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Modeling with R Shiny (Curve Fitting)

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1 Introduction to the Curve Fitting R Shiny tool 曲線擬合R Shiny 工具簡介

R is a powerful statistical programming language that allows us to perform data analysis, which is useful for mathematical modeling. Even better, we have set up a set of online tools using R Shiny so that you can perform various mathematical modelling tasks without any coding background.

R 是一種功能強大的統計程式語言，讓我們能夠進行數據分析，對數學建模十分有用。更理想的是，我們利用R Shiny 建立了一系列線上工具，讓使用者即使不具備程式設計背景，也能夠執行各種數學建模任務。

In particular, the Curve Fitting R Shiny tool allows users to analyse time-series data by applying data filtering and curve fitting methods. Users can first filter the data to reduce short-term fluctuations and then apply different regression models to the filtered data. The tool also allows users to visualize the raw data, filtered data, initial curve and best fit curve, and to predict future data.

具體而言，曲線擬合R Shiny 工具讓使用者可以透過數據過濾及曲線擬合方法分析時間序列數據。使用者可以先對數據進行過濾，以減少短期波動，然後將不同的回歸模型應用於過濾後的數據。工具亦可以顯示原始數據、過濾後的數據、初始曲線及最佳擬合曲線，並可用於預測未來數據。

Here is the guideline on how to use our Curve Fitting R Shiny tool.
以下是有關如何使用我們的曲線擬合R Shiny 工具的指引。

2 Using the Curve Fitting R Shiny tool 使用曲線擬合R Shiny 工具

To use the tool, please visit our main website:
如要使用此工具，可前往我們的主網站：

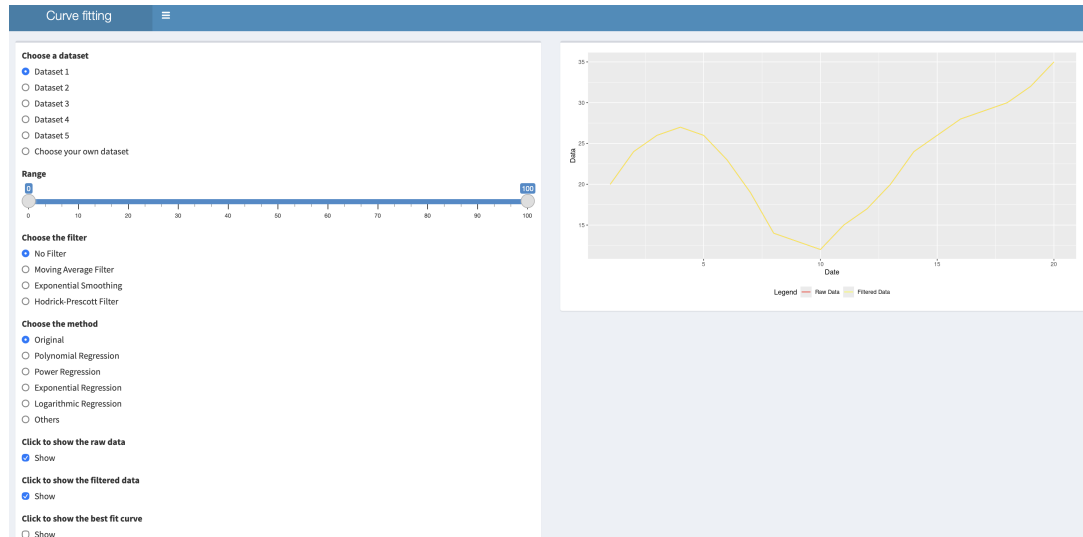
<https://cuhkmathmodel.com/>

for the list of tools, or simply go to
瀏覽工具列表，或直接前往

<https://mathmodelcuhk.shinyapps.io/curve-fitting/>

for the Curve Fitting R Shiny tool.
使用曲線擬合R Shiny 工具。

After getting into the website, you can see the following:
進入網站後，你會看到以下畫面：



Don't worry if you think this is complicated! We will guide you step by step, and you can do curve fitting using our R Shiny tool.
如果你覺得這個界面有點複雜，不用擔心！我們會逐步引導你，讓你能夠順利使用我們的R Shiny 工具進行曲線擬合。

2.1 Step 1: Choose or input a dataset

步驟一：選擇或輸入數據集

At the top of the page, you can see “Choose a dataset”. The tool provides several built-in datasets. You can also select “Choose your own dataset” to upload your own data.

在頁面上方，你會看到「Choose a dataset」。工具提供數個內置數據集，你亦可以選擇「Choose your own dataset」來上傳自己的數據。

Choose a dataset

- ☐ Dataset 1
- ☐ Dataset 2
- ☐ Dataset 3
- ☐ Dataset 4
- ☐ Dataset 5
- ☒ Choose your own dataset

Choose a CSV file (with 1st row being headers, 1st column being dates, 2nd column being data)

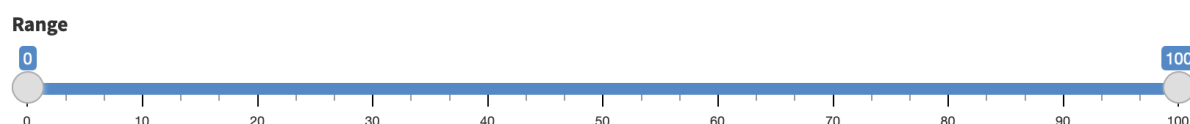
Browse...	No file selected
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If you choose to upload your own dataset, the file should be in CSV format. The first row should contain the column headers, the first column should contain the dates or time points, and the second column should contain the corresponding data values.

如果你選擇上傳自己的數據集，檔案應為CSV 格式。第一行應包含欄位名稱，第一列應包含日期或時間點，而第二列則應包含相應的數據值。

After choosing a dataset, you can use the “Range” slider to select the part of the dataset that you want to analyse.

選擇數據集後，你可以使用「Range」滑桿選擇希望分析的數據範圍。



2.2 Step 2: Data filtering

步驟二：數據過濾

After choosing the dataset and the range of data, you can choose a filtering method under “Choose the filter”. Filtering can be used to reduce short-term fluctuations in the data and make the overall trend easier to observe.

選擇數據集及數據範圍後，你可以在「Choose the filter」中選擇數據過濾方法。數據過濾可以用於減少數據中的短期波動，使整體趨勢更容易觀察。

The tool provides four filtering options: “No Filter”, “Moving Average Filter”, “Exponential Smoothing” and “Hodrick-Prescott Filter”. Depending on the selected method, the tool provides different parameters for controlling the filtering process.

工具提供四種過濾選項：「No Filter」、「Moving Average Filter」、「Exponential Smoothing」及「Hodrick-Prescott Filter」。根據所選的過濾方法，工具會提供不同的參數以控制數據過濾的過程。

Choose the filter

- ☒ No Filter
- ☐ Moving Average Filter
- ☐ Exponential Smoothing
- ☐ Hodrick-Prescott Filter

2.2.1 Moving Average Filter

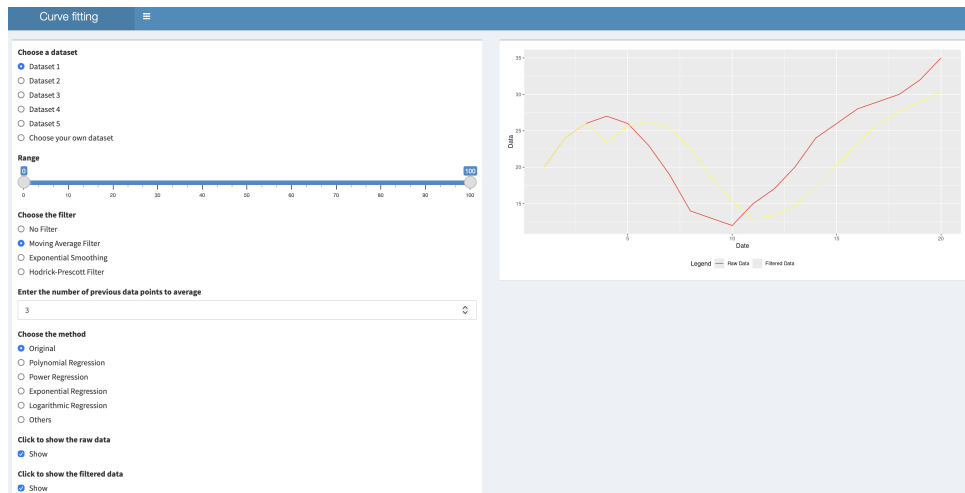
移動平均濾波器

The Moving Average Filter replaces each data value by an average calculated from a specified number of previous data points. To use this method, select “Moving Average Filter” and enter the number of previous data points to average.

移動平均濾波器會使用指定數量的過去數據點計算平均值，並以此平均值表示相應的數據。要使用此方法，選擇「Moving Average Filter」，然後輸入需要計算平均值的過去數據點數量。

For example, if we enter 3, the filtered value is calculated using three consecutive data points according to the filtering procedure. Increasing the number of data points used in the average generally produces a smoother curve, while reducing the number allows more short-term variation to remain visible.

例如，如果我們輸入3，過濾後的數值會根據過濾程序使用三個連續的數據點計算。增加用於計算平均值的數據點數量通常會得到較平滑的曲線，而減少數量則會保留較多短期變化。



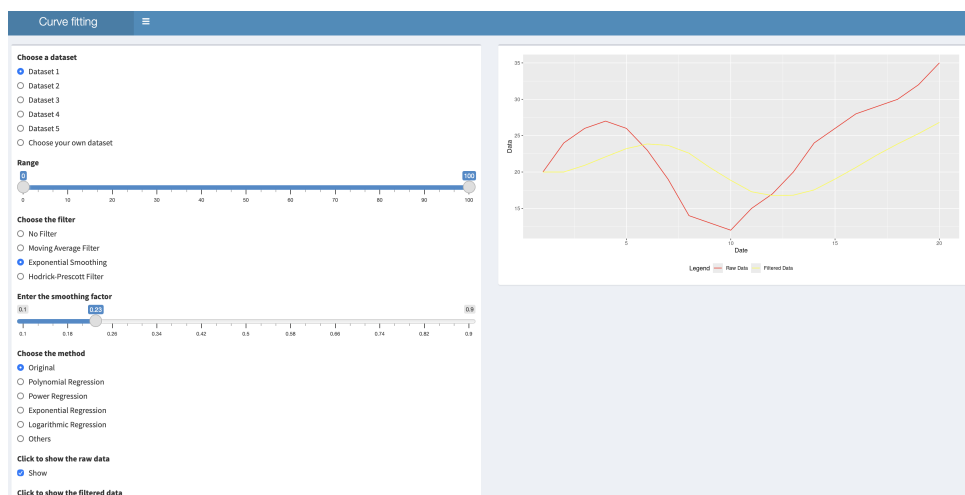
2.2.2 Exponential Smoothing 指數平滑法

Another option is “Exponential Smoothing”. This method gives different weights to the data points, with greater emphasis placed on more recent observations. The smoothing factor controls the degree of smoothing applied to the data.

另一個選項是「Exponential Smoothing」。此方法會對不同的數據點給予不同的權重，並較重視近期的觀察值。平滑因子用於控制數據的平滑程度。

To use exponential smoothing, select “Exponential Smoothing” under “Choose the filter”. A slider will then appear for the smoothing factor, with a range from 0.1 to 0.9. Move the slider to select the desired value.

要使用指數平滑法，請在「Choose the filter」中選擇「Exponential Smoothing」。介面會顯示平滑因子的滑桿，其範圍為0.1 至0.9。移動滑桿以選擇所需的數值。



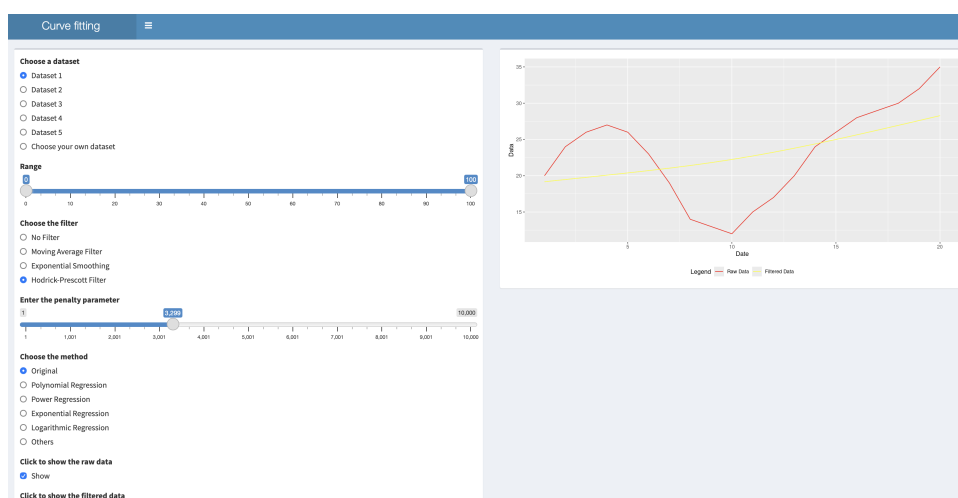
2.2.3 Hodrick-Prescott Filter Hodrick-Prescott 濾波器

The tool also provides a “Hodrick-Prescott Filter”. This method separates a time series into a trend component and a short-term fluctuation component. The penalty parameter controls the smoothness of the extracted trend.

工具亦提供「Hodrick-Prescott Filter」。此方法將時間序列分為趨勢部分及短期波動部分。懲罰參數用於控制所提取趨勢的平滑程度。

To use this method, select “Hodrick-Prescott Filter” under “Choose the filter”. A slider will then appear for the penalty parameter, with a range from 1 to 10000. Move the slider to select the desired value.

要使用此方法，請在「Choose the filter」中選擇「Hodrick-Prescott Filter」。介面會顯示懲罰參數的滑桿，其範圍為1 至10000。移動滑桿以選擇所需的數值。



After choosing a filtering method, select “Show” under “Click to show the filtered data” to display the filtered data on the graph. You can also select “Show” under “Click to show the raw data” to compare the original and filtered data.

選擇過濾方法後，可以在「Click to show the filtered data」下選擇「Show」，在圖表中顯示過濾後的數據。你亦可以在「Click to show the raw data」下選擇「Show」，以比較原始數據及過濾後的數據。

The filtering step does not itself determine the regression model. After obtaining the filtered data, we can proceed to choose a suitable curve fitting method.

數據過濾步驟本身並不會決定所使用的回歸模型。在得到過濾後的數據後，我們可以進一步選擇合適的曲線擬合方法。

2.3 Step 3: Curve fitting

步驟三：曲線擬合

After filtering the data, we can choose a fitting method under “Choose the method”. The selected fitting method is then used to model the data.

完成數據過濾後，我們可以在「Choose the method」中選擇擬合方法。所選的擬合方法會用於建立數據模型。

The tool provides several fitting methods, including “Original”, “Polynomial Regression”, “Power Regression”, “Exponential Regression”, “Logarithmic Regression” and “Others”.

工具提供多種擬合方法，包括「Original」、「Polynomial Regression」、「Power Regression」、「Exponential Regression」、「Logarithmic Regression」及「Others」。

Choose the method

- ☒ Original
- ☐ Polynomial Regression
- ☐ Power Regression
- ☐ Exponential Regression
- ☐ Logarithmic Regression
- ☐ Others

2.3.1 Polynomial Regression

多項式回歸

If “Polynomial Regression” is selected, the tool allows us to choose the degree k of the polynomial. The model has the form

如果選擇「Polynomial Regression」，工具會讓我們選擇多項式的次數 k 。模型形式為

$$y = a_0 + a_1x + a_2x^2 + \cdots + a_kx^k.$$

To use this method, select “Polynomial Regression”. A slider will then appear for the degree k , with a range from 0 to 15. Move the slider to select the desired value

要使用此方法，選擇「Polynomial Regression」，介面會顯示所需的次數 k 的滑桿，其範圍為0 至15。移動滑桿以選擇所需的數值。

Choose the method

☐ Original
☒ Polynomial Regression
☐ Power Regression
☐ Exponential Regression
☐ Logarithmic Regression
☐ Others

Choose the model

☒ Polynomial $y = a_0 + a_1x + \dots + a_kx^k$

Enter the degree k of the polynomial

15

2.3.2 Power Regression 幂回歸

For “Power Regression”, the tool provides the model
對於「Power Regression」，工具提供以下模型：

$$y = at^k.$$

The user needs to provide initial guesses for the parameters a and k . These initial guesses are used as starting values for the fitting procedure.

使用者需要為參數 a 及 k 提供初始估計值。這些初始估計值會作為擬合程序的起始值。

Choose the method

☐ Original
☐ Polynomial Regression
☒ Power Regression
☐ Exponential Regression
☐ Logarithmic Regression
☐ Others

Choose the model

☒ Power Function $y = at^k$

Input the initial guess for a

↕

Input the initial guess for k

↕

2.3.3 Exponential Regression 指數回歸

The tool provides two exponential models:

工具提供兩種指數模型：

$$y = ae^{kt}$$

and

$$y = ab^t.$$

After selecting the desired model, enter the required initial guesses for the parameters.
選擇所需的模型後，輸入相應參數的初始估計值。

Choose the method

☐ Original
☐ Polynomial Regression
☐ Power Regression
☒ Exponential Regression
☐ Logarithmic Regression
☐ Others

Choose the model

☒ Exponential Function $y = ae^{kt}$
☐ Exponential Function $y = ab^t$

Input the initial guess for a

1

Input the initial guess for k

0.1

2.3.4 Logarithmic Regression 對數回歸

The tool also provides two logarithmic models:
工具亦提供兩種對數模型：

$$y = a + k \ln(t)$$

and

$$y = a + \log_b(t).$$

After selecting the desired model, enter the required initial guesses for the parameters.
選擇所需的模型後，輸入相應參數的初始估計值。

Choose the method

☐ Original
☐ Polynomial Regression
☐ Power Regression
☐ Exponential Regression
☒ Logarithmic Regression
☐ Others

Choose the model

☒ Logarithmic Function $y = a + k \ln(t)$
☐ Logarithmic Function $y = a + \log_b(t)$

Input the initial guess for a

0

Input the initial guess for k

1

2.3.5 Other nonlinear models 其他非線性模型

For more advanced curve fitting, select “Others”. The tool provides several nonlinear models, including the Chapman-Richards, Generalized Logistic, Richards, Logistic, Gompertz, Modified Beta, Beta and Weibull functions.

如需進行更進階的曲線擬合，可以選擇「Others」。工具提供多種非線性模型，包括Chapman-Richards、Generalized Logistic、Richards、Logistic、Gompertz、Modified

Beta、Beta 及 Weibull 函數。

These models are useful for modelling data with different growth patterns, such as curves with an upper or lower asymptote, an inflection point, or a changing growth rate. 這些模型可以用於描述不同的增長模式，例如具有上限或下限漸近線、拐點或變化中的增長率的曲線。

Choose the method

- ☐ Original
- ☐ Polynomial Regression
- ☐ Power Regression
- ☐ Exponential Regression
- ☐ Logarithmic Regression
- ☒ Others

Choose the model

- ☒ Chapman-Richards Function $y = y_u \{1 - [1 - (y_l/y_u)^{(1-m)}]e^{(-kt)}\}^{1/(1-m)}$
- ☐ Generalized Logistic Function $y = y_l + (y_u - y_l) / \{[1 + e^{-k(t-t_p)}]\}^{1/v}$
- ☐ Richards Function $y = y_u / \{[1 + e^{-k(t-t_p)}]\}^{1/v}$
- ☐ Logistic Function $y = y_u / [1 + e^{-k(t-t_p)}]$
- ☐ Gompertz Function $y = y_u e^{-e^{-k(t-t_p)}}$
- ☐ Modified Beta Function $y = y_l + (y_u - y_l) [1 + (t_m - t)/(t_m - t_p)] [(t - t_l)/(t_m - t_l)]^{(t_m - t_l)/(t_m - t_p)}$
- ☐ Beta Function $y = y_u [1 + (t_m - t)/(t_m - t_p)] (t/t_m)^{[t_m/(t_m - t_p)]}$
- ☐ Weibull Function $y = y_u - (y_u - y_l)e^{(-kt^m)}$

After selecting a model, the tool asks for initial guesses for the relevant parameters. For example, depending on the model, these may include the lower asymptote y_l , upper asymptote y_u , growth rate k , inflection point t_p and other parameters.

選擇模型後，工具會要求輸入相關參數的初始估計值。例如，視乎所選模型而定，這些參數可以包括下漸近線 y_l 、上漸近線 y_u 、增長率 k 、拐點 t_p 及其他參數。

The initial guesses provide starting values for the fitting procedure. Different initial guesses may affect whether and how quickly the fitting procedure converges to a fitted model.

初始估計值會為擬合程序提供起始值。不同的初始估計值可能會影響擬合程序是否能夠收斂，以及收斂的速度。

2.4 Step 4: Visualizing the fitting results

步驟四：顯示擬合結果

After selecting a fitting method and the required model parameters, we can display different curves on the graph. The tool provides four options: raw data, filtered data, initial curve and best fit curve.

選擇擬合方法及所需的模型參數後，我們可以在圖表中顯示不同的曲線。工具提供四個選項：原始數據、過濾後數據、初始曲線及最佳擬合曲線。

Select “Show” under “Click to show the raw data” to display the original data. Select “Show” under “Click to show the filtered data” to display the data after filtering.

在「Click to show the raw data」下選擇「Show」，可以顯示原始數據；在「Click to show the filtered data」下選擇「Show」，則可以顯示過濾後的數據。

The “initial curve” shows the curve corresponding to the initial parameter values, while the “best fit curve” shows the curve obtained after the fitting procedure. Comparing these curves helps us observe how the model changes during fitting.

「initial curve」顯示根據參數初始估計值所得的曲線，而「best fit curve」則顯示經過擬合程序後得到的曲線。比較這些曲線可以幫助我們觀察模型在擬合過程中的變化。

2.5 Step 5: Prediction

步驟五：預測

After obtaining a fitted curve, the tool can also be used to predict future data. Under “Choose the number of future data to be predicted”, enter the number of future data points that you want to predict.

得到擬合曲線後，工具亦可以用於預測未來數據。在「Choose the number of future data to be predicted」中輸入希望預測的未來數據點數量。

The prediction is based on the selected fitting model. Therefore, the choice of filtering method and fitting model should be made according to the characteristics of the data and the purpose of the analysis.

預測結果會根據所選的擬合模型計算。因此，選擇過濾方法及擬合模型時，應考慮數據的特徵及分析的目的。

3 Conclusion

總結

Curve fitting is a powerful tool in mathematical modelling. By applying different filtering methods and curve fitting models, we can better understand the trends and patterns in datasets and make predictions based on the fitted curves. We hope that this R Shiny Curve Fitting tool may help you with your mathematical modelling journey. Good luck! 曲線擬合是數學建模中極具價值的工具。透過應用不同的數據過濾方法及曲線擬合模型，我們能夠更深入地理解數據集中的趨勢和模式，並根據擬合曲線進行預測。我們衷心希望這個R Shiny 曲線擬合工具能夠在你的數學建模探索旅程中提供協助。祝你一切順利！