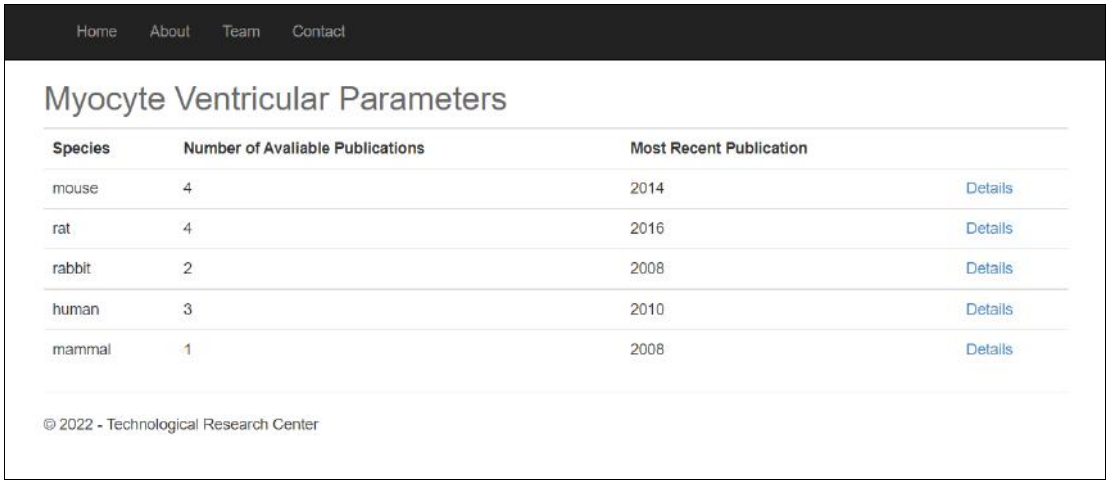


Source: Authors (2022).

3.2.1 Query Module for the Researcher User

Figure 7 shows the main access screen for registered species. Enabling the user to have an overview of the content of the available database. The registered species are described in the first column, and the number of publications is displayed in the second column. The most recent publication year for each species is shown in the third column. In the last column, on the right, access to publications of interest for each item to be selected is available.

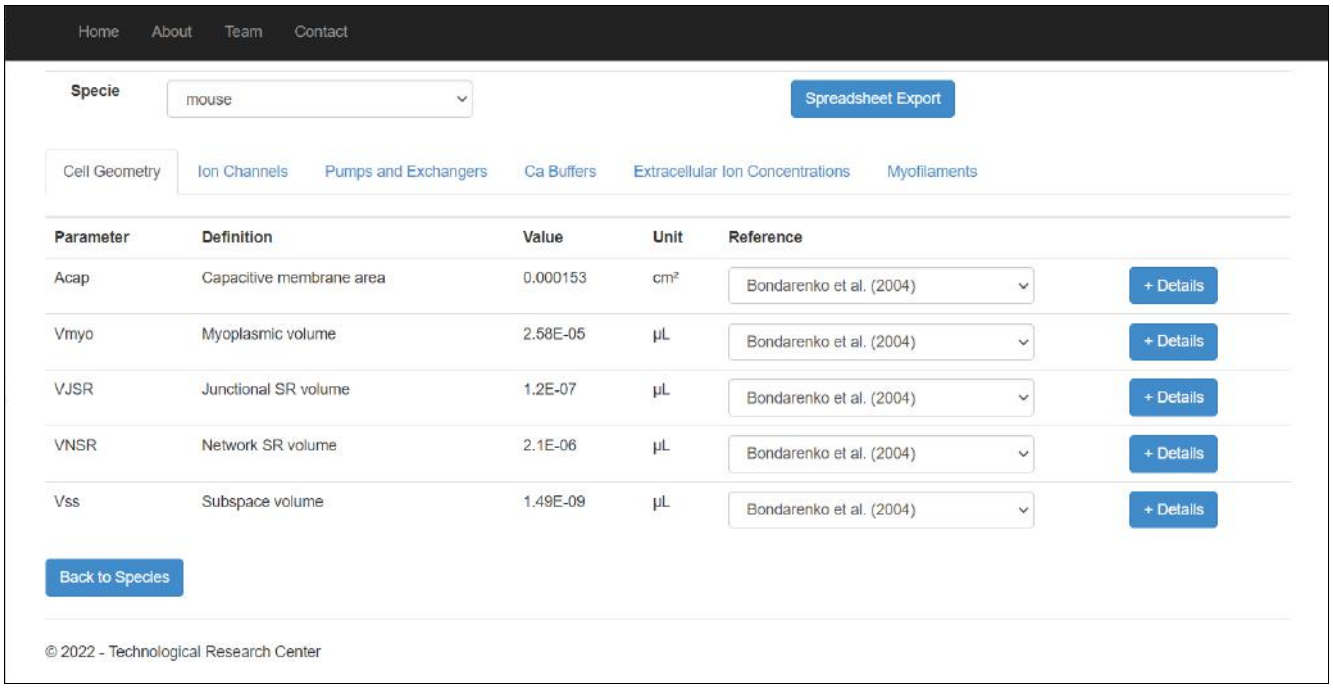
Figure 7 – Main species selection screen.



Source: Authors (2022).

Figure 8 shows the screen of parameters selected for the mouse species. The most common acronyms for each parameter are listed in the first column. The complete definition is described in the second column. The values and measurement units are displayed in the third and fourth columns, respectively. The fifth column shows the selection of the reference of the displayed values. In this column it is possible to select any other reference in the search for parameters within the same species. In the last column, on the right, access to the screen with more detailed information about the parameter of interest is available.

Figure 8 - Parameter screen with the classification allowing access to detailed parameter information.



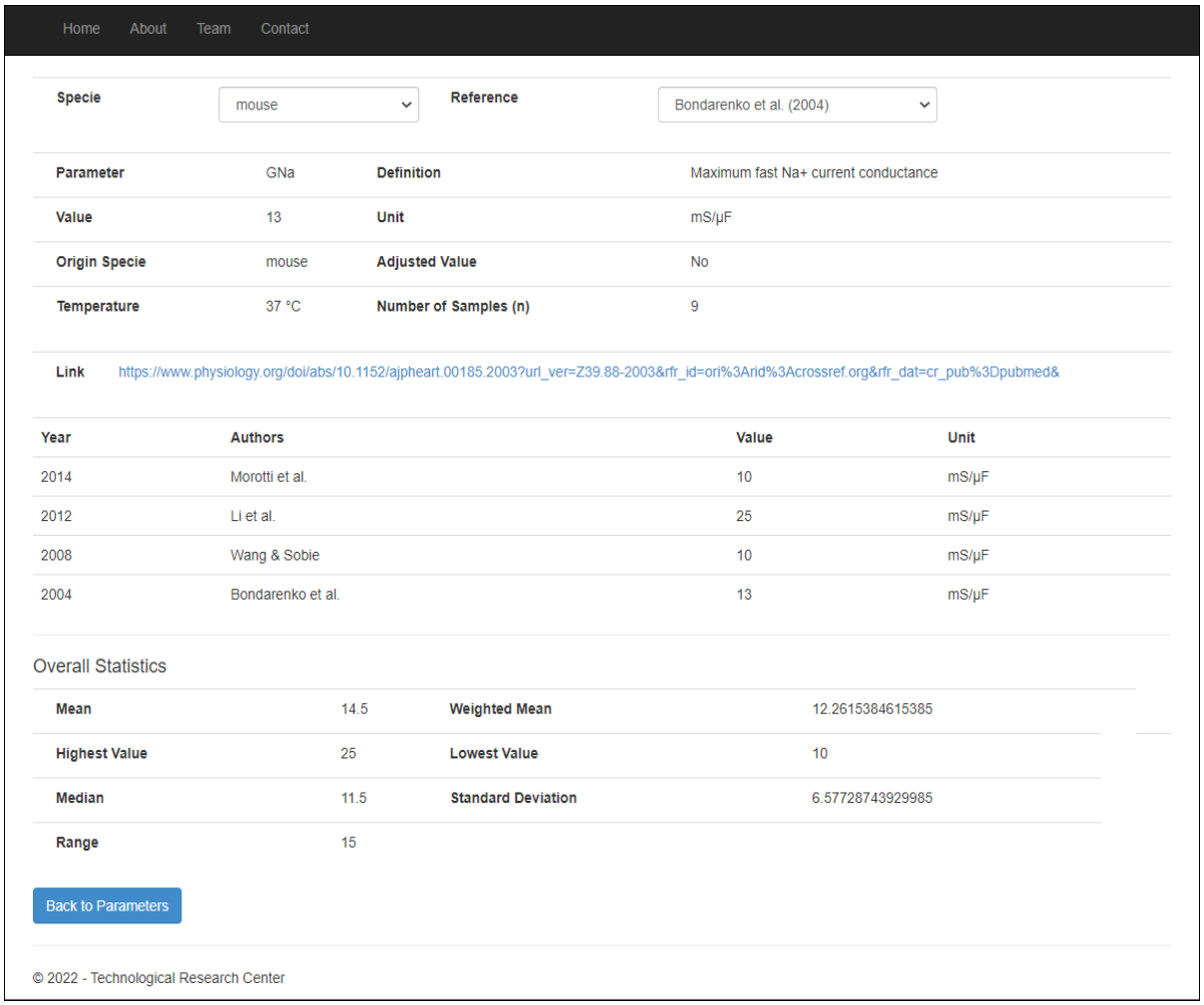
Source: Authors (2022).

In the upper region of this screen, on the left side, the species selection box is available, making it possible to access the set of parameters of another species of interest without having to go back to the species selection screen. The functionality referring to data export to the data sheet format is also provided for the selected animal species through the access available on the upper right side. (Spreadsheet Export).

For better usability purposes, the parameters are available in different selectable tabs corresponding to their classification: i) Cell Geometry; ii) Ionic Channels; iii) Pumps and Exchangers; iv) Calcium Buffers; v) Extracellular Ion Concentrations; vi) Myofilaments.

When selecting access to the screen with detailed information for the parameter of interest, using the access buttons for each item, a larger set of information is displayed. Figure 9 shows the screen with more details of the maximum conductance parameter for the sodium channel and mouse species.

Figure 9 – Screen displaying data about the parameters displayed analytically with statistics.



Source: Authors (2022).

In this view, specific data about the parameter is displayed in the upper area. The access link to the academic work used as the data source is also included. A table with the values of the other authors is also presented. In the case of experimental parameters, the temperature at which the experiment was performed and the sample number (n) are also given.

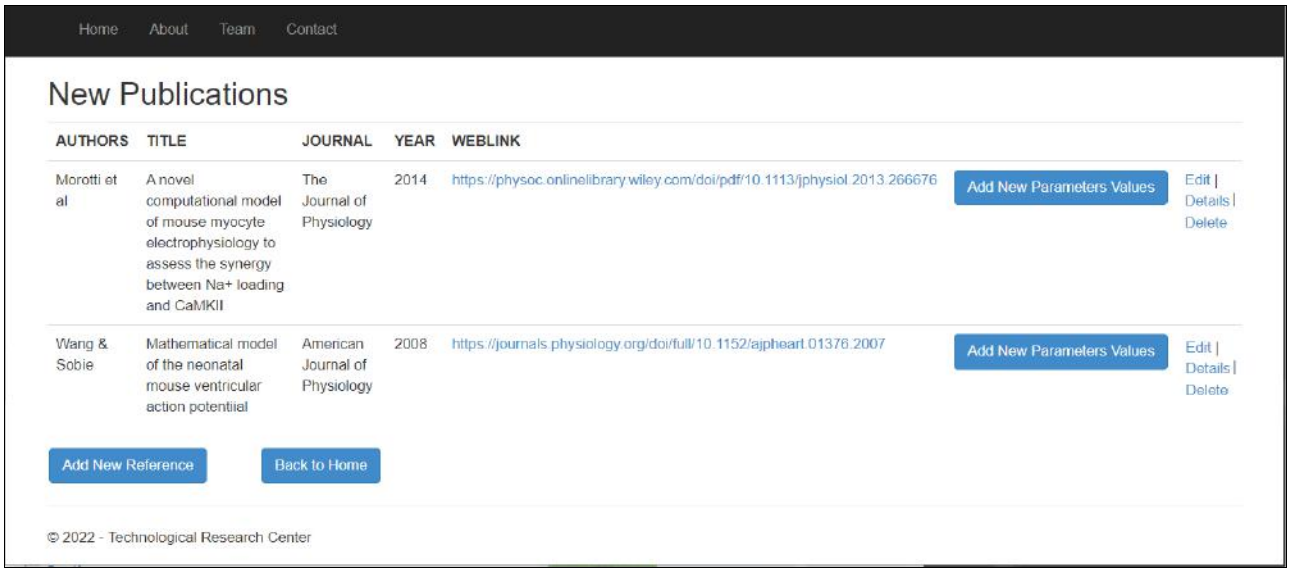
In the lower area, the statistical data (arithmetic average, weighted average, median, standard deviation, minimum value, maximum value and range) of the parameter values in relation to the general dataset of the other records of the same species are displayed.

3.2.2 Contributor User Module

This platform provides registered users with the collaborative user module for the inclusion of new sets of values. In this way, it is possible to constantly update the set of new works in continuous development in the area of cardiac electrophysiology modeling.

Figure 10 illustrates the new publications screen allowing new inclusions by the contributing user. In addition to editing the data of the publication itself, the user can enter new parameter values of the respective publications, as well as add new publications.

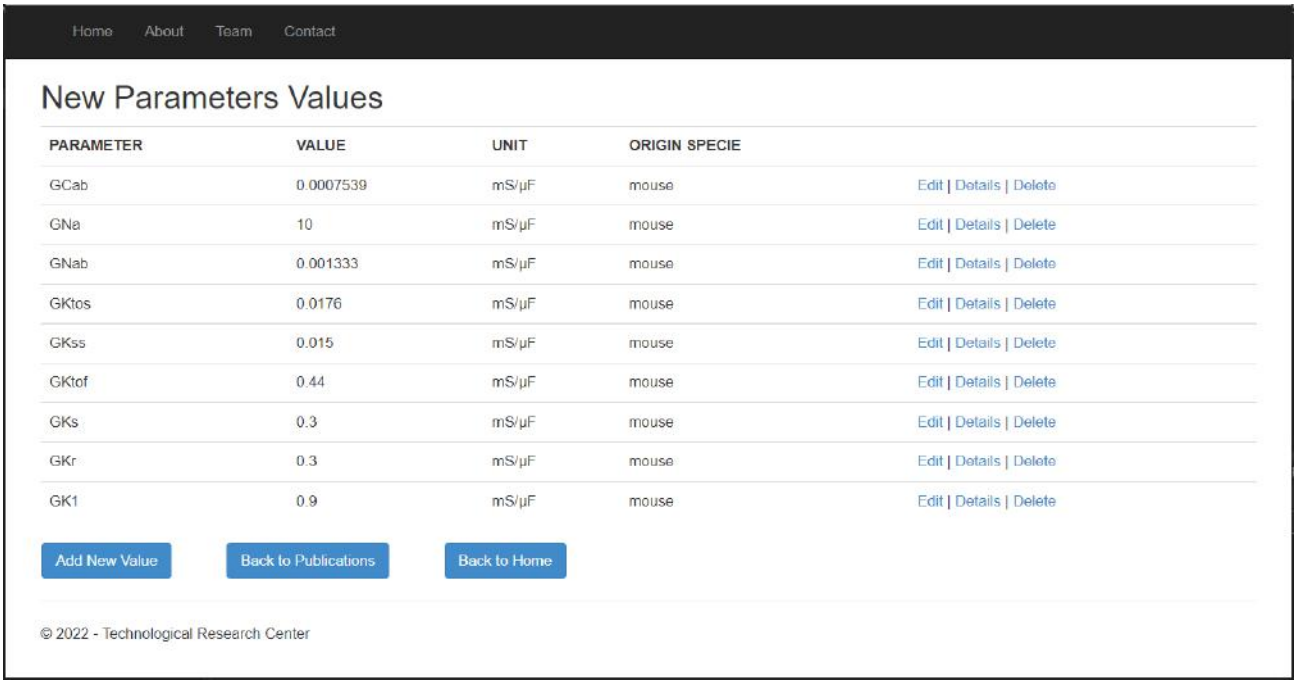
Figure 10 – Main screen for inserting new publications.



Source: Authors (2022).

When adding new parameter values, the user will have access to the screen with the list of new parameter values of the publications to be validated by those responsible for the platform, as shown in Figure 11.

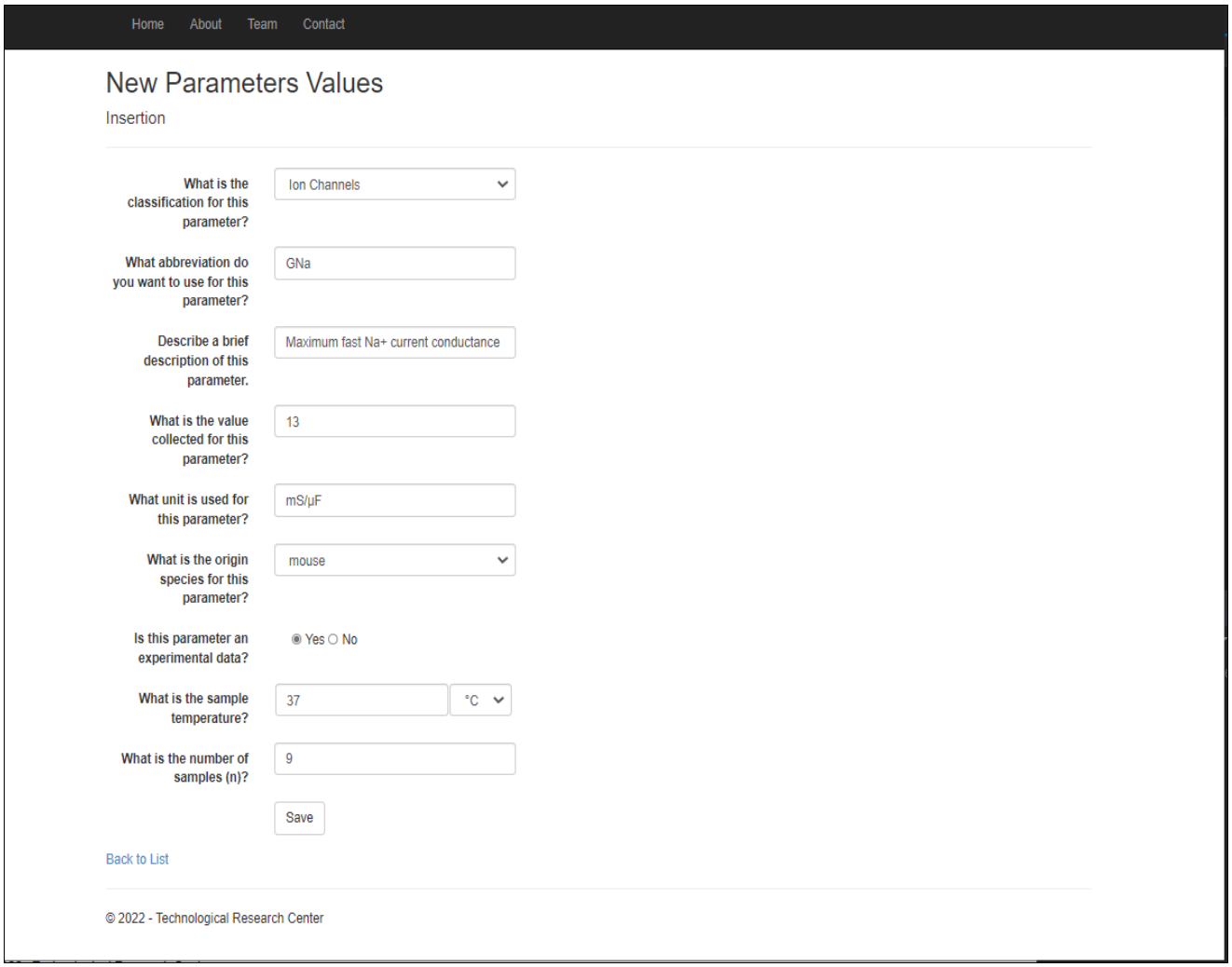
Figure 11 – Access screen for new parameter values.



Source: Authors (2022).

The user will have access to the screen for entering new parameters, either when adding the first parameter value or when adding new additional parameter values from the same publication. Figure 12 illustrates the screen for entering new parameter values, where all the necessary information for these parameters must be provided.

Figure 12 – Screen for entering new parameter values.



Source: Authors (2022).

3.2.3 Administrator User Module

This platform provides administrator users with a specific module for validating new parameter values registered by collaborating users.

It should be noted that the values added by contributors will not be readily available in the platform's searchable dataset. These values must be previously validated by the MyocyteDB platform administrators.

Figure 13 illustrates the validation screen for new publications. This screen displays a complete listing of all new publications available for validation of their parameters.

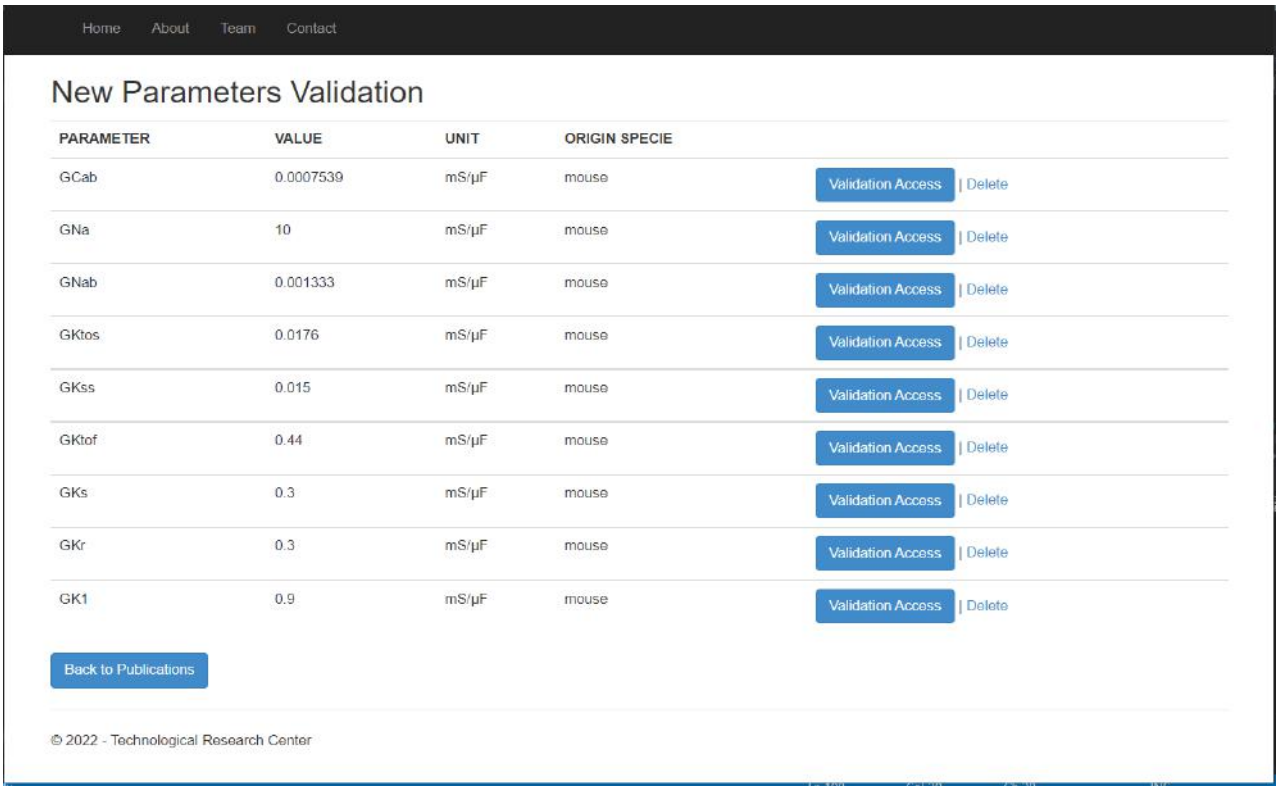
Figure 13 – New publications validation screen.

Source: Authors (2022).

Through this screen, in addition to editing the data of the publication itself, the administrator can validate the parameter values available for the respective publications.

When accessing parameter validation, as shown in Figure 14, the administrator will have access to the list of parameters, as well as their values to be evaluated and validated.

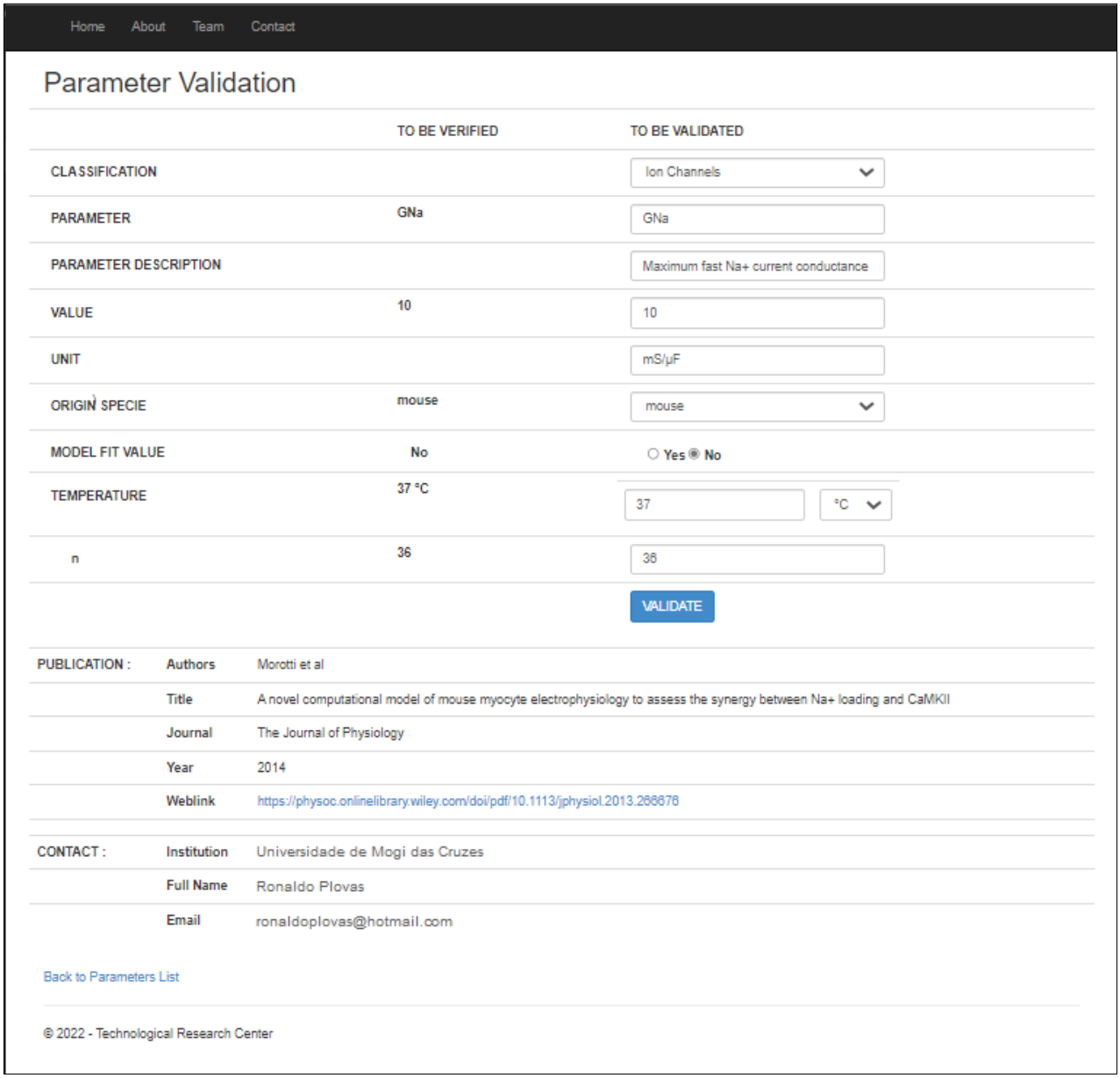
Figure 14 – Screen listing new parameters available for validation.



Source: Authors (2022).

On this screen, the responsible administrator will have an overview of the parameters available for validation. Allowing individual access to each parameter as shown in Figure 15.

Figure 15 – Parameter validation screen.



Source: Authors (2022).

This screen displays all available data about the parameter and its publication of origin. The contact information of the collaborating user, responsible for the initial availability of parameter values for analysis, is also presented. In case of any divergence from the values provided, the collaborating users must be reported by email in search of more details about these values.

During the validation process, the collaborating user will be notified, via email, that the parameter values provided have been validated and are available on the platform for research.

3.2.4 Query Access for the Web API Client

Initially, the Web API of this project was implemented to provide full access to the complete list of parameter values that the platform makes available.

The data provided by this API is, above all, directed to implementations in Web applications, which can use the available data set. This way, the values consulted can be used in different scenarios of computer simulation. Its data can even be accessed without the need for a specific client application, which can be done from a common web page browser at the address: myocyte.azurewebsites.net/api/parametersfull. In this case, the user will receive a file in XML format of the entire dataset of the platform.

The main fields provided are:

a) Parameter: Specification of the abbreviation used for the parameter;

b) Definition: Definition of the parameter in question.

c) Reference: Description of the reference publication from which the parameter value was obtained.

d) Specie: Description of the animal species.

e) Value: Parameter value.

f) Unit: Description of the measurement unit used in the parameter.

g) n: Number n of samples during the collection of values.

h) Year: Year of publication of the referenced publication.

i) WebLink: Access link of the referenced publication.

Information such as statistics by species is not available via the API, as these are calculated in real time during requests from the parameter value details page.

4. Discussion

Considering the advances in available computational capacity in recent years, the number of mathematical models that describe cardiac electrophysiology has been increasing on a broader scale. So that way, it strongly contributes to the continuous expansion of the scientific community's knowledge about the complex process of cardiac excitation-contraction coupling, contributing to the scientific community's enlarging acknowledgment of the complex process of cardiac excitation-contraction coupling (Noble et al., 2012).

Due to the growing number of mathematical models in this area, initiatives were implemented to make them available in repositories accessible via the internet. As an example, the CellML project (https://www.cellml.org/) that provides the academic community with access to a wide range of computational mathematical models. Since the models available use a standard language based on XML (eXtensivble Makup Language) enabling the sharing and reuse of components developed (Lloyd et al., 2004).

Another featured repository initiative is maintained by the PhysioNet online community (www.physionet.org), which provides access to its physiological and clinical dataset and related open source software. Providing means for sharing physiological data and algorithms, which can be submitted, discussed, evaluated, reviewed and scrutinized in detail by researchers participating in the project (Goldberger et al., 2000).

Also noteworthy is the Virtual Physiological Rat Project (http://vpr.sites.uofmhosting.net/), having as main focus the biological systems from the molecular level to the organ level for the study of diverse physiological aspects of cardiovascular diseases (Beard et al., 2012).

In addition to these, there are other important repositories that provide mathematical models (Migliore et al., 2003; Cooper et al., 2016; Rodriguez, 2019). However, despite the diverse number of available repositories, these do not specifically

include resources that will allow greater dynamics in the search for cardiac electrophysiology parameters to be used by modelers.

In this sense, the MyocyteDB platform, being proposed in this work, aims to provide immediate access to biophysical parameters used in mathematical models of cardiac electrophysiology. Providing, above all, to be a resource available for registrations and access to sets of parameters related to the work performed by modelers in this area. This repository will allow access by animal species, different parameters and statistical data for simulation and analysis purposes.

5. Conclusion

Currently, the scientific community has continuously expanded its knowledge about the complex process of cardiac excitation-contraction coupling, contributing to the increase in the number of mathematical models that describe cardiac electrophysiology. (Noble et al., 2012).

In fact, the search for values of cardiac electrophysiology parameters sometimes becomes an extensive task, especially when considering the aspects of increasing complexity of current models. The platform for accessing biophysical parameters used in the modeling of the ventricular myocyte, proposed in this work, aims to provide a means of accessing a wide set of data on parameters of cardiac electrophysiology, helping the work carried out by modelers in this area.

Additionally, this work presents the methodology used to collect the data of initial parameters used in the study of mathematical modeling of the electrophysiology of the ventricular myocyte of different animal species and that were used for initial registration in the MyocyteDB platform.

The current stage of development of this platform has as its main focus the storage of values of biophysical parameters used in the mathematical models. With the progress of this work, the development of methodologies and mechanisms that will help the task of collection and availability, including as a support tool for the collection of experimental values.

With the availability of the MyocyteDB platform (myocytedb.org), the future steps will be the implementation of new resources (implementation of statistical graphs, expansion of classes of available parameters, analysis of additional statistics) with the possible evaluation and validation by specialists.

It is expected that the database platform presented in this work, by providing a consolidated view of the biophysical parameters used in the area of ventricular myocyte research, will contribute to the increasing advances in computational mathematical modeling studies in this area.

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