

# PARAMETERIZED EXERCISES IN SMC

João Pedro Cruz<sup>1</sup>, Paula Oliveira<sup>1</sup>, Dina Seabra<sup>2</sup>

<sup>1</sup>*Departamento de Matemática - University of Aveiro (PORTUGAL)*

<sup>2</sup>*Escola Superior de Tecnologia e Gestão - University of Aveiro (PORTUGAL)*

## Abstract

The authoring of parameterized exercises has been a useful activity both for teachers, who could take advantage of databases of parameterized exercises for preparing study materials, but also for students that learn by producing new problems. This has been verified during the realization of MSc dissertations written by High School teachers that, as students again, have written about the positive aspects of their experience in the production of parameterized exercises. Parameterized exercises can also be used in online systems as a secondary study tool for STEM students (such as SIACUA system [2]).

With these goals in mind, we have been developing a package named MEGUA to handle databases of parameterized exercises in the SageMath platform for mathematics. During the use of this system we gathered several requests from users claiming a better system. In this paper we present a redefined tool as well as some first opinions on the new facilities.

Originally, this package had the old SageMath Notebook [4] as a front-end which has been presented in ICERI 2013 [3]. A new version of this package has been developed for the new platform named "Sage Math Cloud" (SMC) running in a secure and centralized web platform creating, for each new project, a virtual Linux machine with shell command access.

In online systems (or cloud), a supervisor could follow student work and help to solve their problems (at distance) since it can see the student work in progress (no need to send emails with attachments).

Keywords: parameterized exercises, mathematics, STEM, cloud, SageMathCloud (SMC), MEGUA.

## 1 MEGUA FOR SMC: A TEACHING TOOL

Parameterized questions and exercises are one of the most important tools for online assessment and learning. However, creating such exercises or questions needs some support on programming tools and this led to the creation of MEGUA project.

We state our three main goals for this tool: MEGUA is an authoring tool giving an environment for an author/teacher to produce parameterized exercises (models as in PmatE system [1]); having a large set of parameterized exercises, any teacher can prepare documents based on those exercises for examination in paper, online tests, study texts, in an organized manner or simply use others work as a ready-to-go package for study; a last goal of this tool, is to provide a means to give students the task to create their own problems and by this achieving a better understanding of the matters at study.

Teachers and students involved in this process report the benefits of such computer tool and present the MEGUA authors with a range of modifications for its improvement. So, this goals makes the project a never ending job and that's what we have been doing since 2011. At that time, we have developed a first version of MEGUA running in a local server. During these years, the collected suggestions for improvements made us take the decision to redefine MEGUA package to work in a more secure and universal cloud tool for mathematics: SageMathCloud (SMC in the following text).

The following sections describe this tool from a technical point of view. For a small analysis of benefits and future work please read the conclusions section.

### 1.1 SageMathCloud (SMC)

We start presenting SMC [5] because we believe it's a powerful environment to use on practicing mathematics at any level of study, since medium school mathematics to graduate studies.

**SageMath and SMC.** SageMath [4] is a free (GPL) library for mathematics embedded in Python (general purpose language with a multitude of libraries), a general and powerful programming tool. It is build on the top of other GPL packages. SMC is a cloud system that offers many services: access to SageMath library, a powerful LaTeX editor where, for instance, student and supervisor can

communicate, and many other programming environments such as Python and a more dedicated GPL system, R, for statistics. All of this can be reached in a shared, online way in the “cloud”.

**Registering.** SMC is open to registration of any user and free to use with certain limitations of memory, cpu time, and restricted access to the net when inside SMC. For certain projects this could be a limitation but by contributing to SMC, as stated in [6], you are contributing also to the free library SageMath because certain aspects of code require a more sustained development. From our perspective, this is inspiring.

**Projects and Users.** In the context of this paper, a project in SMC is seen as a database of exercises for a certain purpose and this project can be shared among collaborators registered as users in SMC. Exercises can be copied between projects or even transformed into new ones inside a new project. The “settings” button in a project, contains means to allow internet access and requesting or accepting collaborators.

**SageWS worksheets.** In SMC we use SageWS as worksheets, as seen in Fig.1, and each containing one single parameterized exercise: a description of the exercise, some details about its construction, its classification, according to the Mathematics Subject Classification, the LaTeX typeset of the exercise, and the programming details on Python. We may also, generate some instantiations of the exercise to make part of the worksheet.

The worksheet portability is also an advantage as it can be sent as a file to another project or by email.



Figure 1

**Menu FILE.** This first menu or SMC (Fig.1 top left) shows folders like EXERCISES and CATALOGS that are produced by the package MEGUA. They contain the exercise worksheets and the outputs in PDF, like a single document containing all exercises or new exams, and also outputs from MEGUA package.

**BASH (or Terminal).** In SMC a “terminal” appears as a special type of “file”. A SMC project is a Linux virtual machine so it’s easy to open the so called “BASH terminals”. From a terminal one can execute MEGUA commands as described later (ex.: megua catalog).

**LaTeX inside SMC.** SMC has the tools to use LaTeX without installing software on the computer. A newcomer to LaTeX, as it happens many times with MSC students, will receive online help in a cloud system, because supervisor can also see in his computer what is being done. Chapters are compiled individually and thus focusing the attention on that specific chapter without having to wait for a full dissertation to be compiled.

**Contributions to SMC.** Working in our package also generated a few contributions to SMC as the request of introducing some new features will turn SMC into a more complete and configurable tool. We hope MEGUA package itself, can become a third-party plugin to SMC when those features become available.

The text included in the sections or subsections must begin one line after the section or subsection title. Do not use hard tabs and limit the use of hard returns to one return at the end of a paragraph. Please, do not number manually the sections and subsections; the template will do it automatically.

## 1.2 Working with package MEGUA

In this section we will describe the use of MEGUA package, making reference to some of its features, usage details and installation procedures.

In [3] we have defined how to create an exercise, so in this paper we only present a summary shown in the Fig.2. In the image we can see the **Summary, a description including its subject**

**classification**, the **Problem** itself and the detailed **Answer** to the problem. Parameters are simple words like `vila1` or `p1` that in each instantiation will be replaced by values or text defined in the programming part of the exercise. The programming language, as has already been said, is Python.

```

meg.save(r''
%SUMMARY Funções trigonométricas; Aplicação
2010 Mathematics Subject Classification
MSC2010 database www.ams.org/msc/
97I20 Mappings and functions
Funções trigonométricas (33B10) Exponential and trigonometric functions
Também pode ser 26A09 Elementary functions
Problema de aplicação do seno e cosseno à determinação de áreas
Palavras chave: Funções trigonométricas; área do losango; área do círculo; seno; coss

%PROBLEM Rotunda
Em vilaloc{"Aguçadoura", "Aguiar da Beira", "Alcains", "Alcantarilha", "Boticas", "Bucelas
Maior", "Canedo", "Favaios", "Freixianda", "Izedã", "Lazarim", "Maceda", "Moimenta da Beira"
}dl$ metros de diâmetro.

\begin{minipage}{7cm}
No seu centro haverá um jardim em forma de losango com $pl$ metros de perímetro.

%ANSWER
\begin{enumerate}
\item A área de um losango é metade do produto das diagonais, 
$$A_{\text{losango}} = \frac{d_1}{2} \times \frac{d_2}{2}$$

Para determinar as diagonais do losango considere-se um dos triângulos retângulos da figura, por exemplo,
perímetro do losango. Como os lados são todos iguais, 
$$\overline{AD} = \frac{pl}{4} = \text{side}lr$$$

```

Figure 2

**Types of exercises.** We are planning MEGUA to manage several types of exercises. Currently we have only LaTeX exercises for paper work or exams, multiple choice questions specifically directed to the SIACUA online system for study [2] and AutoMultipleChoice system (AMC) for paper work (first version). New types of exercises are being planned as they are requested by users.

The names given to the exercises follow some rules according to its type. “E” stands for exercise followed by the Mathematics Subject Classification code. The following field is the name of the topic or its abbreviation and a number, usually composed by three digits regarding the number of exercises on that specific subject. Finally, we have the type of exercise, for instance, LaTeX or Siacua and the extension sagews, for example:

- E97H60\_MatrixProblem\_001\_siacua.sagews
- E97H60\_MatrixProblem\_001\_latex.sagews

**HTML and LaTeX.** The exercises used on web platforms need to be written in HTML and the exercises for paper work are written in LaTeX. In order to ease the conversion of exercises from one type to another some routines were developed, improving the conversion of simple LaTeX commands to HTML.

**Creating a random exercise.** In the first version of MEGUA we declared two routines: `make_random` and `solve`. The first one generates the parameters to be used in the **Problem** section and the latter is used to calculate variables and parameters that appear in the **Answer** part of the exercise. We reached the conclusion that a single routine “`make_random`” is enough for both sections. This function, `make_random`, now has new features allowing to instantiate a class of exercises given a specific group of parameters or cases. For instance, one of the variables of the parameterized exercise can assume positive or negative values, but for a given course the author requests only positive values. That can be specified in the `make_random` function.

**BASH terminal.** As said in the previous section, SMC uses “BASH terminals” where, one can type commands to interact with `megua`. Current commands are:

- `$ megua =>` (shows help),

- \$ megua new => (creates a new exercise and opens the editor),
- \$ megua catalog =>(creates a catalog of all exercises in the project)
- \$ megua remove => (to remove an exercise).

More commands are expected as the package grows.

**EXERCISES folder.** The name of this folder is configured during the installation of MEGUA package. It stores all the parameterized exercises created in the scope of the project. To locate an exercise within this folder is very easy, one just has to use the menu Find at the top.

To **add a new exercise**, one can use the top right box and write the command

- cp <current\_exercise\_name.sagews> <new\_name\_for\_exercise.sagews>

which is used to copy an existing exercise that needs to be modified or adapted.

or, open a BASH terminal and write the command

- megua new <new\_name\_for\_exercise.sagews>

to create a completely new exercise.

To **remove an exercise**, the proper manner is to issue, at a BASH terminal:

- megua remove <name\_of\_exercise.sagews>

To **modify a filename** one can select the menu file and choose the SMC rename button. After renaming the exercise, it must be opened and execute the meg.save cell to acknowledge the changes inside (name is automatically changed).

**CATALOGS folder.** As the name suggests, it's a catalog of all the exercises in a given project. In a BASH terminal, typing

- megua catalog

will create a LaTeX document with an instance of all the existing exercises in the project, including those in other formats besides LaTeX.

We are developing new commands providing different outputs in this folder.

**Error messages.** When creating an exercise using LaTeX and Python, syntactic errors occur frequently. Detecting those errors was a difficult task in the previous versions of MEGUA. The error message is now more informative, showing the text or code nearby the place where the error has been detected by the compiler, making it easier to locate and correct the error.

**Rewriting output expressions.** Sometimes it is important to rewrite expressions that appear in the output of an exercise. For example, instead of “ $e^{2x}$ ” one wishes to read simply “ $e^{2x}$ ”. This could be done by a replacement set of changes like the Fig.3 shows for several cases:

```

modifications = [
    ( ur'e^{\left((.?)\right)}' , r'e^{1}' ),
    ( ur'\log\left((.?)\right)' , ur'\ln\left(1\right)' ),
    ( ur'dy x y', ur'x y dy' ),
    ( ur'dx x y', ur'x y dx' ),
    ( ur'dy x', ur'x dy' ),
    ( ur'dy y', ur'y dy' ),
    ( ur'dx x', ur'x dx' ),
    ( ur'dx y', ur'y dx' ),
    ( ur'^{\left((.?)\right)}' , r'^{1}' )
]

```

Figure 3

**Installing and contributing to MEGUA.** Installing MEGUA package in SMC is easy, following the set of steps in the README section of [3b]. One just needs to create an account in SMC and create a first project.

After the package lands in SMC it is possible to edit `~/megua/conf.py` and give new names to folders and configure parameters. Contributions are welcome and should be mailed to the maintainer at [pedrocruz@ua.pt](mailto:pedrocruz@ua.pt).

## 2 ACHIEVEMENTS AND CONCLUSIONS

Parameterized exercises are essential to the development of online assessment, however elaborating this kind of materials needs some mathematical background, as well as some imagination.

This is the challenge the authors of this paper make to their MSc students. Usually the student picks a mathematics topic he needs for his classes, does a deep study on it, and thinks of exercises he would like to propose to his students.

The next step is to create a parameterized exercise, and if it's a multiple choice questions, he still has the task of creating incorrect answers, distractors, to fulfill the various options of answer. Besides the simple question, a detailed answer to the exercise has to be constructed.

The first contact is a difficult one, but then it's like a game, and MSc students enjoy creating new exercises, knowing that in the future they are provided with different instantiations of an exercise whenever they need.

We found that this type of work, empowers students with a critical thinking about the methods they use to teach their own students, as well as helps them to use a correct mathematical language, specially when writing the detailed answers.

The development of a new MEGUA package for SMC was a response to the requests of our MSc students and other colleagues in University of Aveiro, some of them very profitable in the production of new study materials.

The authors expect to capture more users who dare to create their own exercises, using the new features of MEGUA.

In the future we plan to incorporate internal statistics of usage. Our experience has shown that there are some commands or functions that are often used in several exercises and that could be improved or defined new commands for them.

Also, these statistics could also show us how to direct our students for the essential on creating a parameterized exercise.

For example, we have compiled all 2011-2015 chunks of Python code and realized that instructions with variable attribution (like "var = random value") and some few control instructions using "if statement" are enough to the vast majority of exercises. So, this is where we should start teaching about programming in Python and using the SageMath library.

This kind of studies will help us to improve the quality of exercise production as well as simplifying their construction.

The addition of external statistics of usage of the produced exercises for instance on examinations (online or paper), online self-assessment, could help teachers to plan some other activities or strategies improving the students learning outcomes.

## ACKNOWLEDGEMENTS

This paper was supported by Portuguese funds through the CIDMA - Center for Research and Development in Mathematics and Applications, and the Portuguese Foundation for Science and Technology ("FCT-Fundação para a Ciência e a Tecnologia"), within project PEst-OE/MAT/UI4106/2014.

## REFERENCES

- [1] P. Oliveira, A. Fonseca, A. Ramos, E. Peixoto, S. Gomes, PmatE – 25 Years at the Forefront of Education, Proceedings 11th International Conference on Hands-On Science, January 2014.
- [2] L. Descalço, P. Carvalho, J.P. Cruz, P. Oliveira, D. Seabra. "Using bayesian networks and parameterized questions in independent study". 7th International Conference on Education and New Learning Technologies Barcelona, 6th - 8th of July 2015 (<http://siacua.web.ua.pt>).
- [3] Pedro Cruz, Paula Oliveira, Dina Seabra. "MEGUA package for parameterized exercises." 6th International Conference of Education, Research and Innovation. Seville, Spain. 18-20 November, 2013
  - a. Code in <https://github.com/jpedroan/megua>
  - b. Institutional page in <http://cms.ua.pt/megua>
- [4] W.A. Stein et al., Sage Mathematics Software (Version 7.1), The Sage Development Team, 2016.
- [5] SageMath, Inc., *SageMathCloud Online Computational Mathematics*, 2016. <https://cloud.sagemath.com/>.
- [6] William Stein. "Why should I purchase a subscription?" [github.com/sagemathinc/smc/wiki/Why-should-I-purchase-a-subscription%3F](https://github.com/sagemathinc/smc/wiki/Why-should-I-purchase-a-subscription%3F).

