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SPREADSHEETS AND LATEX – A PERFECT UNION FOR THE CREATION OF TESTBANKS FOR ONLINE ASSESSMENT

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Abstract

The current COVID-19 pandemic forced an instant shift in teaching from the traditional classrooms to an online format. While it was relatively easy to switch the teaching to online mode, the assessment process presents bigger challenges. Specifically, the assessment quality is compromised because during an online test, most students are able to seek help from their fellow test-takers as well as from different online sources. One way of discouraging the students' tendency to share the answers among themselves is to inform them they will be given different questions than their peers. In this paper, we propose to use spreadsheets to create test questions in Latex format, thus making it easy to present each student with a 'unique' question-set during a test. The uniqueness of the testbank questions comes from randomly generated variable values in numerical questions. The spreadsheet also produces the answers to the questions to help automate the grading process. Such testbanks are suitable not only for normally sized courses, but also for the larger massive open online courses. We have successfully used such testbanks for multiple courses in our university's Computer Engineering program. Originally, we had used the testbanks for in-class assessment. After the classes shifted online, we ported the testbanks to our learning management system to enable online assessment.

Keywords: *Automated assessment, testbank generation, spreadsheet, massive open online course, learning management system (LMS).*

1. Introduction

A challenge faced by an online course, especially a massive open online course (MOOC) is its 'non-equivalence' to an in-person course (Banks & Mienert 2016). A reason for the non-equivalence is the credibility of the online assessment (Ip et al. 2019, Cross et al. 2019, De Rosa & Pistolese 2019). A few companies (for example, ProctorU, Examity, ProctorFree, etc.) offer online/video-based solutions for test proctoring. However, the scalability and the cost of such solutions make virtual proctoring unfeasible for widespread use.

The ongoing COVID-19 pandemic has adversely affected the assessment quality, whether formative and/or summative, for normally sized classes. Not having enough confidence in the online assessment has led many universities worldwide, to assign pass or fail grades, instead of the usual letter grades to the courses.

The testbanks for online assessment need to be created differently than the traditional paper versions. Conventionally, all students in a class were presented single version of a test. However, this approach is not suitable when the students are taking an online test. It is simply because it is now possible, more than ever, for the test-takers to get assistance from their peers and/or other online sources. However, making the students aware that each one of them is getting a 'unique' set of questions, is expected to discourage them from seeking peer help; this will in turn improve the assessment credibility and quality. Generally, for any course that relies on calculations (mathematics, statistics, algebra, etc.), a large testbank comprising unique questions can be created easily. It also implies that such testbanks can be used not only for conventionally sized classes with a dozen to a few hundred students, but also for MOOCs with several thousand students (Anon 2021, Uda 2021). Understandably, the MOOC attendees may vary widely in terms of knowledge, experience, cultural backgrounds, etc., so the testbanks have to be tailored accordingly (Hao & Huiyan 2018).

A few techniques for improving the credibility of online/ unsupervised tests include (Petrovic et al. 2017, Yanes et al. 2020): (a) limiting the time a test is available online, (b) randomizing the question sequence in a test, (c) randomizing answers in multiple choice questions, and (d) presenting each test-taker with the questions that are different from the other test-takers. While the common learning management systems (LMSs) allow the randomization of question sequence and multiple-choice answers, the responsibility of creating testbanks that are large enough to present somewhat if not completely unique tests still lies with the course instructors.

In this paper, we propose a spreadsheet-driven method for creating randomized sets of questions in Latex format. (It is well-known that Latex enables the creation of properly formatted text, equations and diagrams). Such questions are suitable for the testbanks for both the traditional paper-based tests and the online tests. Note that our method does not require any special setup, i.e., online databases, data servers, etc. The questions generated by this method can be readily used with an LMS.

The organization of this paper is as follows: Section 2 provides a brief literature review related to assessment and testbanks. Section 3 includes the details of the proposed spreadsheet-driven approach for automatically creating questions and answers for testbanks. Section 4 explains how to utilize the testbanks for course assessment. Section 5 concludes the paper.

2. Literature review

An academic assessment involves the creation of test questions, most of which are created manually. However, there are alternatives, for example: static test generation based on integer linear programming using multiple assessment variables (Nguyen & Fong 2013), or semantic-based method (Miranda et al. 2013). The dynamic approach of test creation uses the bi-proportional matrix scaling technique (Paul and Pawar 2013). Yuan-Bin and Jie (2012) proposed a fishnet algorithm for automatically generating test sheets for the Examination System of Electrical Energy Measurement. Herman and Handzik (2010) and Herman and Loui (2011) introduced concept inventory for digital logic courses, but they mentioned question creation sans any details. They also did not mention how the answers to the questions would be produced. An adaptive learning approach for creating customized learning paths can be used for the students in the MOOCs or the traditional courses. The learning paths can be tailored using common artificial intelligence techniques, such as data mining, machine learning and predictive analytics (Lu et al. 2018). Ahmed et al. (2018) utilized cosine similarity scores for grading students' text-based answers. They used similarity scores for correct answers and keywords or phrases in the students' answers. Oliveira et al. (2018) proposed the use of online peer assessment using rubrics. This was to evoke motivation and creativity among the students. Beg and Beg (2018) proposed using Latex for generating diagrams for an electrical circuit analysis course. Beg (2020) also proposed using Latex for generating the questions with digital logic diagrams. Both papers relied on Octave-based scripting for generating the Latex code, which meant the test-taker had to have sufficient programming knowledge.

No published literature known to the authors reports using spreadsheets for the purpose of generating Latex-based questions and answers for the testbanks for different fields of study (e.g., business/finance, engineering, science, etc.) – and hence the motivation for this work.

3. Creating test questions and answers using spreadsheets

Our proposed method of using a spreadsheet to generate unique sets of Latex-formatted questions and answers is novel. This method does not require any commercial software or any elaborate setup of database servers, etc. To create the questions, the knowledge of a few spreadsheet functions is sufficient in most cases, and no scripting or programming skills are required.

Our method can be utilized for generating questions that involve numerical calculations, such as, in the fields of engineering, science, business, finance, etc. The method requires the use of two common applications: a spreadsheet (for example, the open-source Libre Office Calc or MS-Excel) and a Latex compiler. If needed, the same compiler can be used to generate image files containing the questions in the desired graphics format, e.g., .PNG, .JPG, etc.

The proposed method of generating questions and answers entails the following steps:

- Generate questions using spreadsheet formulae and pre-defined parameter ranges
- Create randomized diagrams (using Latex-Tikz) if needed
- Generate single answers for the fill-in-the-blank questions or multiple answers for the multiple-choice questions
- Randomize the order of the answers or choices, if using multiple choices
- Generate readily usable Latex code for questions and- answers.

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We have used this method to create fully formatted Latex questions of different types: text-only, text with equations, and text with diagrams. The examples below show two test questions for a digital logic course. The first question involves the creation of text and equations, whereas the second question requires the generation of both text and graphics. For the image, the spreadsheet's `RANDBETWEEN()` and `LOOKUP()` functions randomly specify the logic gates. The gates are inter-connected and then the labels are placed in their proper locations.

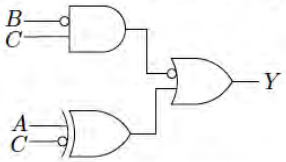
Minimize the following function using Boolean theorems:

$$\bar{A}\bar{B}\bar{C} + \bar{A}\bar{B}C + A\bar{B}C$$

Choose one of the following answers:

(a) $\bar{B}$
(b) $A\bar{B}$
(c) $\bar{C}$
(d) $\bar{B}C + \bar{A}\bar{B}$

Write a Boolean equation for the following logic circuit:



The proposed method can be used for many fields of study. As examples, we have arbitrarily chosen three questions from the fields of computer engineering, physics, and finance. The explanation of each question's creation in Latex format using a spreadsheet is provided.

Example 1: A typical question involving the number system conversion of a mixed number in a digital logic design course may look like this:

Convert the following decimal mixed number into binary format: $26\frac{15}{16}$

Table 1 shows how the question and answer are generated. The question requires three integer values (integer, numerator and denominator) within different ranges. These values are generated using the `RANDBETWEEN()` function. The values are embedded within the question text to form a Latex command. A correct answer is automatically generated by using the `DEC2BIN()` function in cell A6.

Example 2: A typical question on mechanics in a physics course may look like this:

Calculate the distance travelled by a car in 4.9 seconds, if the initial velocity (V_i) = 8 m/s and the acceleration (a) = 3 m/s^2.

The above question is based on this formula:

$$S = V_i t + \frac{1}{2}at^2,$$

where S is the travelled distance, V_i is the initial velocity, a is the acceleration, and t is travel time of a moving object.

Table 2 shows how the question is created and formatted using a spreadsheet. This question uses three randomly assigned parameter values within the specified ranges, utilizing the `RANDBETWEEN()` function. These numerical values are used inside the Latex formatted question text. A correct answer is calculated using basic arithmetic operations in cell A5.

Example 3: In a course on finance, a typical question may require the calculation of present value (PV), as shown below:

Calculate the present value (PV) with compounding, if future value (FV) = 1000, interest rate (r) = 2.5, number of periods (n) = 5, and compounding frequency (m) = 0.5.

The PV is calculated using this formula:

$$PV = \frac{FV}{\left(1 + \frac{r}{m}\right)^{n-m}},$$

where FV is the future value, r is the interest rate, n is the number of periods, and m is the compounding frequency.

Table 3 shows the details of the question creation. The four parameter values are assigned random values based on the specified ranges using the `RANDBETWEEN()` function. The question text and the numerical values are properly combined into Latex format. The correct answer comes from the arithmetic operations in the cell A6.

4. Using the spreadsheet-generated questions and answers for assessment

We have used the proposed method for creating formative and assessment tools, i.e., tests and examinations. The assessment covered three undergraduate courses offered by our university's Department of Computer & Network Engineering.

In the years 2017–2019, we had used our method for creating testbanks for paper-based assessment. After the current pandemic struck, we uploaded the testbanks comprising hundreds of questions into our university's LMS (Blackboard). In the Spring-2020 and Fall-2020 semesters, we successfully used the testbanks to administer LMS-based tests and examinations.

The format of the questions depended on the topics. The questions that were entirely text-based were uploaded in the LMS purely in plain-text format, whereas the questions that included equations and diagrams were uploaded as image files.

5. Conclusions

Our proposed method of generating testbanks for questions can be used in the assessment of a variety of courses. This method has been used in paper-based and LMS-based assessment in our Computer Engineering program. For us, the next task is to use this method in assessing the students in business and finance courses offered by our university's College of Business & Economics. Yet another planned task is to scale the assessment for a MOOC.

Table 1. Creating a question and answer for number system conversion in a digital logic design course.

Cell No.	Formula	Parameter values and Latex output	Comments
A1	`=RANDBETWEEN(20,50)`	26	Integer
A2	`=RANDBETWEEN(4,6)`	4	Fraction – $\log_2$ of denominator
A3	`=2^A2`	16	Fraction – denominator
A4	`=2*RANDBETWEEN(3,A3/2)-1`	15	Fraction – numerator (an odd number)
A5	`="Convert the following decimal mixed number into binary format: $" & A1 & "\frac{" & A4 & "}{" & A3 & "}$"`	Convert the following decimal mixed number into binary format: $26\frac{15}{16}$	Question
A6	`=DEC2BIN(A1,6) & "." & DEC2BIN(A4,A2)`	011010.1111	Answer

Table 2. Creating a question and answer for speed calculation in a physics/mechanics course.

Cell No.	Formula	Parameter values and Latex output	Comments
A1	`=RANDBETWEEN(2,5)`	3	Acceleration (a)
A2	`=RANDBETWEEN(2,10)`	8	Initial velocity (V_i)
A3	`=RANDBETWEEN(20,100)/10`	4.9	Time (t)
A4	`="Calculate the distance travelled by a car in " & A3 & " seconds, if its initial velocity $V_i$ is " & A2 & " m/s and the acceleration is " & A1 & "m/s\hat{}2."`	Calculate the distance travelled by a car in 4.9 seconds, if its initial velocity V_i is 8 m/s and the acceleration is 3 m/s^2.	Question
A5	`=A2*A3+0.5*A1*A3*A3`	75.215	Answer

Table 3. Creating a question and answer for present value calculation in a finance course.

Cell No.	Formula	Parameter values and Latex output	Comments
A1	`=RANDBETWEEN(2,5)*1000`	4000	Future value (FV)
A2	`=RANDBETWEEN(3,10)/2`	2	Interest rate (r)
A3	`=RANDBETWEEN(3,10)`	6	Number of periods (n)
A4	`=RANDBETWEEN(3,10)/2`	4	Compounding frequency (m)
A5	`="Calculate the present value (PV) with compounding, if future value (FV) = " & A1 & "; interest rate (r) = " & A2 & "; number of periods (n) = " & A3 & "; and compounding frequency (m) = " & A4 & "."`	Calculate the present value (PV) with compounding, if future value (FV) = 4000; interest rate (r) = 2; number of periods (n) = 6; and compounding frequency (m) = 4.	Question
A6	`=A1/(1+A2/A4)^(A3-A4)`	1777.8	Answer

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