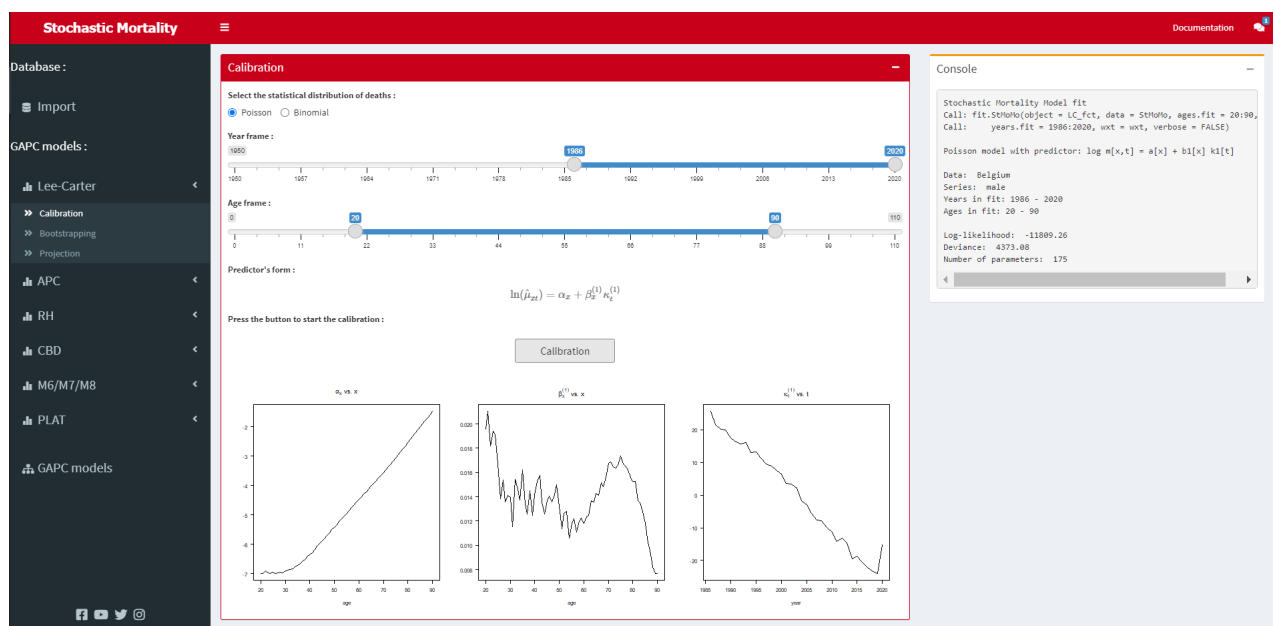


Stochastic Mortality Modeling

Documentation of the R-shiny app: GAPC



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1 Introduction

The purpose of this document is to quickly explain how the R-shiny application works and some of the main features present in the application. The main objective of the application is to provide an intuitive way to work with the R package StMoMo. The application allows the user to quickly calibrate and simulate one-year mortality rates/death probabilities with various generalized age-period-cohort (GAPC) models available in this package. The following document does not explain in detail each algorithm present in the application but rather how to use the application effectively. For more details on how to use some of the functions of the StMoMo package, please consult the StMoMo package documentation available [here](#)¹.

In the following section, we will first discuss the general aspect of the application, and then we will detail each section of the application one by one.

2 General aspect

The application can be started by opening and executing the R file [app-GAPC.R](#) in the folder "TOOL"². A recent version of R is required (the app was developed under the version 4.0.4) and the following packages must be installed :

- [shiny](#)
- [shinydashboard](#)
- [dashboardthemes](#)
- [shinycssloaders](#)
- [demography](#)
- [StMoMo](#)
- [fanplot](#)
- [collapsibleTree](#)
- [sfsmisc](#)
- [forecast](#)

We recommend that you select the "Run External" option (for RStudio users only) available by clicking on the small down arrow next to the "Run App" button. Once the application is launched, a new tab in your default web browser will open and display the

¹<https://cran.r-project.org/web/packages/StMoMo/vignettes/StMoMoVignette.pdf>

²We invite the user to not move files outside the folder!

application (Figure 1).

In the Figure 1, the sidebar is on the left and allows the user to navigate through different sections. The app is composed of two main sections :

- ☐ Database
- ☐ GAPC models

The Database section allows the user to import the chosen database and the GAPC Models section allows the user to choose a particular stochastic mortality model to use on the selected database.

The "GAPC Models" section presents the classification of the different GAPC models in the form of an interactive retractable tree (Figure 2).

At the top right, the "Documentation" box directs the user to the documentation of the R-package StMoMo.

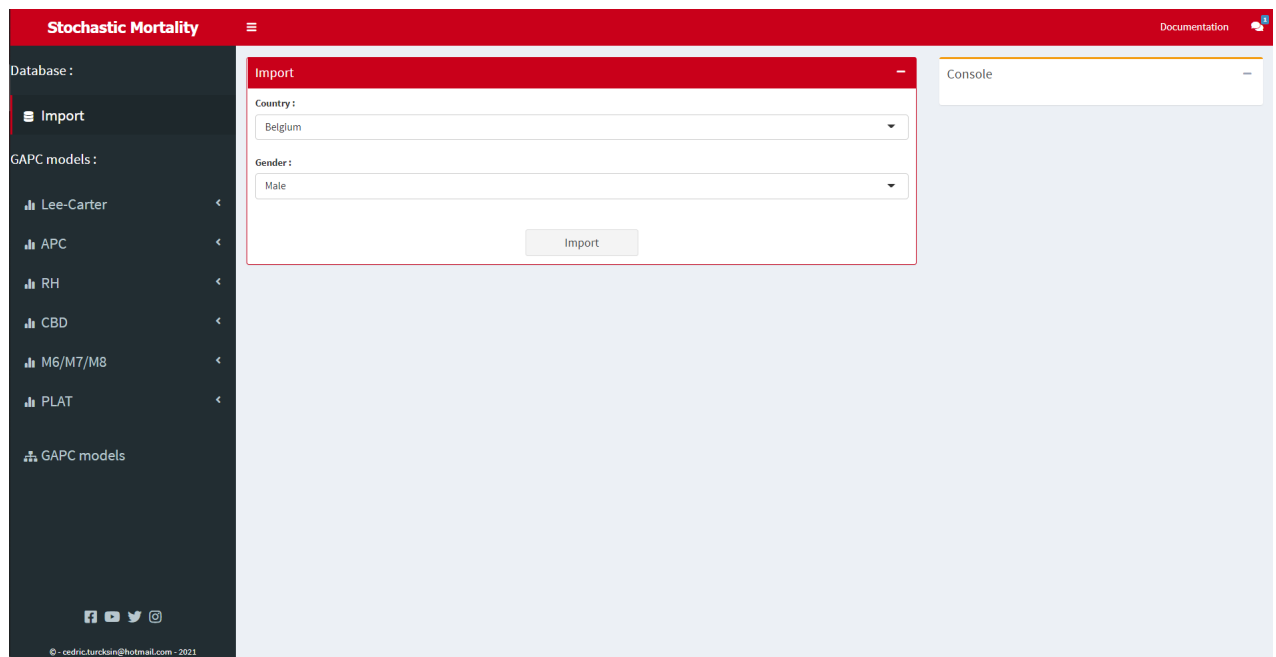


Figure 1: Overview of the application.

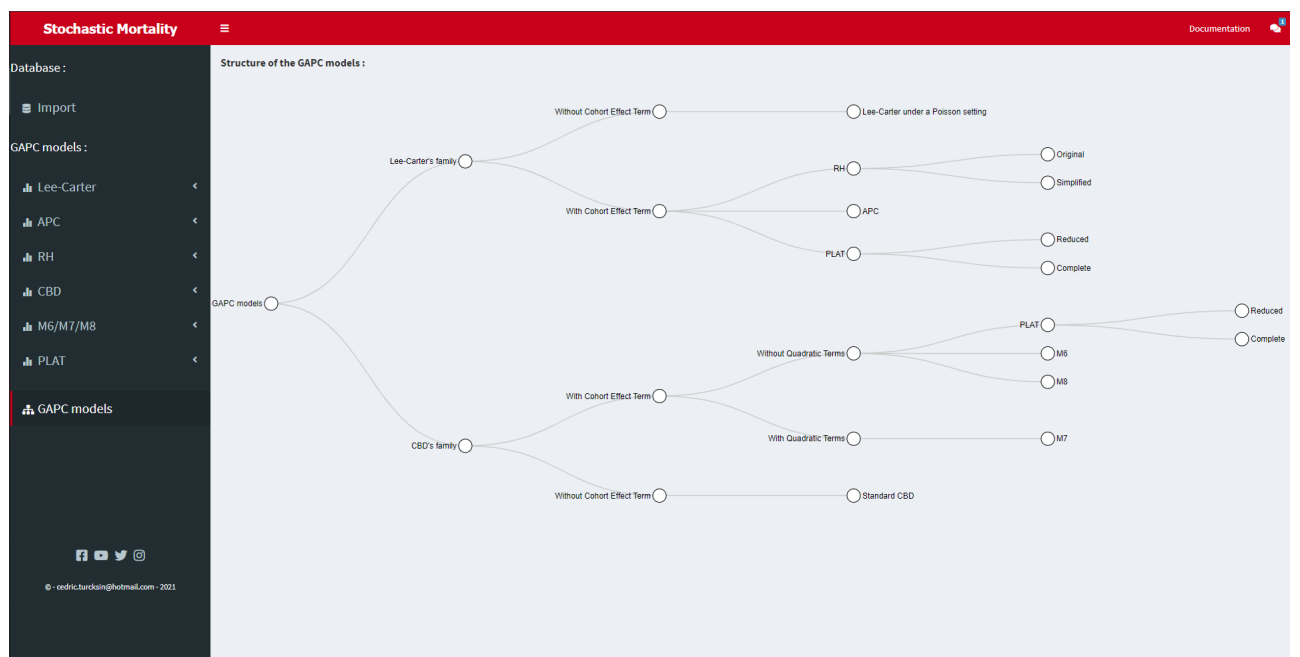


Figure 2: The GAPC models section.

3 Import

The first step is to select the desired database. To achieve this, the user selects the import section from the sidebar (as in Figure 1). Then, in the **Import** tab, the user selects the appropriate country and gender of interest. After this, the user presses the "Import" button and after a moment, a text is displayed in the **Console** tab showing some information about the database. If the user wishes to select another country or gender at a later stage, he simply selects the new country or gender and press the "Import" button again. There is no need to restart the application.

A few words about the database. To calibrate a GAPC model, the application needs two different tables. One is a table containing the number of deaths and the other contains the risk exposure by age and year. Some countries are present in the application but the user may be interested in adding his own database. To do this, the user simply places the desired database in the "Other" folder of the "Database" folder. The user can place the two tables containing the number of deaths and the risk exposure there. We invite the user to make sure that his table is compatible with the application by looking at a database already present in the application to avoid format errors. Indeed, the tables must be in ".txt" format and with "tab" as column separator (Figure 3).

The last thing to do is to put the file name of the two tables in the [app-GAPC.R](#) file on lines 2 and 3.

Year	Age	Female	Male	Total
1950	0	3307.13	4479.54	7786.67
1950	1	206.00	274.03	480.03
1950	2	106.00	152.02	258.02
1950	3	84.00	117.02	201.02
1950	4	55.00	71.00	126.00
1950	5	39.00	47.00	86.00
1950	6	29.00	43.00	72.00
1950	7	30.00	37.00	67.00
1950	8	18.00	25.00	43.00
1950	9	26.00	34.00	60.00
1950	10	28.00	42.00	70.00

Figure 3: Example of a table containing the number of deaths respecting the required format.

4 GAPC models

Once the import phase is done, the user can use various GAPC model present in the StMoMo package :

- Lee-Carter model under a Poisson setting
- APC model
- Renshaw and Haberman model
- CBD model
- M6/M7/M8 model
- Plat model

The user then needs to click on the GAPC model of his choice in the sidebar and three new subsections will appear: Calibration, Bootstrapping and Projection (Figure 4). Each sub-section will be detailed in the following.

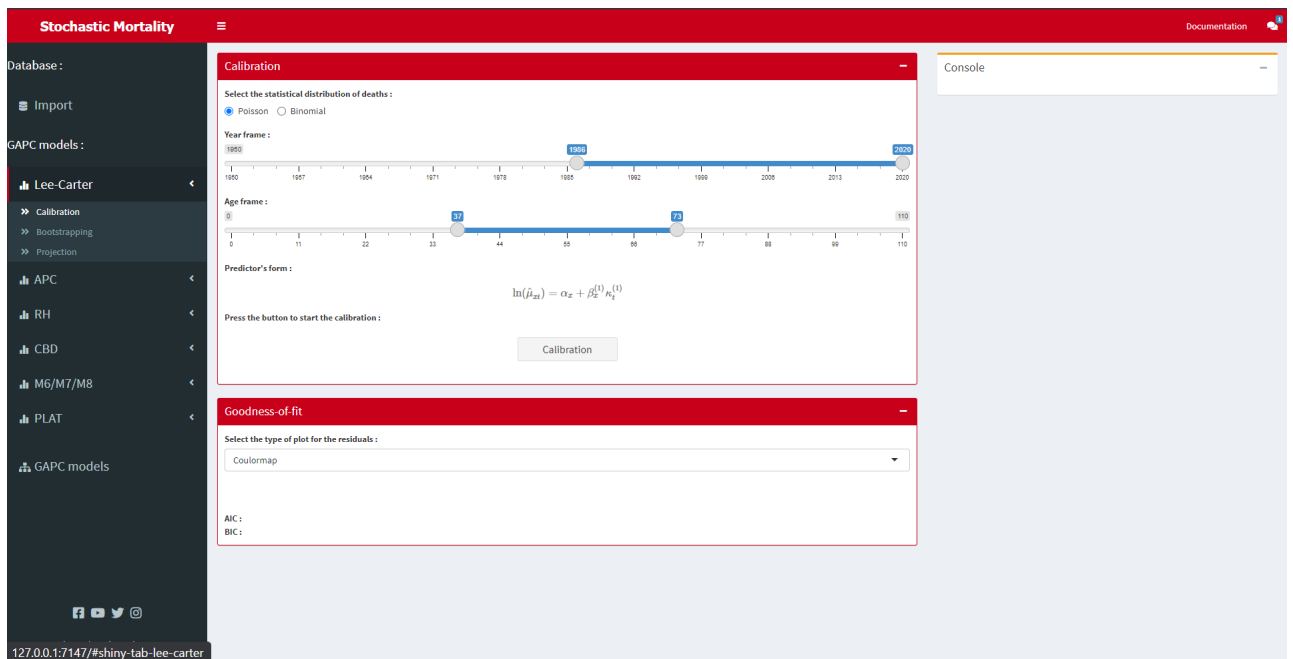


Figure 4: The three new subsections after the user clicks on the Lee-Carter model.

4.1 Calibration

This subsection is composed of 3 different tabs :

- Calibration
- Goodness-of-fit
- Console

In the **Calibration** tab, the user can select the statistical distribution of deaths, the year and the age frame. If the user chooses the Poisson distribution, then the calibration targets the force of mortality μ_{xt} . On the other hand, if he chooses the Binomial distribution then the calibration targets the one-year death probabilities q_{xt} .

Once the user has selected the desired options, he can press the "Calibration" button. The calibration is performed with the function *fit.StMoMo(.)* and the parameters of the GAPC model appear below the button. In addition, some information about the calibration is displayed in the **Console** tab and in the **Goodness-of-fit** tab as we can see in Figure 5.

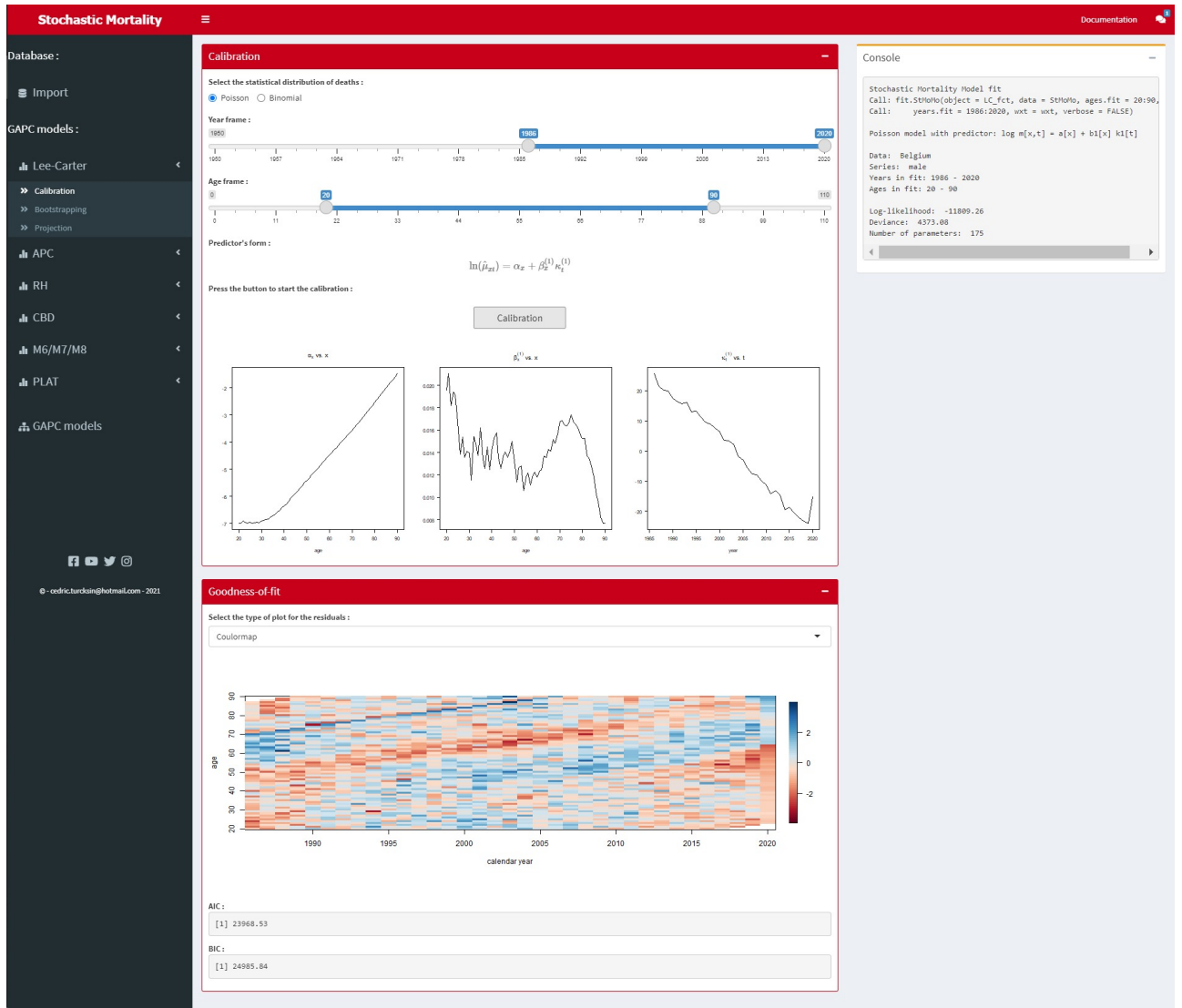


Figure 5: The Calibration subsection for the Lee-Carter model.

4.2 Bootstrapping

Two tabs are present in this section: **Parameter uncertainty** and **Console**. In the **Parameter uncertainty** tab, the user can select the bootstrap method and the number of bootstrap samples to produce. Then, by pressing the "Bootstrapping" button, the parameter uncertainty associated with each parameter of the selected GAPC model is displayed below the button (Figure 6).

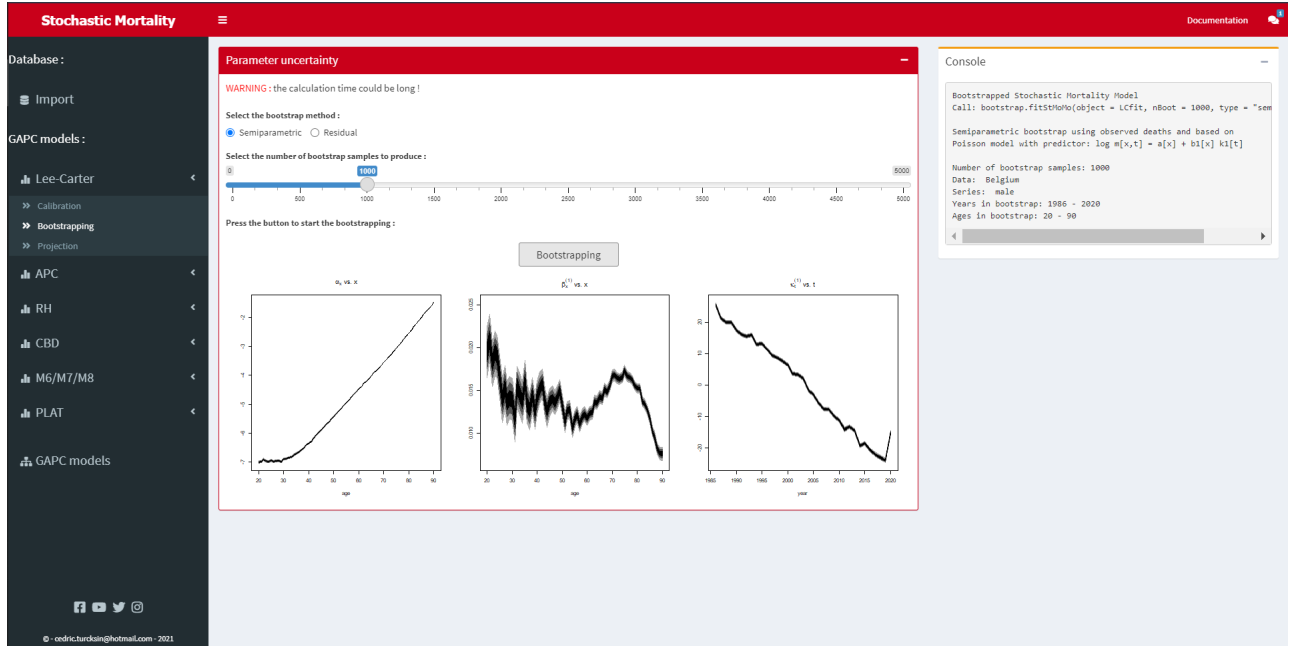


Figure 6: The Bootstrapping subsection.

The bootstrapping procedure is done with the function *bootstrap.fitStMoMo(.)*. As this procedure can be time-consuming, it is possible to skip this step and go directly to the next subsection.

4.3 Projection

The last subsection is composed of 5 different tabs :

- Projection
- Mortality rates
- Life expectancies
- Console
- Download

In the **Projection** tab, the user must choose 5 different options for the projection. The first one is the method of projection for the time-dependent parameters: MRWD³ or ARIMA. If the ARIMA method is selected, the estimation and forecasting of the ARIMA processes is done with the function *Arima(.)* and *auto.arima(.)* from the package Forecast. The second option concerns the jump-off rates, i.e. the rates from the final year of

³MRWD stands for multivariate random walk with drift

observation (the observed one or the fitted one) to be used in the projection of mortality rates. The third one allows the user to set or not the *set.seed(.)* before simulating the time series. The last 2 tabs allow the user to choose the maximum projection year and the number of simulations. Once the appropriate options have been selected, the user can press the "Projection" button and the projected time-dependent parameters of the GAPC model are displayed below along with some information about the projection in the **Console** tab (Figure 7).

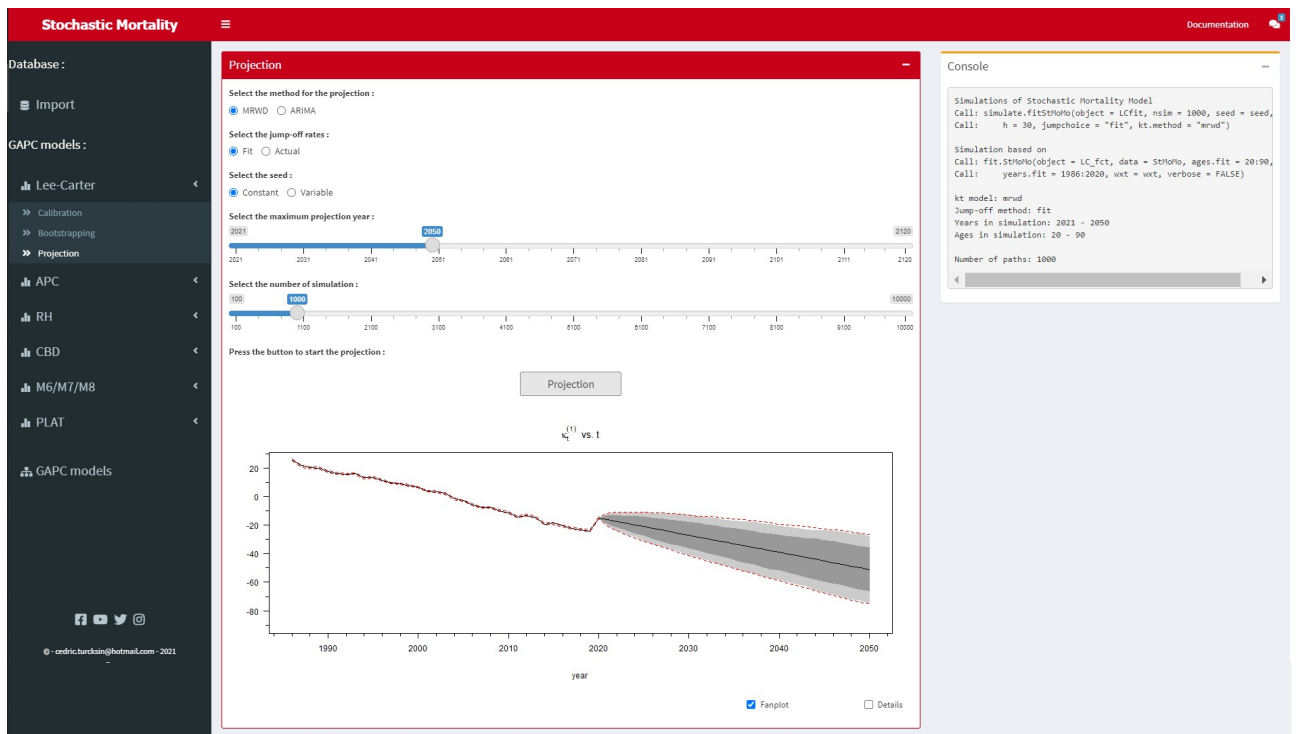


Figure 7: The Projection subsection with the **Projection** tab and the **Console** tab.

The black line in the plot in Figure 7 represents the central forecast. The dark grey corresponds to a confidence interval of 80% and the light grey a confidence interval of 95%. If the bootstrapping step has been done, the red dotted line corresponds to a confidence interval of 95% taking into account the uncertainty of the parameters.

Two small check boxes are present at the bottom of the tab. The "Fanplot" is always selected and displays the graph with the confidence interval. If the box is unchecked, it displays some simulated trajectories of the time-dependent parameters of the GAPC model. The "Details" check box shows some details about the legend of the graph.

After pressing the "Projection" button, the fitted and projected mortality rates and life expectancies appear in the tabs **Mortality rates** and **Life expectancies** (Figure 8 and Figure 9).

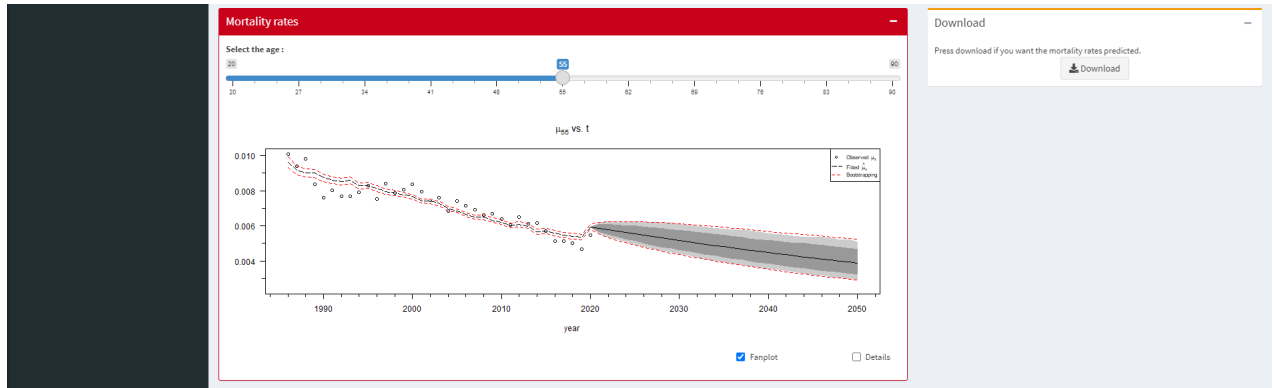


Figure 8: The **Mortality rates** tab and the **Download** tab.

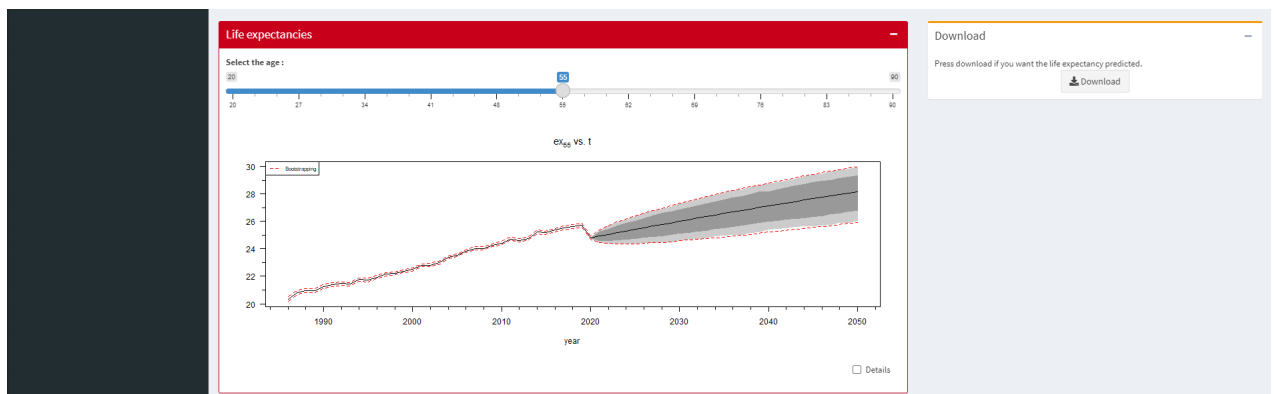


Figure 9: The **Life expectancies** tab and the **Download** tab.

Life expectancies are calculated vertically, which means that the life expectancies for a particular year n are calculated by taking only the mortality rates for that particular year n .

A feature available only for the **Mortality rates** tab and **Life expectancies** tab is hidden in the "details" check box. Once the box is checked, a box appears below the graph with information about the legend and the possibility of obtaining the exact value of the mortality rate or life expectancy of a particular year (Figure 10).

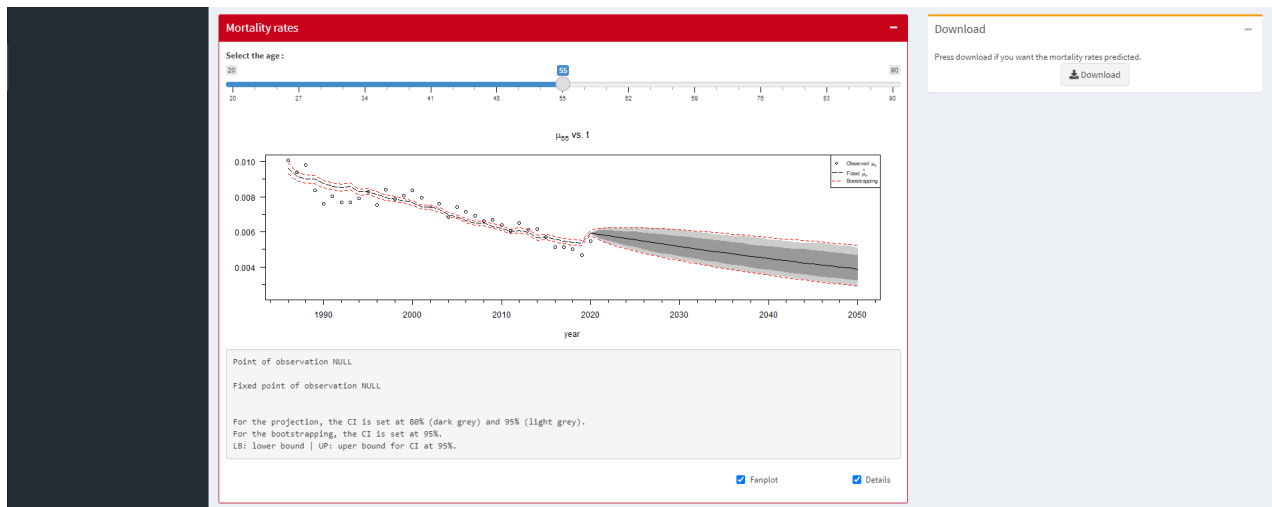


Figure 10: The **Mortality rates** tab with the "details" check box open.

If the user moves the mouse pointer in the graph, the value of the fitted and observed mortality rate for the particular year where the mouse pointer is located is displayed. These values are displayed under "Observation point". If the user clicks on a particular point in the graph, the fitted and observed mortality rate values are displayed under "Fixed observation point".

The last thing to note is that the application allows the user to download the mortality rates and life expectancies obtained with the application. A CSV file is obtained with the following columns:

- Year
- Age
- mx_central
- mx_lower_2.5
- mx_lower_10
- mx_upper_90
- mx_upper_97.5
- mx_lower_BOO_2.5
- mx_upper_BOO_97.5

The `mx.central` corresponds to the fitted mortality rates and the central forecast. The `mx.lower_2.5` and `mx.lower_10` are the lower bound for a confidence interval equal to 95% and 80% respectively. These values are only present for projected years and not for the years present in the calibration step. The `mx.upper_90` and `mx.upper_97.5` are the same but this time for the upper bound. If the bootstrapping step has been performed, the columns `mx.lower_BOO_2.5` and `mx.lower_BOO_97.5` appear for the fitted and projected mortality rates. These 2 columns corresponds to the lower and upper bound of the parameter uncertainty with a confidence interval of 95%.

If you have any further questions, please do not hesitate to contact the author of the application at : cedric.turcksin@hotmail.com

References

- [1] Abel GJ (2015). “fanplot: An R Package for Visualising Sequential Distributions.” *The R Journal*, 7(2), 15–23, URL <https://journal.r-project.org/archive/2015-1/abel.pdf>.
- [2] Hyndman R, Athanasopoulos G, Bergmeir C, Caceres G, Chhay L, O’Hara-Wild M, Petropoulos F, Razbash S, Wang E, Yasmeeen F (2021). *forecast: Forecasting functions for time series and linear models*. R package version 8.15, URL <https://pkg.robjhyndman.com/forecast/>.
- [3] Hyndman R, Khandakar Y (2008). “Automatic time series forecasting: the forecast package for R.” *Journal of Statistical Software*, 26(3), 1–22, URL <https://www.jstatsoft.org/article/view/v027i03>.
- [4] Villegas AM, Kaishev VK and Millossovich P (2018). “StMoMo: An R Package for Stochastic Mortality Modeling.” *Journal of Statistical Software*, 84(3), 1–38, URL <https://CRAN.R-project.org/package=StMoMo>.