

## Methodology for automated generation of multiple choice questions in self-assessment

**Alfredo Sanz-Lobera**

[a.slobera@upm.es](mailto:a.slobera@upm.es)

Universidad Politécnica de Madrid  
Spain

**Alfredo González Roig**

[alfredo.gonzalez.roig@hotmail.com](mailto:alfredo.gonzalez.roig@hotmail.com)

Universidad Politécnica de Madrid  
Spain

**Ignacio González Requena**

[ignaciof.gonzalez@upm.es](mailto:ignaciof.gonzalez@upm.es)

Universidad Politécnica de Madrid  
Spain

**Abstract:** *Current trends in the European Higher Education Area (EHEA) are moving towards the continuous evaluation of the students in substitution of the traditional evaluation based on a single test or exam. This fact and the increase in the number of students during last years in Engineering Schools, requires to modify evaluation procedures making them compatible with the educational and research activities. This work presents a methodology for the automatic generation of questions. These questions can be used as self assessment questions by the student and/or as queries by the teacher. The proposed approach is based on the utilization of parametric questions, formulated as multiple choice questions and generated and supported by the utilization of common programs of data sheets and word processors. Through this approach, every teacher can apply the proposed methodology without the use of programs or tools different from those normally used in his/her daily activity.*

## Introduction - overall layout

Subjects with a strong technological character inevitably require examples of application and problemsolving for the achievement of educational goals with minimum levels of quality (Kolmos and Graaff, 2003). However, the time dedicated to practical samples resolution is low compared to time spent teaching of theoretical concepts as evidenced the surveys carried out among students in their final years of engineering studies (Sanz, 2010). This situation is aggravated by the implementation of the basic principles which underpin the European High Education Area (EHEA, 1999) setting a trend towards continuous assessment of the student in substitution of other assessment methods traditionally used such as semester tests. Furthermore, in the case of the ETSI Aeronautics of the Polytechnic University of Madrid, the number of undergraduate students is increased significantly due to the join in a single degree the skills provided from two separate degree programs: the degrees of medium grade and the first cycle of higher grade degrees.

This situation leads to the need to provide students with a sufficiently large number of practical applications of the theory, all of them with different solutions in a way that allow students to base their skills accordingly to their needs and their rhythm of work and study. The number of questions will depend principally on the knowledge, skills and study habits of each student, so cannot be fixed at a certain value. In the attempt to satisfy this request, there is a risk of creating "collections of problems" in which the student learns to solve problems-type in an automatic way without too much reflection, hoping to be able to identify the statements presented in the evaluation tests with one of these problems-type. The experience of the authors advised against the creation of such kind of collections, since, even resulting "comfortable" for students and even producing satisfactory academic progress, lead to a kind of learning opposite to professional reality requirements where rarely appear problems type.

To avoid falling in the aforementioned error, there is the need to generate and manage a relatively large number of different exercises, maintaining a similar difficulty level in all of them. This paper aims to provide a method that allows the teacher to organize and manage a significantly high number of implementation issues, using for this purpose common work resources such as spreadsheets and word processors and all oriented the diffusion of the questions using a b-learning platform. It may seem at first glance, that the approach proposed is already solved, as the b-learning platforms provide editing tools for the generation of questions of practical application (Lawrence, 2009), however when the number of such questions increases and reaches the value of thousands, editing and management tools through their own platform becomes almost impossible. For example, for the next course 2010 2011, the number of self assessment questions that have been developed are around 8000. This is certainly a point to resolve while not the only one. Indeed, it is also necessary to choose the way students access to the questions and establish a standard procedure that allows the generation of a sufficiently large number and variety of questions.(Rice and Smith Nash, 2010).

## Structure

In order to establish a theoretical framework, below the theoretical concepts that will be used are proposed. The questions of practical application purpose of this study pose problems or exercises with a numerical solution, although, as will be seen, the proposed methodology is also applicable to non-numerical resolution issues.

The formulation of the questions is performed in "parametric form". A parametric question is a question whose formulation contains one or more variable elements or parameters. For example, suppose you are working on the study of parabolic motion and ask the following question based on Figure 1.

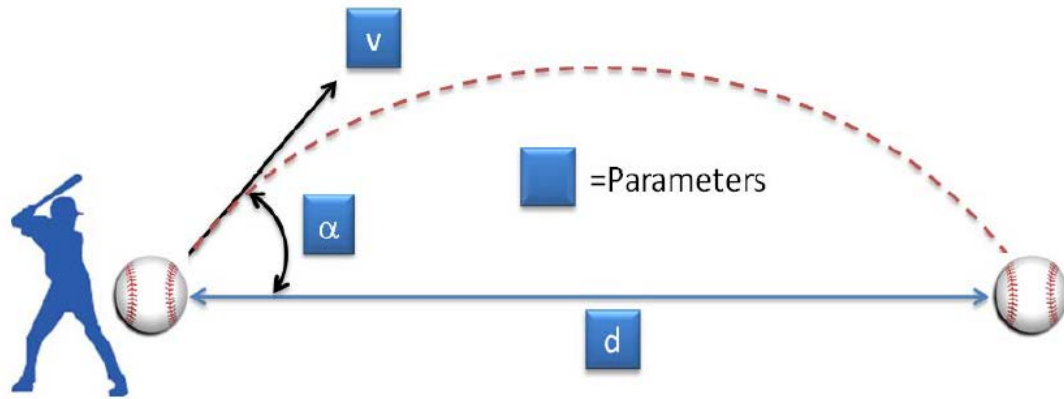


Figure 1: Parametric sample question

"What would be the horizontal distance travelled by a baseball, after being batted, is impelled at a speed of 70 km/h, if the angle at which the batter hits it is 30 degrees?". This question can be redefined using as parameters the values of speed **P1** and **P2** angle, so the question parametric mode enunciate as "What is the horizontal distance travelled by a baseball, after being batted is impelled at a speed of **P1** km / h, if the angle at which hits the batter is **P2** degrees?". Parameterization is not necessarily limited to numerical parameters and thus, for example, the question can be parameterized also the units of measure in the form "What is the horizontal distance travelled by a baseball after being batted is impelled to **P3 P1** speed if the angle at which hits the batter is **P2 P4**?".

Setting out the questions requires the use of a b-learning platform. There are several platforms that allow this like Moodle, Blackboard or WebCT among others.

## Methodology

For numerical applications and without prejudice to other alternatives, the two alternatives considered most appropriate to pose the questions are the *numerical answer* and the *alternative answer*. The proposed methodology can be described through the stages represented in Figure 2.

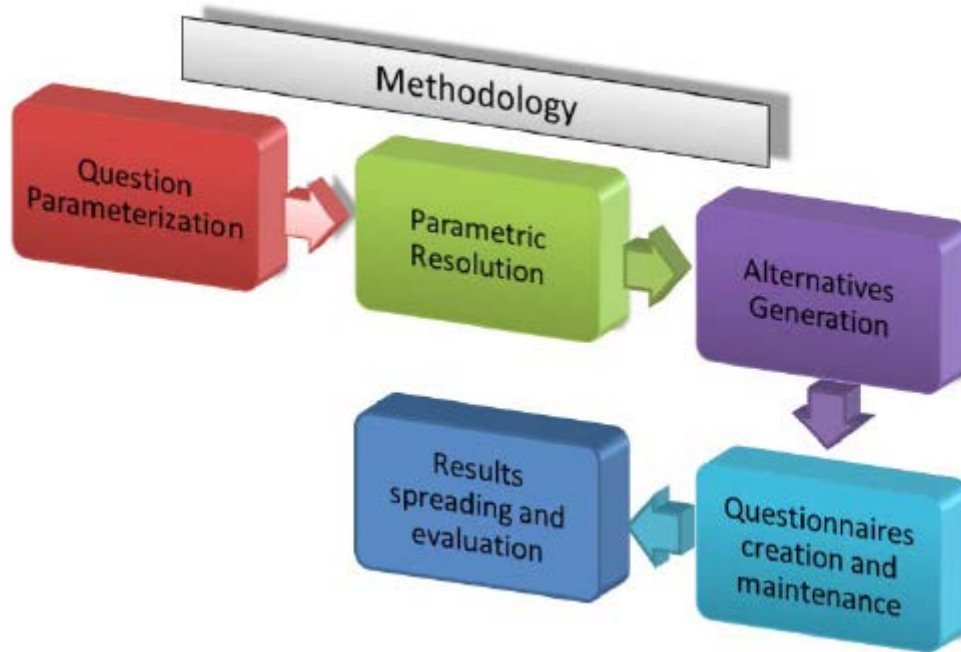


Figure 2: Methodology types

**Question parameterization:** stage that defines the variable values (parameters of a statement) and their ranges of variation. These ranges may be continuous or discrete; the latter is the most suitable for the generation of self-evaluation exercises.

**Parametric resolution:** at this stage the exercise must be resolved for all combinations of values of parameters defined in the previous step. To do this, it is very appropriate to use a spreadsheet in which each field corresponds to a variable in the question and each record to a complete question.

**Alternatives generation:** at this stage alternative responses are generated. Only it's being done if multiple choice questions is used as method of spread results.

**Questionnaires creation and maintenance:** at this stage, the issue is created and, using the combination of text options, questions are generated. It also includes management and the questions maintenance.

**Results spreading and evaluation:** At this stage, the contents of the previously created and selected issues is distributed to students

## Results

In order to validate the proposed methodology, we present the results, applied to the example of the baseball batter described in "Structure" paragraph.

Question parameterization: Velocity values ( $v$ ), angle of batting ( $\alpha$ ) and speed units ( $v\_units$ ) are the selected parameters. The range of each parameter are the integer values

$v = \{70, \dots, 100\}$ ,  $\alpha = \{20, \dots, 50\}$  and the units  $v\_units = \{m/s, km/h\}$ . In these circumstances it would have a total of  $31 \times 31 \times 2 = 1922$  possible variants.

Parametric resolution: A spreadsheet is used. The formulas that allow the resolution of the problem are  $t = \frac{2}{9.8} v_0 \sin \alpha$  and  $d = v_0 \cos \alpha t$ , where  $t$  is the time that the ball is in motion and  $d$  represents the horizontal distance expressed in meters. The spreadsheet will look exactly as shown in Table 1, where **Q1**, **Q2** and **Q3** represent numerical examples, **Vars** represents the variables used in the example (parameters and intermediate or final results) and **Formulae** represents the formulas used. The existence of auxiliary parameters such as **random**, **v\_ms** or **time** helps the resolution of the exercise or allows to choice between several options.

**Table 1: Sample parametric resolution**

(*)	1	2	3	4	5
	<b>Vars</b>	<b>Formulae</b>	<b>Q1</b>	<b>Q2</b>	<b>Q3</b>
A	random	=RANDBETWEEN(0;1)	15	1	0
B	v	=IF(random=0;RANDBETWEEN(3;10)*5;RANDBETWEEN(5;15)*10)	100	140	20
C	v_units	=IF(random=0;"m/s";"km/h")	km/h	km/h	m/s
D	v_ms	=ROUND(IF(v_units="m/s";B3;B3/3.6);2)	27.78	38.89	20
E	alpha	=RANDBETWEEN(2;16)*5	75	50	70
F	time	=ROUND(2*v_ms*SIN(alpha*PI()/180)/9.8;1)	5.5	6.1	3.8

(\*) To provide a clearer representation, the order between rows and columns into Table 1 has been transposed regarding their normal distribution in spreadsheets.

Table 1 also shows common functions of spreadsheets. These are PI () representing the relationship between the length and diameter of a circle, RANDBETWEEN () that provides a random value on the interval described, ROUND () that rounds a value to a certain number of decimals, IF () to choose between two values out from a condition and SIN () and COS () that are the trigonometric functions of sine and cosine. For more information any book about spreadsheets like (Albright and Winston, 2004) can be consulted. Once the exercise is solved in one row for the first parametric case, the rest of the questions are immediately got by scrolling the solved case until the desired number of questions.

Alternatives generation: If the question is formulated requesting a numerical answer is not necessary to generate alternatives, but when the question is formulated in the way of multiple choice questions, the generation of alternatives becomes a very important role in the success of the approach. In this case, it is necessary to define, in addition to the solution, alternative answers that are "credible". To do this, the choose of the numerical values in alternative responses must be taken with care because if not, it is possible to generate some kind of pattern in the answers that would achieve the correct answer without solving the proposed problem.

**Table 2: Sample alternative generation**

(**)	1	2	3	4	5
	<b>Vars</b>	<b>Formulae</b>	<b>Q1</b>	<b>Q2</b>	<b>Q3</b>
G	distance	=ROUND(time *COS(alpha *PI()/180)* v_ms;1)	39.5	152.5	26
H	offset	=RANDBETWEEN(-1;1)	-1	0	0
I	inc	=ROUND(distance /10;1)	4	15.3	2.6
J	R1	= distance -(2* inc)+ offset *2* inc	23.5	121.9	20.8
K	R2	=R1+ inc	27.5	137.2	23.4
L	R3	=R2+ inc	31.5	152.5	26
M	R4	=R3+ inc	35.5	167.8	28.6
N	R5	=R4+ inc	39.5	183.1	31.2
O	p1	5	5	5	5
P	p2	1	1	1	1
Q	p3	3	3	3	3
R	p4	2	2	2	2
S	ra	=ROUND(CHOOSE(p1;R1;R2;R3;R4;R5);1)	39.5	183.1	31.2
T	rb	=ROUND(CHOOSE(p2; R1;R2;R3;R4;R5);1)	23.5	121.9	20.8
U	rc	=ROUND(CHOOSE(p3; R1;R2;R3;R4;R5);1)	31.5	152.5	26
V	rd	=ROUND(CHOOSE(p4; R1;R2;R3;R4;R5);1)	27.5	137.2	23.4
W	TF_ra	=IF(ra= distance;TRUE;FALSE)	TRUE	FALSE	FALSE
X	TF_rb	=IF(rb= distance;TRUE;FALSE)	FALSE	FALSE	FALSE
Y	TF_rc	=IF(rc= distance;TRUE;FALSE)	FALSE	TRUE	TRUE
Z	TF_rd	=IF(rd= distance;TRUE;FALSE)	FALSE	FALSE	FALSE

(\*) This table contents the continuation of the spreadsheet in Table 1 showed using the same layout

For example, if the correct solution is a certain numerical value, and as alternative answers are used this number plus a random value and this number less a random value, the student will end up detecting that the correct answer is one whose numerical value is located in the center position. In this case he/she doesn't know how to solve the exercise to get the correct answer. If this same case is used as an alternative response "none of the other three" the resolution is not as obvious because it is possible that the central value was also incorrect. However, the probability to guess the correct answer will always be greater when choosing the central value.

One possible way to solve this problem is to generate a number **n** of responses greater than the number **m** of alternatives offered in the question and randomly select **m-1** alternatives with the correct answer. At same time, the generation of alternatives must be made in a way that the correct value occupies a random position with respect the other values because, otherwise, an alternative numerical centered with respect to other two, always have a higher probability of being the correct answer. This is achieved fixing a random value that defines the alternative with the lowest numerical value and a successive increase that generates the alternative values. Continuing with the example presented, the obtained results are given in Table 2. It can be observed how to five random responses (n = 5), have been generated. These are designated as **R1** to **R5**. Fields **p1** to **p4** contain a random combination of n elements taken from **m** in **m**, and are used as variables for the random choice of the **m** responses (**m = 4**) by the function CHOOSE (). These

responses appear in the fields ra, rb, rc and rd with the corresponding results TRUE/FALSE in the fields **TF\_ra**, **TF\_rb**, **TF\_rc** and **TF\_rd**.

Questionnaires creation and maintenance: To generate the questionnaire from the spreadsheet is necessary to create a template which present each questions generated, with the text and the desired format. The template should be generated in a word processor that allows merging between text and spreadsheet data. The creation of the questionnaire will consist of writing the text and combining it with the corresponding fields in the spreadsheet. Figure 3 contains the template created for the sample.

```

→          A baseball player hits the ball with an initial velocity of «v» «v_units» and an elevation
angle of «alpha» degrees. Neglecting the aerodynamic effects on the ball, the range in meters will be {
«TFa» →    a) «ra»
«TFb» →    b) «rb»
«TFc» →    c) «rc»
«TFd» →    d) «rd»}
    
```

Figure 3: Questions' template

It shows, in bold, the merged fields that correspond to fields from the spreadsheet. Also, appear in bold two delimitation characters "{" and "}". Both are necessary to separate the question body from responses. Finally, the character → appears representing a tab.

Results spreading and evaluation: To carry out this step is necessary to use a platform b-learning. The combination of the above will have generated a number of issues equal to the number of rows with data from the spreadsheet. To incorporate all of these issues automatically to the platform should generate a file with one of the formats of import and export of questions.

```

A baseball player hits the ball with an initial velocity of 150 km/h and an elevation angle of 25 degrees. Neglecting the
aerodynamic effects on the ball, the range in meters will be {
=136
~152
~137
~149}
A baseball player hits the ball with an initial velocity of 60 km/h and an elevation angle of 30 degrees. Neglecting the
aerodynamic effects on the ball, the range in meters will be {
~31,5
~25,5
=24,5
~18,5}
    
```

Figure 4: Two questions in GIFT format

Although there are several formats, it was considered that the format GIFT (GIFT, 2011) is very appropriate for its versatility and its wide diffusion among b-learning platforms. If the template has been generated in accordance with established rules in the previous section, to obtain the battery of questions in GIFT format is immediate from the merged file. It is sufficient to replace terms "TRUE" and "FALSE" by the characters "= " and "~" (ASCII 126) respectively. The result is shown in Figure 4. Finally, GIFT file can be imported

into b-learning platform, obtaining a result as shown in Figure 5, which has been copied from Moodle platform at Polytechnic University.



Figure 5: Final view in b-learning platform

## Conclusions

The generation of helping tools for questionnaires is a widespread idea throughout the educational community (Itkonen, 2006). Nevertheless, and despite the existence of simple solutions for the forms generations, no one of them has got a system to automate easily the creation of questions and answers arrays. The main contribution of the presented work is to provide an automatic method of generation of large number of questions using standard tools and without the need of using more complex applications. It is also proposed a method of storage and manage the questions, which again, using common tools that can be undertaken quickly and easily. In this way, engineering students have a sufficiently large number of application exercises which allow carrying out, according to their own necessities, the consolidation of acquired knowledge and self-assessment of their learning without compromising the time required for teaching of theoretical content. In addition to the use of guided repetition as a teaching technique, the high number of questions provides a tool to prevent, reduce and even eliminate cheating (Jeschofnig, 2011). Finally it should be remarked that proposed methodology has been implemented at ETSI Aeronautics in Polytechnic University since last year. Although it is premature to make an assessment, impressions received from students and teachers involved have been very positive.

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