Chapter 15
Mathematics Exercise Generator: The Language of Parameterized Exercises

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ABSTRACT

Nowadays, the process of teaching and learning is changing from a traditional model in which teachers were the source of information to a model in which teachers appear as advisors who carefully observe students, assist in the selection of information by identifying their learning needs, and support students in their autonomous study. In this chapter, the authors describe an approach used in curricular units of first year in science and engineer degrees, which results from a connection of three projects born in University of Aveiro—MEGUA, SIACUA, and PmatE—and the interconnections of their informatics platforms. Although any scientific area besides mathematics can use this tool, the authors focus in a case study using an example on a specific topic of calculus courses for first year students on Engineering: Sequences and Series of Functions. The methodology described allows teachers to achieve further goals on learning strategies and students to have enough material to practice.

INTRODUCTION

In recent years, the process of teaching and learning has undergone great transformations in its essence. It has been a gradual change from a traditional model in which teachers were the source of information and knowledge to a model in which teachers appear as advisors, or tutors, who carefully observe students, assist in the selection of information by identifying their learning needs and support students in
their autonomous study. Every academic year instructors face the problem of producing several materials for their students. In particular, they seek and produce new problems and new exercises, although what they really do are slight variations of previous exercises as changing the values in an equation, or a parameter in a function. This is a tedious and time-consuming process, and this time is precious for other professional requests as new methodologies to foster learning. It is taken for granted that students want on-line exercises and an immediate feedback on their performance. Furthermore, the paradigm

*studying mathematics = solving hundreds of exercises*

is a problem teachers have to deal with frequently, although they know that there are students who need to practice a lot until they understand the concepts underlying the exercises, whereas some others only need to solve a few exercises to catch all those concepts. Creating new exercises and finding the correspondent solutions is a slow-paced process. To overcome this feature, it appeared in University of Aveiro in the early 90’s, a computer platform, named *PmatE*, that developed the concept of question generator model, QGM (Oliveira, Carvalho, & Vieira, 2004). Since then it has been created a large set of QGMs producing a huge number of exercises on Calculus of one, or several variables, that are being used for self-assessment and evaluation in Calculus courses, enrolling hundreds of students each academic year.

Although random generation data begins to be a tool used in several areas, automated exercise generation and grading is a much more immature problem. Automatic exercise grading is a problem that has been mostly solved, but automated problem generation is a much more open problem (DuFrene, 2016).

Regarding Mathematics, an exercise generator more than simply producing many exercises, is a methodology that works for a general class of proof problems, which involves establishing the validity of a given set of algebraic identities. An exercise generator might be considered as a class of exercises, on one curricular topic, with the same didactic purpose and similar complexity. Each of those classes is characterized by a set of variables assuming random values in their domains, usually subject to some constraints. Whenever the random variables are instantiated, with random values taken from the range defined by the exercise’s author, these values spread all over the scope of the generated exercise. In this way, the whole class of exercises is authored at once by authoring one highly annotated randomized exercise.

This work presents a design of an automated generation of template-based questions, ensuring that most students get different questions of similar complexity, thus benefiting the (self-) assessment process and allowing each student to learn at his own pace. The authors describe an approach used in curricular units of first year in Science and Engineer degrees, which results from a connection of three projects born in University of Aveiro: *MEGUA, SIACUA* and the already cited *PmatE*, and the interconnections of their informatics platforms. To be more precise, the main goal of MEGUA project (Mathematics Exercise Generator, University of Aveiro) (Cruz, Oliveira, & Seabra, 2013) is to create and share parameterized content among several authors. On the other hand, the SIACUA project (Siacua: Interactive Computer Learning System, University of Aveiro, 2017) aims to create computer systems with interaction and feedback to support the autonomous study of students and, in addition with other resources, makes use of a large amount of content created under the MEGUA project. Finally, the *PmatE* project is an evaluation platform, that uses contents created both in the MEGUA platform and in PmatE itself (Projecto Matemática Ensino da Universidade de Aveiro – PmatE/UA, 2019).

The chapter is organized as follows: after a brief background, the formal description of a Mathematics Exercise Generator is introduced, followed by an example withdrawn from a Calculus course for Science
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