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Solving Bernoulli Type Differential Equations Using a Maple Graphical User Interface (GUI) Application

Isa MUSLU*

Abstract

Maplets are Java applets, which are written with Maple that hold all the algebraic computational power of Maple. A Maplet contains one or more windows, which interact with the user by means of buttons, checkboxes, text fields, and other standard graphical controls. Almost all of the Maplets that are available with Maple either display something or compute something; it helps to avoid the standard Maple syntax. The Maplets try to improve the students' intuitive and computational abilities while covering graphical, numerical, and analytical aspects. In this paper, we represent a Maplet application "Solutions of Bernoulli Differential Equations". The Maplet was developed to solve and to teach the solution methods of a Bernoulli Equation. How to use the developed Maplet was explained in the paper. The developed Maplet for Solving Bernoulli type of equations is pedagogical that they ask a student to do something, provide some hints and guidance along the way, and inform the student if their responses are correct or incorrect. It is also possible to see the graph of the solution displayed on the interface as well.

Keywords: Maple, Maplets, Education, Calculus, Differential Equations, Bernoulli Differential Equations.

Introduction

A Maplet enables user access to the parts of Maple relevant to their needs while shielding them from any problems associated with Maple syntax. What the student sees in using Maplets: ***Maplets and Java Swing Classes.***

Maplets use calls to the Java Swing Classes to handle Graphic User Interface (GUI) details. The screen image of the First-Order Linear Differential Equations example provided is typical enough. The elements from the Swing Classes used include dialog boxes (TextBox), and buttons. Items not

Illustrated there are pull-down menus, checkboxes, etc. (One may imagine pedagogic variations of the example in which these might be used. For example, in education, it is often appropriate to ask students to do tasks, and here it may be appropriate to ask them to select from a list of intervals provided via an appropriate element where the function is increasing, etc. Maplets and the Swing Classes cope with this easily.) Many of the other GUI elements are illustrated in the Maplet examples publicly available at the mapleapps.com. Maplets are launched from Maple. Once Maple knows the definition of myMaplet (say), the Maple command for running it is: Maplets [Display](myMaplet): One could hide the Maple - both that defining myMaplet and also the callout to it - in a script or, on Windows, a.bat file. The script would be one which started Maple, read in Maple code which in turn launched the Maplet. (For better methods that will come with Maple 15, see the section, "How Maplets work").

The Instructor: Authoring Maplets

The writing of complex code is a detailed business. The layout has to be specified. The Maplets package for Maple 15 enables the writing of the GUI code to be done from Maple. In writing a Maplet, the first command to Maple is with (Maplets [Elements]);

In my opinion, the easiest way to start writing Maplets is to begin with the examples, and modify them. You will have no difficulty writing simple Maplets. The Maplets package makes intelligent decisions on layout, and for a simple GUI, writing a Maplet is easy; it is also capable of writing more complicated and sophisticated GUIs.

How Maplet works?

The following is a short, description of the Maplets architecture based on that provided by Jason Schattman of Waterloo Maple. The user (student or staff) interacts with the Maplets package within Maple. The Maplets [Elements] part of the package generates an XML description of a Maplet. Using Maplets [Display], this description is sent to the Maplets runtime engine, which is written in Java. This runtime engine interprets the XML description of the Maplet, dynamically creates the necessary user interface (Java Swing) components, and displays the Maplet. There is no single-handed Java code associated to a specific Maplet. Maplets are XML descriptions that are taken as input by a generic runtime engine. We now quote verbatim from the

* *A Lecturer at the University of International Ataturk-Alatoo, imuslu2001@hotmail.com*

Waterloo Maple source: “That said, in Maple 15, users will be able to save a Maplet to a single-handed file, which can be shared with other users. Using “Save as ... Maplet” stores all the information necessary to reconstruct a Maplet to a file. Executing (double-clicking) this file on any computer that has a Maple 15 installation launches the Maplet.”

As a small incremental change? One view of software is that it can come in two main parts - “appliance software” as one part, “environments” as another. “Appliance software” does just one task. Appliance software is easy to use. However, if different appliances come in too many different styles, it can be confusing. Maplets, by using Java Swing classes, should feel familiar to our students. “Computing environments” are, for us, big packages like Maple, Mathematica or Matlab or similar. Such software, which might do many different tasks. The obvious problem with environments is that they can become bloom and hence difficult to maintain as trustworthy software. Maple has avoided too much in-package word processing (as LaTeX does the job) and too much in-package float numeric (as Matlab/Octave) does the job.

Maple aims at extending its functionality by intelligent connection or inter-relation with other software. Adding to its functionality the production of (Java-Swing-based) Maplets seems a reasonable increment. In the near future, maybe most first year students in mathematics departments where Maple is the dominant package in teaching will use Maplets rather than Maple. There should then be a smooth transition at second year to students using pre-prepared Worksheets more than Maplets, with some Maplets around both for those who really don’t want to program and to get continuity with the first year experience. At third year it seems trustworthy to expect all mathematics students to be able to program in Maple to solve proper tasks of their own.

Pedagogic Targets for Maplets Combined with Larger-Scale Teaching Software?

Many Calculus, etc. CDs, DVDs have been written. Some even have Maple as an algebra engine reinforcing them. I imagine that Maplets might provide an attractive way of getting a consistent feel to pedagogic materials of this kind. Perhaps if the Math’s project were to have started now rather than a decade earlier, Maplets would have been seriously considered to reinforce it. In reference (Quinney D., 2001) Douglas Quinney describes “Calculus Machina”. This builds on Java, and is reinforced by its own Computer Algebra system (CAC). Once more again, a reasonable fraction of the work described there could be implemented effectively in Maplets if one were to choose to do so.

In the future? Java, Computer Algebra (CA) and the Web

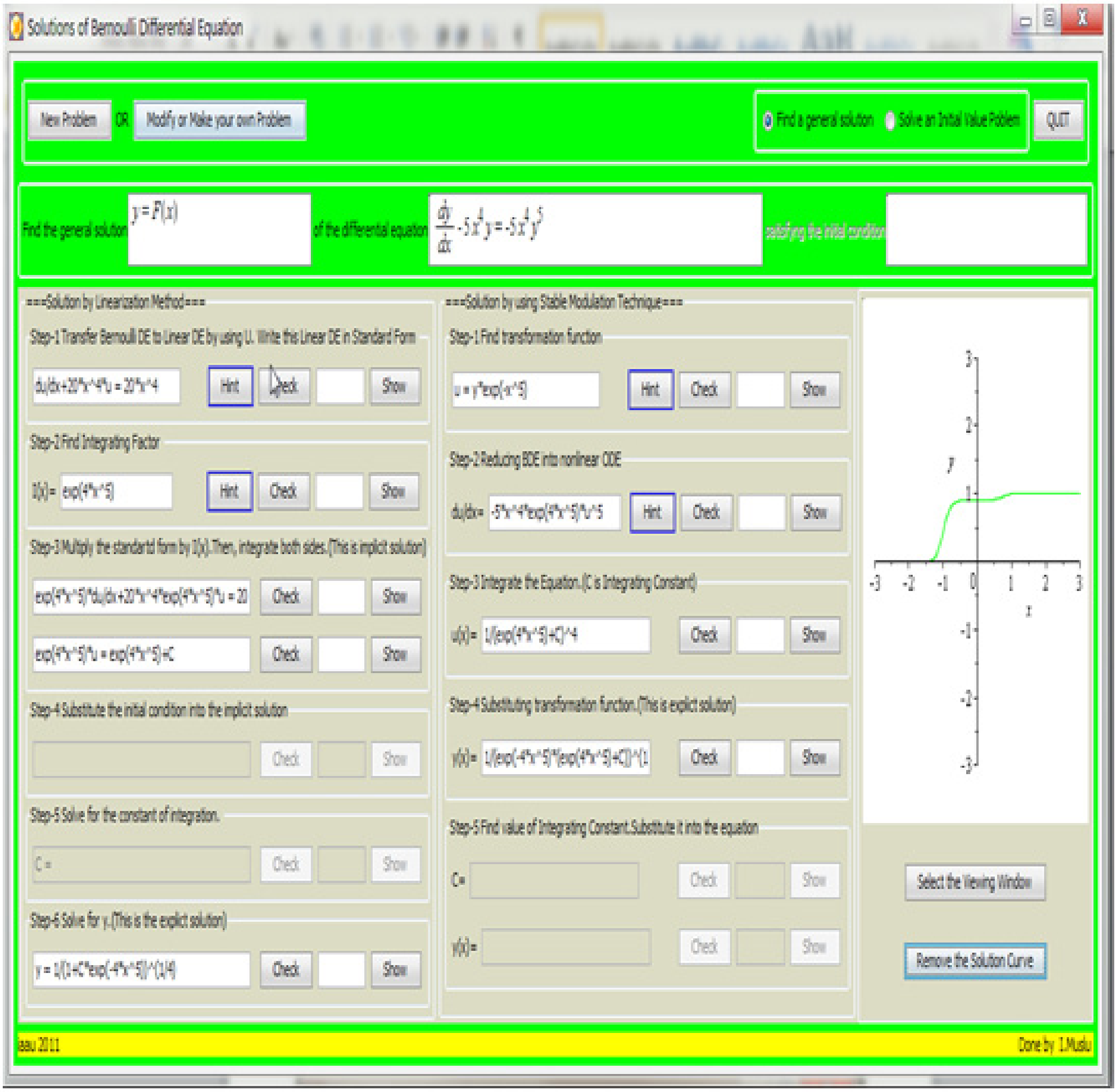
I know of at least three Java-Maple combinations, all Web-server related. The first one is AIM. AIM is reviewed in (Strickland N., 2002). AIM uses Java servlets. The next two use JSP pages and involve GAP or Maple as alternatives in the algebra engine used. They are java math, and the next edition of “Algebra Interactive”. LiveMath, and then called Math View that was reviewed in (Keady G. & Hill D., 1997). At some stage in the future, one can imagine the functionality of LiveMath being delivered from something Maple based. Maybe it will be something that to the students and instructors will feel Maplets-like. It will almost certainly involve some sort of Maple-Java combination. This is enough imagination about the future. Maplets will have some role on the way through to it.

How to Use the Software? “Solutions of Bernoulli Differential Equations”

In the following figures, we represent the usage of the Maplet “Solutions of Bernoulli Differential Equations.” Here we are going to represent two different solution methods “Solution by Linearization Method” and “Solution by using Stable Modulation Technique”. It is both possible to find general solution and solve an initial value problem (IVP) by using the Maplet. Solution steps shall be represented.

In the figure 1-solution steps with two solution methods, solution curve are seen. Here interactively it is possible to see the buttons “New Problem” or “Modify or Make Your Own Problem”, to make new problem automatically or to make your own problem, “hint”, “check”, “show”, “Quit”, To see hint about solution of the problem, to check if our solution is correct or not and to see solution, ”Select the viewing Window” and ”Remove the Solution Curve”. As seen also for the general solution, step three is the last step. In this interface if we choose “Find a general solution”, and then after third step we can see the result of the problem that is chosen automatically or our own problem. If we choose “Solve an Initial Value Problem”, then after the third step the given initial values are going to be inserted in the general solution and after the sixth step we are going to see the exact solution of the chosen problem or our own problem. Graph of solution can be seen at the right side of the Maplet as well.

In the figure 2 it is possible to modify the existing problem or it is possible for the user that to make their own problem. If we want to solve our own problem via this Maplet, we have to insert our problem just by modifying the existing problem. In this interface, we can also change the initial conditions as we wish.



Solutions of Bernoulli Differential Equation

New Problem OR Modify or Make your own Problem

● Find a general solution ○ Solve an Initial Value Problem QUIT

Find the general solution $y = F(x)$ of the differential equation $\frac{dy}{dx} - 5x^4 y = -5x^4 y^5$ satisfying the initial condition

===Solution by Linearization Method===

Step-1 Transfer Bernoulli DE to Linear DE by using U. Write the Linear DE in Standard Form

du/dx+20*x^4*u = 20*x^4

Step-2 Find Integrating Factor

I(x)= exp(4*x^5)

Step-3 Multiply the standartd form by I(x).Then, integrate both sides.(This is implicit solution)

exp(4*x^5)*du/dx+20*x^4*exp(4*x^5)*u = 20

exp(4*x^5)*u = exp(4*x^5)+C

Step-4 Substitute the initial condition into the implicit solution

Step-5 Solve for the constant of integration.

C =

Step-6 Solve for y.(This is the explicit solution)

y = 1/(1+C*exp(-4*x^5))^(1/4)

===Solution by using Stable Modulation Technique===

Step-1 Find transformation function

u = y^4*exp(-x^5)

Step-2 Reducing BDE into nonlinear ODE

du/dx= -5*x^4*exp(4*x^5)*u^5

Step-3 Integrate the Equation.(C is Integrating Constant)

u(x)= 1/(exp(4*x^5)+C)^4

Step-4 Substituting transformation function.(This is explicit solution)

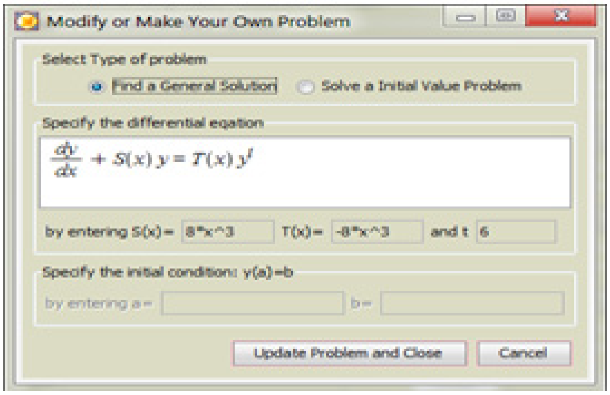
y(x)= 1/(exp(-4*x^5)*(exp(4*x^5)+C))^(1

Step-5 Find value of Integrating Constant.Substitute it into the equation

C=

y(x)=

Figure 1. *General view of "Solutions of Bemoulli Type Differential Equations" Maplet*



Modify or Make Your Own Problem

Select Type of problem

● Find a General Solution ○ Solve a Initial Value Problem

Specify the differential eqation

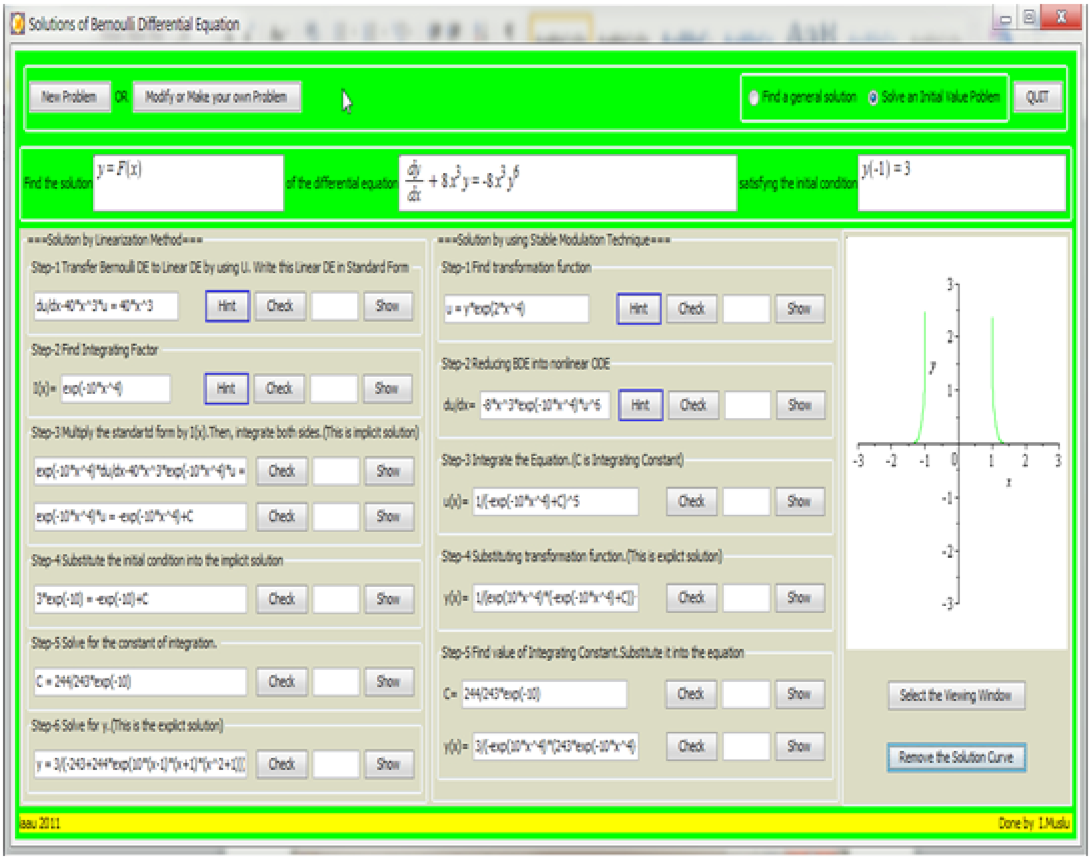
$\frac{dy}{dx} + S(x)\,y = T(x)\,y^t$

by entering S(x)= 8*x^3 T(x)= -8*x^3 and t 6

Specify the initial condition: y(a)=b

by entering a= b=

Figure 2. *Modify or make your own Problem*


Solutions of Bernoulli Differential Equation
New Problem
OR
Modify or Make your own Problem
○ Find a general solution
● Solve an Initial Value Problem
QUIT
Hint
Check
Show
Select the Viewing Window
Remove the Solution Curve
y
x
3
2
1
-1
-2
-3
-3
-2
-1
0
1
2
3
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Find the solution $y = F(x)$ of the differential equation $\frac{dy}{dx} + 8x^3 y = -8x^3 y^5$ satisfying the initial condition $y(-1) = 3$

===Solution by Linearization Method===

Step-1 Transfer Bernoulli DE to Linear DE by using U. Write this Linear DE in Standard Form

du/dx-40*x^3*u = 40*x^3

Step-2 Find Integrating Factor

I(x)= exp(-10*x^4)

Step-3 Multiply the standartd form by I(x).Then, integrate both sides.(This is implict solution)

exp(-10*x^4)*du/dx-40*x^3*exp(-10*x^4)*u =

exp(-10*x^4)*u = -exp(-10*x^4)+C

Step-4 Substitute the initial condition into the implict solution

3*exp(-10) = -exp(-10)+C

Step-5 Solve for the constant of integration.

C = 244/(243*exp(-10))

Step-6 Solve for y.(This is the explict solution)

y = 3/(-243+244*exp(10*(x-1)*(x+1)*(x^2+1)))

===Solution by using Stable Modulation Technique===

Step-1 Find transformation function

u = y*exp(2*x^4)

Step-2 Reducing BDE into nonlinear ODE

du/dx= -8*x^3*exp(-10*x^4)*u^5

Step-3 Integrate the Equation.(C is Integrating Constant)

u(x)= 1/(-exp(-10*x^4)+C)^5

Step-4 Substituting transformation function.(This is explict solution)

y(x)= 1/(exp(10*x^4)*(-exp(-10*x^4)+C))

Step-5 Find value of Integrating Constant.Substitute it into the equation

C= 244/(243*exp(-10))

y(x)= 3/(-exp(10*x^4)*(243*exp(-10*x^4)

Figure 3: Solution steps of initial-value problem, Solution Curves

After changing the values just by clicking the button “Update Problem and Close”, we can update the problem. Then on the main interface, the values will be changed automatically.

In figure 3 the solution of an initial-value problem interface is seen. The difference in this interface and the main interface is giving the initial values. In the main interface, some of the fields and buttons are disabled. These disabled buttons are being enabled when we choose “Solve an Initial Value Problem” radio button. In this interface, the solution steps of initial value problem are seen. Here solution of the problem is finished in five steps because with the third step the initial conditions are added. At the right side of the application, the exact solution of the initial value problem can be seen.

Conclusion

In the presented paper a Maple Graphical User Interface (GUI) application, “Solutions of Bernoulli Differential Equations” Maplet, for a nonlinear differential equation, Bernoulli type, is presented. With this pedagogic way, students or users have control if their solution steps are correct or not or they can get hint about the problem solution. They can check the steps if correct or not. If not they can see the hint about the step even if they still can’t find them, they can see the results. After solving the problem, it is possible to plot solution curves of the problem.

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