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A New Methodology to Teach Numerical Methods With MS Excel

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ABSTRACT

Numerical methods are one of the principal tools employed by engineers to solve typical problems that commonly arise at work. These methods are generally only useful when implemented with a computer programming language. Despite this, typical mathematical resources for numerical analysis present an unfriendly environment that prevents a student from acquiring a deeper knowledge of the theory employed to solve each equation and to distinguish between each of the numerical methods in parameters like time and number of iterations. To counter this, the University of A Coruña, in its IV contract program proposed that marine engineering professors define a new educational methodology to implement the learning of numerical methods. Results showed that the principal numerical methods resolution could be solved with Microsoft Excel, where students can attain a higher level of understanding, especially when implemented with graphical representation. Finally, the feasibility of implementing this teaching methodology needs to be analyzed with programming languages like Visual Basic for Applications that when introduced in Microsoft Excel, will allow for better developing the methodology in the future.

1. Introduction

Engineers use Numerical Methods as one of the principal tools to solve common challenges at work. These methods are distinguished as elementary ones such as finding the root of an equation, integrating a function or solving a linear system of equations and as intensive ones such as the finite element method (Numerical methods, 2009). While developing numerical methods, simplifications must be made to progress towards a solution: for example, general functions may need to be approximated by polynomials and in any case computers cannot generally represent numbers exactly. Therefore, numerical methods do not always provide the exact answer to a given problem. They can only tend towards getting closer and closer to a solution with each iteration. Numerical methods are generally only useful when implemented on a computer using a computer programming language.

Despite this, typical mathematical resources present an unfriendly environment that prevents students from understanding the theory employed to solve each equation and to differentiate between each of the numerical methods in parameters like time and number of iterations. This effect is more obvious when we want to express the results in a graphical representation. Consequently, students invest excess time in learning the language and programming the process than in understanding the methodology. These results in marine engineers rejecting all the subjects related with these applications, thus limiting their working abilities and expectations when they complete their studies.

To solve this problem, the University of A Coruña, in its IV contract program proposed to marine engineering professors, to define, a new methodology for engineering education to implement teaching numerical methods in accordance with other research studies (Bustos and Nussbaum, 2008; Welfert and Aguilar, 1998). Consequently, the professors analyzed the principal computing software resources employed to teach mathematics such as C, Matlab, Mathematica, Pascal, FORTRAN, Visual Basic and VBA, from prior experiences in thermodynamics education (Orosa, 2009). Thus they concluded that Microsoft Excel (Canakci, 2007; Alfredo and Noemí, 2000) was the best way to solve these typical engineering problems while working, and that it must be learned at the high school level.

However, this solution does pose a problem when searching for bibliography to do an in-depth analysis of the proposed methodology. No information could be found as there are no books available for a serious study of numerical methods with Microsoft Excel. Furthermore, there was no book on real ap-

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plied case studies either as most books were authored by professors of mathematics and not by engineers. Consequently, in this paper a new methodology for teaching numerical methods was developed with Microsoft Excel.

2. Objectives

The objective of this project was to determine the feasibility of MS Excel to solve the principal numerical methods problems and generate guidebooks with real case studies for marine engineers. The objective is to improve the learning process with less time spent on classes and student, assistance, in accordance with the Bologna declaration.

3. Materials

To achieve these objectives software resources like Matlab (Chapra, 2008), Mathematica (Castillo et al., 1994) and Microsoft Excel (Roman, 2002) were utilized. However, software like Mathematica and Matlab present clear disadvantages in programming time and graphical interpretation when compared with MS Excel. Therefore, this software will permit typical resolution with Matlab and a new resolution with Microsoft Excel 2003.

4. Methods

Professors of the Department of Energy and Marine Propulsion collaborated with professional marine engineers to recompile the most important numerical methods of applications by marine engineers in their daily work.

Following the recompilation process, these professors, along with the professors of the Department of Mathematics of the University of A Coruña, began a resolution process of each typical problem with MS Excel and compiled these resolutions in a guidebook for marine engineering students. The first step was to solve the typical teaching problems and after successfully solving them, realistic applications were done.

To compare the typical software employed for solving numerical methods like matlab and this new procedure with MS Excel, two groups of marine engineers students were compared to solve different equations.

5. Results

5.1. Iteration process in MS Excel

We used the iterative option of MS Excel to emulate the close loop system needed in each iteration process. As seen in Figure 1, if this option is not selected MS Excel will show an error message.

Figure 1: Iteration problems.

To use this option we must select it in the iteration box of the options menu, as seen in Figure 2. In this same Figure the maximum number of iterations and the maximum change are also shown.

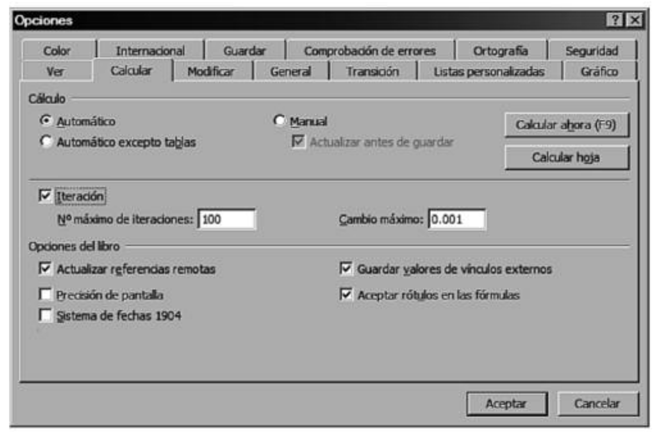

Figure 2: Iteration option.

5.2.Typical MS Excel problems

After defining the iteration process, each of the principal problems was solved employing MS Excel, as shown in Table 1. This table shows the index of the chapters on general numerical methods solved with MS Excel.

Table 1: Problems solved with MS Excel.

1. ROOTS OF EQUATIONS: CLOSED METHODS	
	Bisection method
	The false position method
2. ROOTS OF EQUATIONS OPEN- METHODS	
	Simple Iteration fixed point
	Newton-Raphson Method
	Drying method
	Modified drying method
	Fixed point Iteration for a nonlinear system.
	Raphson methods for a nonlinear system.
3. LINEAR ALGEBRAIC EQUATIONS	
	Determinants
	Cramer rule
	Simple Gaussian elimination
	Inverse matrix
	Gauss Seidel method
4. OPTIMIZATION	
	Finding the Golden Section
	Newton-Raphson method.

5. SET OF CURVES
Linear regression
Linearization of a power equation
Polynomial regression
6. INTERPOLATION
Linear interpolation
7. INTEGRATION
Multiple trapeze rule
Simpson's 1 / 3 Rule of multiple application
8. ORDINARY DIFFERENTIAL EQUATIONS
Euler method
Runge-Kutta method of fourth order
Euler method for ODE systems
Runge-Kutta method of fourth-order systems for EDO

From this table we can deduce that nearly all the numerical problems employed in other subjects can be solved with Microsoft Excel. For example, ordinary differential equations are employed in subjects like control methods (Natick, 2006) where the selection of one or another method depends on the knowledge obtained in previous numerical methods.

5.3. Typical problems for Marine engineers

After determining how to iterate in MS Excel and solve each basic case, some practical case studies were proposed. For example, a typical problem is the duct design. This design depends of the friction coefficient (f) determined by the Colebrook equation, represented in Eq.1.

$$\frac{1}{\sqrt{f}} = -2\log\left(\frac{RR}{3.7} + \frac{2.51}{\mathrm{Re}\sqrt{f}}\right) \tag{1}$$

Where;

RR is the relative roughness.

Re is the Reynolds number.

In our case study the relative roughness will be equal to 0,001 and the Reynolds number 600000. To solve this equation we used the fixed point method based on Eq.2 and an initial value of x=0 to calculate g(x).

$$g(x) = x \tag{2}$$

As this process is convergent, this value will correspond to a better solution, as evident in Eq.3.

$$x^{(n+1)} = g(x^{(n)}) \tag{3}$$

In Figure 3 close loop of MS Excel is seen. In cell A1 the Colebrook equation was introduced with respect to Reynolds number (cell B5) and the relative roughness (cell B4). Finally, in cell A2 it was found that it is equal to cell A1, generating a close loop.

Next, the same problem was solved employing the drag method to better interpret the iterative resolution, as shown in Figure 4. In cell D3 an initial value was introduced and in cell D4 the equation was introduced before the values were obtained.

	D	E	F
1			
2	f^(0.5)	f	Absolute error
3	0.0000001	=D3^0.5	=(E4-E3)/E4*100
4	=1/(-2*LOG((0.001/3.7)+(2.51/(600000*D3))))	=D4^0.5	=(E5-E4)/E5*100

Figure 4: Equations insertion for the drag method.

After inserting the equations the second file of equations was to be dragged down and stopped when the absolute error of the process was zero, as we seen in Figure 5.

	D	E	F
1			
2	f^(0,5)	f	Absolute Error
3	0.0000001	0.00031623	#¡NUM!
4	-0.30835165	#¡NUM!	#¡NUM!
5	0.13925373	0.37316716	0.95341927
6	0.14194753	0.37675925	-0.0117134
7	0.14191429	0.37671512	0.00014197
8	0.14191469	0.37671566	-1.721E-06
9	0.14191468	0.37671565	2.0862E-08
10	0.14191468	0.37671565	-2.529E-10
11	0.14191468	0.37671565	3.065E-12
12	0.14191468	0.37671565	-4.421E-14
13	0.14191468	0.37671565	0
14	0.14191468	0.37671565	0
15	0.14191468	0.37671565	0

Figure 5: Drag method resolution.

As shown in Figure 5, this methodology allows the student to understand the importance of several iterations and to get an instantaneous graphical representation of the process, as shown in Figure 6.

In Figure 6 a graphical representation of the friction coefficient in relation to the number of iterations employed is seen. After four or five iterations the absolute error will show null value and thereby indicate the iteration process is complete, Figure 7.

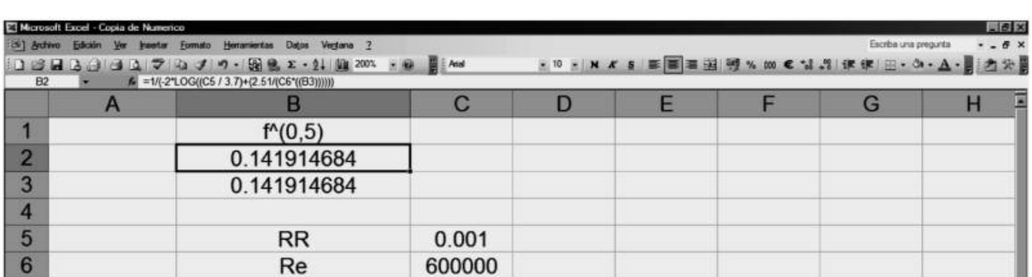

Figure 3: Colebrook equation resolution with the close loop method.

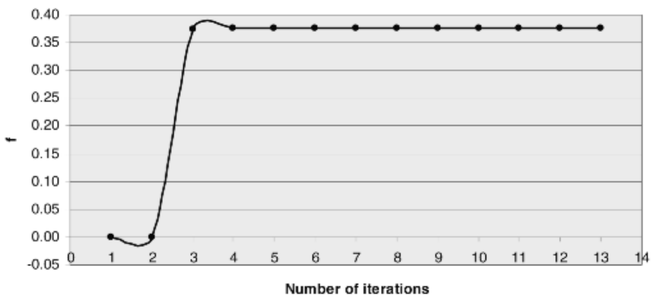

Figure 6: Graphical representation friction coefficient.

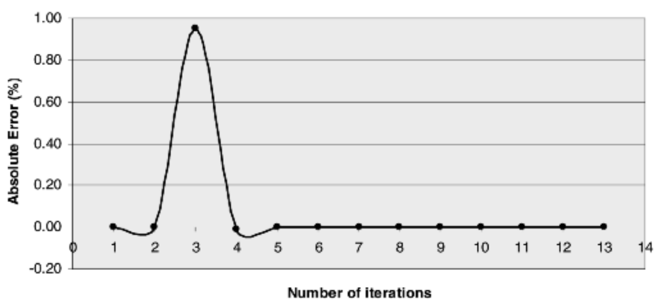

Figure 7: Graphical representation of absolute error.

From this easy and practical resolution of a typical engineering problem the student can understand and represent its typical diagrams as the Moody diagram evident in Figure 8.

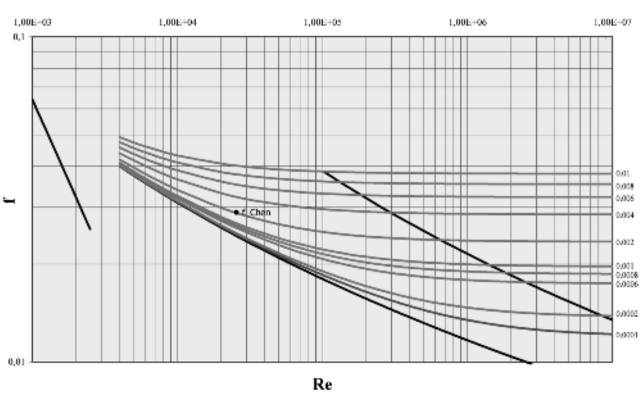

Figure 8: Moody diagram

As in this case, all the typical problems were solved step by step in a book (Orosa and Calvo 2009) that, today has become the guidebook for the new Master of Marine Engineers. With this new methodology and resource, marine engineering students will receive semi-presence education that is according to the Bologna plan with real situation work in ships and power stations away from the high school.

Finally, more collaboration must be done between departments to provide adequate teaching methodology with real situations professional work and not merely purely mathematical resolutions that are not focused on real applications.

6. Conclusions

As discussed, resolutions with the principal numerical methods can be solved with Microsoft Excel. Furthermore, this methodology allows students to clearly understand processes like the time elapsed and the number of iterations employed, expressed as the number of files with the drag method. When students employ the close loop method they understand the importance of time and the need for logical conditions that permit the convergence of its resolutions. Another important difference in the typical numerical resolutions is the graphical representation that allows students to represent and analyze the obtained results in just a few seconds.

However, professors of the different departments need to collaborate in a synergetic process to adapt the mathematical resolution to real case studies. Furthermore, the universities must sponsor these activities to produce their results in books for a semi-presence education.

Finally, future research works needs to be done to quantify the real learning time and its advantages obtained after implementing this new methodology in accordance with the Bologna declaration. Furthermore, the feasibility of implementing this teaching methodology needs to be analyzed with programming languages like Visual Basic for Applications that when introduced in Microsoft Excel, will allow for better developing the methodology in the future.

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