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Scientific Computing and Visualization with Maple in Economics and Economic Research

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***Abstract*—The aim of this paper is to map selected tools offered by Maple and user support provided by Maplesoft Inc. for professional and modern implementation in the field of scientific computing, modeling and visualizations in economics. Such support will be a significant technical advantage in time for use in economic research. The paper analyzes the latest version of the mathematical software Maple for scientific computing in economics and finance. It terms of its implementation in the quantitative modeling, calculations and graphics visualizations, both the direct using of built-in elements and the communication platform supported by the Canadian company Maplesoft Inc. that has developed Maple since 1980. Solutions of economic problems are intimately linked in the number of areas of society. At present, continuous innovations and using of new information technologies is trend in science, education and researches that occurs all over the world. Our efforts in this analysis are one of the preparatory stages to meet the primary objective of the solution of the project "Construction of a complex multi-methods evaluation of performance in selected sectors" (Reg. No. P403/11/2085) realized at the Brno University of Technology and the Mendel University in Brno.**

***Keywords*—economics; Maple system; mathematics; modeling; research**

I. Introduction

Economic modeling represents an inevitable part of contemporary science and researches. The magnitude of the problems in scientific computing [10], [11] in economics is so high that their solving does not only need experts in their particular economic fields but also in computer science in order to perform high-performance computations on today's computing architectures like grids, clouds, and supercomputers [16]. Scientists, teachers and all academicians must be ready to communicate and collaborate in heterogeneous teams to solve current problems in economics. It requires well-structured and highly-developed soft-skills which must be well founded in terms of psychological approaches and pedagogical methods, and supported by information and communication technology (ICT) tools. Simon and Blume in [30] wrote: "*Within the last thirty years, mathematics has emerged as the language of economics. Today economists view mathematics as an invaluable tool at all levels of study, ranging from the statistical expression of real-world trends to the development of fully abstract economic system.*"

The use of quantitative methods in economics (i.e. the methods based in particular on mathematic discipline outputs) is nowadays supported firmly by introduction of numerous mathematical software e.g. the Maple of the company Maplesoft Inc. (Canada), MathCAD of the company PTC Corporate Headquarters (USA), Mathematica of Wolfram Research Inc. (USA), MuPAD of SciFace Software GmbH & Co. KG (Germany), etc. The latest scientific computing in economics are connected with solution of the real problems by applying these ICT [19], [25], [32] where we choose Maple because of its long term use at the Mendel University in Brno (MENDELU) and the Brno University Technology (BUT) since about 1994. The research teams of Faculty of Business and Management (FBM) of BUT and Faculty of Business and Economics (FBE) of MENDELU in Brno are taking part in the research project No P403/11/2085 "*Construction of Methods for Multi-factorial Assessment of Company Complex Performance in Selected Sectors*" since January 2011. The project is being solved thru years 2011-2013 and funded by the Czech Science Foundation. The Maple system has become an important support for processing of this research.

The base for economic modeling and analyses at decision making is focused on mathematical modeling of economic phenomena. Economic modeling is able to have a different character (effected the different access, the option of methods, the availability of means etc.). Mathematical, numerical and statistical methods in economic modeling lead to quantitative modeling and simulation based on so-called deep or shallow way. However primarily at formulation of a real problem from economics we have to provide a qualitative analysis based on intuition, estimation, experiences and common-sense reasoning with the use of efficient ICT tools.

Current economic models used in scientific computing [2], [4], [10] and economic modeling [14], [17], [21], [22], [23], [30] are becoming large and the number of computations needed for their numerical simulation is increasing. Simultaneously, the requirements on economic model performance and accuracy are growing. When simulation economic models are designed we encounter several problems that must be solved in order to achieve these goals. The mathematical software Maple of the Canadian company

Maplesoft Inc. is an appropriate ICT tool and computer environment enabling to solve such problems. Maplesoft's tools provide "whitebox" modeling analysis and optimization tools that give you full control and insight into economic models. With the powerful programming and analysis environment, economists can investigate models in ways not possible with other tools [12], [22], [23].

The extensive collection of powerful analytical tools, including multibody analysis, optimization, sensitivity analysis, and more:

- Sophisticated programming language for customizing existing analysis tools and creating new ones to meet requirements for solving economic problems.
- Easy access to complicated operations, such as symbolic differentiation, symbolic integration, order reduction, variable isolation, and analytical solving of sets of equations, at the click of a button or a single statement.
- Optimizations run with the fastest auto-generated code, providing scalable solutions for enterprise (microeconomics), regional, national and global-level (macroeconomics) requirements.
- Unlimited analysis potential with access to the underlying system equations and the powerful Maple mathematical engine.

A Maple web site offers all of Maplesoft's key user resources in one central location. There is also link to Financial modeling web page [9], which we will introduce later.

Financial and quantitative analysts can use Maplesoft's mathematical environment to analyze data and create forecasts, measure risks, and develop econometric and quantitative algorithms to support their market-making strategies. They are able [3] to use:

- Advanced mathematical and statistical modeling tools. Powerful symbolic and numeric solvers.
- Mathematics-aware programming language for fast prototyping and solution development. Code generation tools for further deployment.
- Full technical document environment which combines live calculations and interactive computations with explanations, images, and more.

Maple gives users an edge in their mathematic, economic and engineering courses. They can finish their assignments faster, improve their understanding of even the most difficult subjects, and explore on their own. Users get in Maple environment:

- *Clickable Mathematics.* [6] They can start solving problems instantly with a click of the mouse. Clickable Math techniques can be applied to problems from all your math, engineering, and science courses.
- *Get help from experts.* Maple brings the problem-solving power of expert mathematicians and economists to student computer.
- *More than just the answer*. Maple provides interactive tutors, mathematical applications (Math Apps), and other learning tools that help students to understand the concept, not just give them the answer of solved tasks. Some tutors, including those for integration and differentiation, even display all the required steps of the solution and offer hints so students can practice on their own.
- *Thousands of functions.* Maple covers virtually every area of mathematics, including calculus, algebra, differential equations, linear systems, statistics, linear algebra, geometry, and transforms, further economics, including one hundred fifty-three matching applications in this category and finance engineering, including twenty-six matching applications in this category [22].

The Student Help Center of Maplesoft [31] offers a Maple student forum, on-line mathematic Oracles, training videos and a mathematics homework resource guide.

The Teacher Resource Center of Maplesoft [34] brings teachers the most of Maple users teaching experience with Maple. It provides sample applications, course material, training videos, white papers, e-books, podcasts, and tips.

Maple's user community is now over two million people in the world. Together with this community the company Maplesoft has built large collections of Maple worksheets and Maple programs, many of them are freely available on at the Application Centre on the Maplesoft web [28] for Maple users to reuse or learn from them [22].

The paper is discussed chosen features of the last versions of Maple (Release16) for scientific computing in economics and its visualization, including economic modeling on-line and its applications in scientific disciplines, especially in the area of economic / financial modeling. Students can learn mathematical modeling as an important interactive support for understanding and presenting solved real economic and financial problems. In this paper is presented chosen basic ideas on process of mathematical modeling of economic phenomena which are demonstrated in examples including Maple visualization tools [1], [3], [9], [12], [28], [31].

II. Interactive Economic Modeling and Simulation with Maple

A. Maple Environment and Clickable Mathematics 3.0

In this chapter we demonstrate chosen previously implemented cross-sectional examples of a utilization and usability of Maple tools to interactive economic modeling and simulation, i.e. construction, analysis, computing and modification of nontrivial economic models of selected real phenomena from practices which need high performance computing [7], [8], [34]. (Note, by reason of the paper extent we will present these facts only very simply.)

With built-in database connectivity, Maple allows economists and scientists to quickly develop and deploy powerful applications that combine large enterprise and open government datasets with the state-of-the-art analysis and

visualization tools of Maple. Maple users can easily query, create, and update your databases within the interactive, user-friendly Maple environment, without any detailed SQL knowledge [21], [24].

The majority of the mathematical algorithms in Maple are written in the very efficient and user friendly Maple Programming Language [3]. Maple users can write simple programs using the same basic tools which the Maple developers themselves use. Moreover Maple users can easily view most of the code in the Maple library and they can even extend the Maple statements, trying their programs in with existing functionality.

New release Maple 16 offers over five thousand functions with the breadth, depth, and performance to handle every type of mathematics [3]. Now, Maple 16 will raise the bar even higher, introducing new, innovative ways to explore mathematics including economic and finance modeling.

Maple is supported by an extensive range of academic resources, including curriculum content, e-books, and application add-on components [12], [13], [15], [17], [18], [22], [24], [33]. We shortly introduce the most important interfaces in Maple 16, which enable on-line economic modeling.

With the Maple environment, the user can create powerful interactive documents. This environment also allows the user to start solving problems right away by entering mathematical expressions in "2-D Math" and solving these expressions using point-and-click interfaces [3]. With Maple, the user can drag input, output, or curves in a plot region into a new input region. This is done by highlighting the input or selecting the curve and dragging it with Maple user mouse into a new input region. We present at (Fig. 1) an example of the Maple worksheet environment.

Maple's remarkable set of user-interface features that makes common mathematical operations as easy as pointing and clicking. For example users can use *Smart Popups* which are interactive pop up menus that are automatically displayed when users select an expression or individual terms in an expression (Fig. 2). They provide a choice of options for manipulating user selection, such as plotting, expanding, factoring, substituting trigonometric expressions, etc. *Smart Popups* work only on the output of a Maple expression or equation.

We can summarize Maple 16 provides both computational power and a new-generation user interface that allows scientists, teachers and students to become proficient with Maple without the burden of learning its commands (statements) and their related syntax. The result is that for example teachers can spend their time teaching mathematics and solving economic phenomena rather than the Maple commands. Overall, teaching, learning and solving problems in economics become more efficient and effective. With collection of Clickable Math tools, including palettes, interactive Assistants, context-sensitive menus, Tutors, and more, Maple has set the standard for making it easy to learn, teach, and do mathematics and solve mathematical problems in economics.

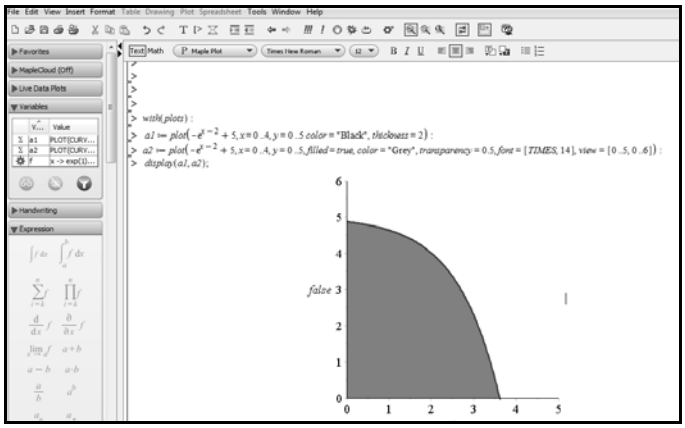

Fig. 1. Smart Maple environment in Maple 16. Source: Own work in Maple

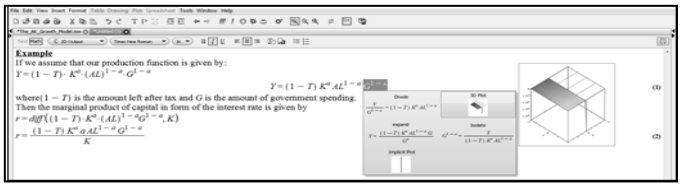

Fig. 2. Smart Popups menu in Maple 16. Source: Own work in Maple

B. Interactive Statistical Computation and Live Data Plots

Statistical computations in Maple 16 combine the ease of working in a high-level, interactive environment with a very large and powerful set of statistical algorithms. Large data sets can be handled efficiently with thirty-five built-in statistical distributions, sampling, estimations, data smoothing, hypothesis testing, and visualization algorithms. In addition, integration with the Maple symbolic engine means that user can easily specify his distributions by combining existing distributions or simply by giving a formula for the probability or cumulative distribution function.

New in Maple 16 are following possibilities [3]:

- Discrete distributions, which are important in many areas from game theory to algorithm analysis, are significantly enhanced, with support for non-integer values as well as sampling of custom discrete distributions.
- Maximum likelihood estimation now allows for multiple parameters and is significantly faster.
- It is easier to split data into subsets based on particular criteria, enhancing your ability to analyse data and identify patterns.
- Statistical visualization is easier than ever before. In addition to the new Live Data Plots, enhancements like variable bin-width histograms and new options for pie charts provide Maple user with extra control over how data is presented.

A new palette in Maple 16 makes it easy to create and customize statistical plots, including area charts, histograms, pie charts, and scatter plots. For more information (bellow).

New Live Data Plots in Maple 16 help with insight, understanding, and publication of Maple user data, all at the click of a button. These plots make it even easier for user to present his data in a form that is visually appealing and conveys meaning. Using the new Live Data Plots Maple user can quickly generate and modify: *Area Charts, Bubble plots, Pie charts, Bar charts, Histograms, Scatter plots, Box plots* and *Line charts*.

Clicking on any of the items (e.g. Scatter plot) in the *Live Data Plots palettes* (Fig. 3) Maple user inserts a task template that lets him to create a customized statistical plot. Maple user simply replaces the placeholder with his own dataset. Both the plot and the plotting statement are displayed, and either can be copied into other parts of Maple user worksheet [3].

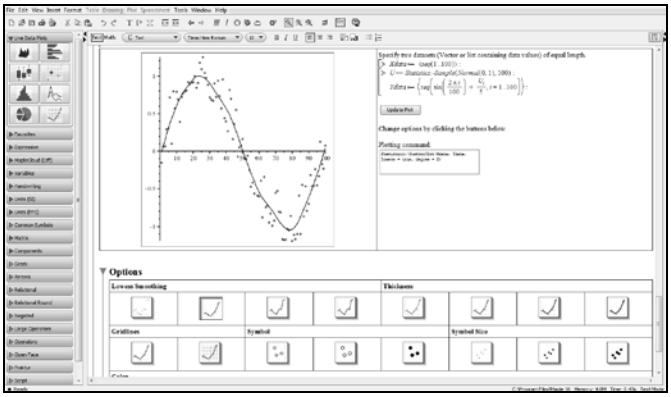

Fig. 3. Example of Live Data Plots palettes for Scatter plot in Maple
Source: Own work in Maple

III. Interactive Modeling and Simulation of the Mortgage Loan with Maple

The Financial Modeling package [9] is a collection of tools for mathematical finance. This package builds on the functionality available in other packages of Maple such as LinearAlgebra, Statistics, Optimization, and CurveFitting. This package supports a wide range of common tasks such as date arithmetic, cash flow analysis, option pricing, term structure analysis, and simulation [28].

The Maple system provides co-called *Quick Help* for Finance package in the *Finance Tour*. (Take a Tour: *Building Trinomial Trees*; *Term Structures of Interest Rates*; *Simulating SVJJ Processes and Sample Document*s: *Calendars and Day Count Conventions*; *Local Volatility and Implied Volatility*; *Pricing Arithmetic Asian Options*; *Pricing European Options*.) [28]

The Finance package obtains following topics: *Date Arithmetic*; *Cash Flow Analysis*; *Financial Instruments*; *Interest Rates; Lattice Methods*; *Short Rate Models; Stochastic Processes*; *Personal Finance*; *Notes*. Furthermore Maple system refers to other applications in the subsection named *See Also*. [28]

The Financial Modeling package gives to companies the important advantage of the technological and informatics support, which can provide in a short period of time a clear position in which the business is located. This simple, effective, and flexibly modifiable system is able to evaluate the current situation, respectively, possible to simulate the situation of the company. It can also provide the support for decision-making and management of the top management of any company.

At first we note, by reason of the paper extent we present this problem in the very simple form.

A. Mortgage Loan

The performance of a company is determined by a number of indicators of economic, environmental, social and corporate governance character. The credit policy of the country offers various types of loans. A low debt ratio may be advantageous for the company.

A mortgage is the basic method for individuals and businesses how they can purchase real property without the need to pay – its value immediately using their own resources, saving. A mortgage is a loan secured by real estate.

We present the example using the Maple which provides important information for the modeling of mortgage. We will use both the interactive elements of the Maple environment (clickable calculus, sliders, visualization) and easily modifiable with built-in support in the area of finance *(Help > Manuals*, *Resources > Math Apps > Finance and Economics*) and its statistical package (Statistics). Note: Based on the theoretical bases in [4], [5], [9], [12], [27], [29] [28], [31] we lead our considerations bellow.

The mortgage loan (mortgage) is a loan intended for natural and legal persons. Several parameters determine the basic characteristics, the structure and the total cost of a mortgage.

Let us consider [9], [28], [31]:

- *DU* (we use the term *DU*, because the term *D* is a fixed predefined the Maple term) – the designation of the principal (equity),
- *i* – the annual nominal interest rate (a decimal number corresponding to an interest rate in percentage),
- *m* – the frequency of payments (the number of times the interest is compounded per year),
- *n* – the number of years (the amortization period, total time for repayment),
- *a* – the annuity (the mortgage payment),
- *v* – the discount factor,
- *A* – the amortization,
- *I* – interest.

Then we can determine the designation *DU* in Maple

$$DU := a\frac{1}{1+i} + a\left(\frac{1}{1+i}\right)^2 + ... + a\left(\frac{1}{1+i}\right)^n \quad (1)$$

Let us denote v:=$(1+i)^{-1}$ discount factor, then from the convenient formula for a geometric series ($v \neq 1$)) follows:

$$DU := \frac{a\,v\left(v^n - 1\right)}{v - 1} \quad . \quad (2)$$

We use Maple commands `subs` and `solve` to receive the corresponding formula for annuity

$$a := -\frac{DU\,i}{\left(\frac{1}{1+i}\right)^n - 1} = \frac{i \cdot DU}{1 - (v)^n} \quad (3)$$

and we obtain for frequency of payments m times per year formula

$$DU := a\frac{1 - \left(\frac{1}{1+\frac{i}{m}}\right)^{mn}}{\frac{i}{m}} \quad . \quad (4)$$

Top managers of a company often have to deal with the evaluation of different situations to make decisions about the mortgage.

B. Example

Define abbreviations and acronyms the first time they are used in the text, even after they have been defined in the abstract. Abbreviations such as IEEE, SI, MKS, CGS, sc, dc, and rms do not have to be defined. Do not use abbreviations in the title or heads unless they are unavoidable.

In this case the annuity a (the mortgage payment) is constant. To do this, we need to know the values of the payment schedule. We use relationships (1) to (6).

We can use Maple commands `seq` which is used to construct a sequence of these values [29].

The most typical calling command in Maple is seq(f(i), i = 1..n), which generates the sequence $f(1), f(2), ..., f(n)$.

More generally, the command `seq`(f(i), i = m..n) generates the sequence $f(m), f(m+1), ..., f(n)$ [9], [28].

After setting and calculating inputs

$i := 0.05 : \; n := 10 : \; DU := 400000 : \; v := \frac{1}{1+i};$

$v := 0.9523809524 ; a := \left(\frac{DU \cdot i}{\left(1 - (v(i))^n\right)}\right); \; a := 51801.83$

and using command according to [29]:

$$matrix\left(10, 5, \left[seq\left(\left[j, a, a\cdot\left(1 - (v(i))^{(n-j+1)}\right), a \cdot (v(i))^{(n-j+1)}, a\cdot\frac{\left(1 - (v(i))^{(n-j)}\right)}{i}\right], j = 1..n\right)\right]\right)$$

we receive the values of the amortization and interest payments (Tab. 1).

TABLE I. THE SCHEDULE FOR REPAYMENT OF PRINCIPAL

Year n	***Annuity a***	***Interest***	***Amortization***	***Rest***
0				$4.0000000\,10^5$
1	51801.83001	20000.00000	31801.83001	$3.6819817\,00\,10^5$
2	51801.83001	18409.90850	33391.92151	$3.3480624\,86\,10^5$
3	51801.83001	16740.31243	35061.51758	$2.9974473\,10\,10^5$
4	51801.83001	14987.23655	6814.59346	$2.6293013\,76\,10^5$
5	51801.83001	13146.50688	38655.32313	$2.2427481\,44\,10^5$
6	51801.83001	11213.74072	40588.08929	$1.8368672\,51\,10^5$
7	51801.83001	9184.336256	42617.49375	$1.4106923\,14\,10^5$
8	51801.83001	7053.461571	44748.36844	96320.86302
9	51801.83001	4816.043151	46985.78686	49335.07618
10	51801.83001	2466.753809	49335.07620	0
$\sum$	$5.1801830\,01\,10^5$ $n \cdot a$	$1.1801829\,99\,10^5$ $n \cdot a - DU$	$4.0000000\,10^5$ DU	--

Source: Owen work according to [29]

Note: Most mortgage lenders offer on their web pages the interactive mortgage payment calculator to determine at least the approximate plan for principal repayment.

Firstly, we can apply *the statistical* package (Statistics) in Maple (especially, subsections *regression*, *plots*) and create the graphic model for the visualization of evaluation development proportions or simulation of development repayments over time (as the composition of the value of amortization paid and interest paid). Both models are exponential functions (Fig.4). (Note: The graphs only approximate given values it can be seen especially near the intersections of curves with axes. But for our orientation, it is enough. The Maple enables to use the weight function *W* = *weights* to strengthen the chosen values of the vector, they are chosen according to economic interpretation.)

Secondly, we can apply the modification of *built-in tools: Math Apps - Finance and Economics* in Maple according to [9], [28]. The great advantage is that the Maple user (without having to create a Maple program) can easily adapt into an existing command structure of the Maple program own commands according to his needs and take the advantage of the built-in worksheet which Maple offers.

We can determine the schedule for repayment of principal with the combination of Maple commands matrix and `seq` (as we mentioned above (Tab. 1), (Fig. 4)). We use relationships (1) to (6).

In this case parameters *n*, *m*, *DU*, *i* are fixed. We have to determine the annuity *a*, which is constant in this case.

Results: If mortgage parameters are *DU* = 400 000 CZK, *n* = 10, *m* = 1, *i* = 0.05 then the annuity *a* is equal to 51 801,83001 CZK and the mortgage total cost is equal to 518 018,30 CZK thereof the interest is equal to 118 018,30 CZK.

Now, we want to compare how the situation will change if we pay every month (10 years), i.e. now *m* = 12. Therefore

using the slider just set the appropriate value of *m*. After setting inputs *DU*:=400 000 and *mn* := 120 calculating *i*:=0.00416666667, *v*:=0.9958506221 and *a:*= 4242.620368 in Maple, we can determine in (Tab. 1) the other matrix of corresponding values analogy with. (Formally, we assign *mn* and *i/m* as *n* and i for reasons of simplification of designation encoded in the source Maple programs, i.e. *n*:=*mn*=120, *i*:=*i/m*=0.05/12).

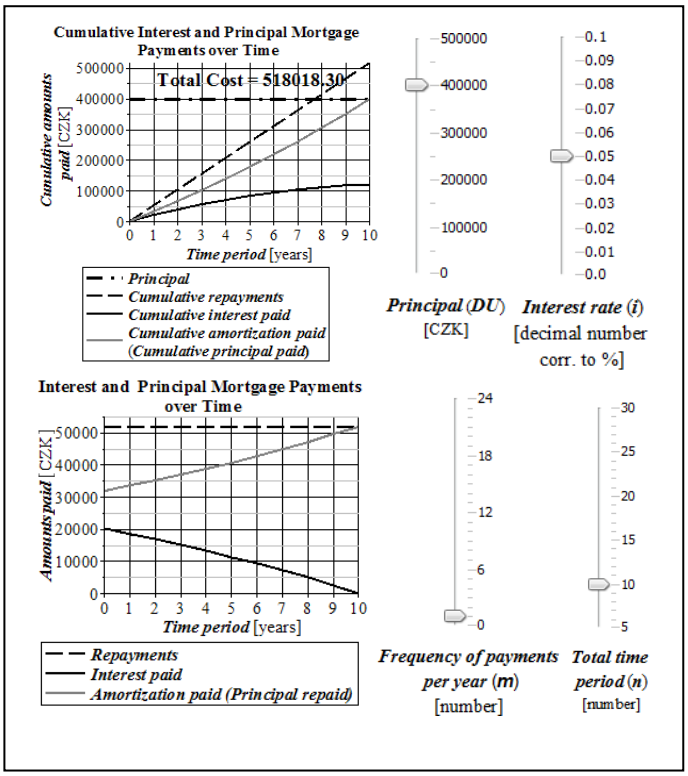

Fig. 4. Development: Interest paid and Amortization paid / Cumulative Interest paid and Amortization paid and Input settings with interactive elements *(sliders*) in Maple with using bulit-in support (*Finance and Economics*).
Source: Own work in worksheet *Mortgage* in Maple 16 [9], [28]. Example of Live Data Plots palettes for Scatter plot in Maple

Results: If mortgage parametres are *DU* = 400 000 CZK, *n* =10, *m* =12, *i* = 0.05 then annuity *a* is equal to 4242,620368 CZK and mortgage total cost is equal to 509 114.44420 CZK thereof the interest is equal to 109 114.44420 CZK.

Finally, we remark that, similarly, we can proceed (using a modification of the presented supports in Maple) when the annuity *a* is a fixed input pre-chosen value and we must calculate the number of years *n* and a residual value for the last installment using derived implementations of mathematical formulas in the source program:

$$n - 1 := \left\lfloor \frac{\ln\left(1 - \frac{i \cdot DU}{a}\right)}{\ln(v)} \right\rfloor , \qquad (5)$$

where for every $x \in \boldsymbol{R}$: floor(*x*) in Maple is the greatest integer less than or equal to *x* (defined by the set equations $[x] \leq x < [x] + 1$). Then the residual value for the last installment is

$$b := \frac{DU - a\frac{1 - v^{n-1}}{i}}{v^n} . \qquad (6)$$

(In our case if we choose the annuity for example *a* = 125 000 CZK, *n* = 4 years ($n - 1 :=$ floor$(3.573535571) = 3$ and *b* = 72436,87508). Further, for the fixed amortization value (a_m) in our case for *DU*:= 400 000, *n*:= 10, *m:*=1 a_m is equal to 40 000.The word "data" is plural, not singular.

IV. Discussion and Conclusion

Our experience in scientific computing and visualization in economics with Maple has followed from teaching, practice and current research in the field of using mathematical modeling of economic phenomena discovered and confirmed a number of important aspects and trends. New competencies of professionals and managers (such as teamwork, communication, other soft-skills, interactivity, intensive knowledge sharing and transfer) are supported by modern tools, as well as by the progress in information and communication technologies represented by grids, clouds, and virtualization in general.

The basic principle of use of Maple system is to create models of economic or financial reality and analyze them. [12], [23]. Thus economic phenomena can have both quantitative and qualitative character [13], [22]. The most of the experiments cannot be repeated [20]. We can obtain often economic data with difficulty [13]. They can be very complex [16], [21]. Data sets can be also very large. [21], [24]. Problems tend to have an interdisciplinary character [21], [26]. The professionals and managers behavior is often based on expert decisions and analysis. Therefore we need a fast and reliable calculations, visualizations, simulations and animations.

The philosophy of the Maple developers is not only in dealing with mathematics, but they take into account the different needs of the users. They continually improve and make a comfortable the working environment. They support the user groups with the specific topics of expertise. They have developed the targeted packages and applications in the documents for other disciplines, courses and competencies of the users. Also, the area of economics and finance is strongly supported. Maple system supports a wide range of professional activities and communications in their specialized and maintained centers.

We have demonstrated through implemented cross-sectional examples of a utilization and usability of Maple tools in scientific computing and visualization of chosen economic problems and phenomena for interactive economic modeling and simulation, i.e. construction, analysis, computing and modification of nontrivial economic models of selected real phenomena from practices. There are also economic problems which need high performance computing. We have also mentioned these properties of Maple system for cloud and grid computing. After the text edit has been completed, the paper is

ready for the template. Duplicate the template file by using the Save As command, and use the naming convention prescribed by your conference for the name of your paper. In this newly created file, highlight all of the contents and import your prepared text file. You are now ready to style your paper; use the scroll down window on the left of the MS Word Formatting toolbar.

Finally, we note that there are currently new version Maple 17 distributed. Previous version Maple 16 was newly distributed in spring 2012.

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