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Novel educational assessment for building structures: Automatic evaluation of on-line graphics

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Abstract

This article presents a new automatic evaluation for on-line graphics, its application and the numerous advantages achieved applying this developed correcting method. The software application developed by the Innovation in Education Group "E4", from the Technical University of Madrid, is oriented for the online self-assessment of the graphic drawings that students carry out as continuous training. The adaptation to the European Higher Educational Area is an important opportunity to research about the possibilities of on-line education assessment. In this way, a new software tool has been developed for continuous self-testing by undergraduates. Using this software it is possible to evaluate the graphical answer of the students. Thus, the drawings made on-line by students are automatically corrected according to the geometry (straight lines, sloping lines or second order curves) and by sizes (depending on the specific values which define the graphics).

Keywords: graphics evaluation; on-line questionnaires; e-learning; self-correction tool; continuous training.

1. Introduction

The educational experience and the computer application developed described in this work were made in the subject of Structural Analysis (SA) of the Architecture Technical University of Madrid (UPM). Structural Analysis is a discipline with a large scientific and technical tradition. Its study comprises an evident technical component based on rational mechanic laws, and a second technical component equally important, because of the big economical and social responsibility that comes with its application to construction: not only a conceptual, but also a numerical error can be unacceptable due to the gross economical losses that can derive from it, but mainly because it could threaten people's life (West & Geschwindner, 2002).

SA needs of numerical precision. In this regard, the combination of practice with the theoretical part of the subject make the Information and Communications Technologies (ICT) a suitable complement for the traditional face-to-face teaching. In traditional education the monitoring of each member of a medium/big size student group with the level of detail allowed by the ICT, would take a huge amount of professor's time. This time limitation usually turns into a final desertion of the continuous assessment techniques.

Years ago, the continued work of the student was encouraged through weekly voluntary practices in SA subject. Those practices were made at the classroom after the theoretical explanation, as immediate application. During this second part of the class, in a distended atmosphere, both the teacher-student communication and communication between students were favored in order to solve the different possible doubts that could show up in the practical application of the previously exposed theoretical concepts. In the typical medium and big size students groups in SA subject, the later review of the students exercises by the professor had to be reduced to a limited number of students or to a limited number of answers from all students. In any case, the ratio between the time the professor spent on those evaluation tasks, and the benefits obtained were, at most, scant.

With the arrival of ICT the previously mentioned second part of the class was complemented with the virtual learning technique (e-learning), which encouraged both the continuous assessment and the individual monitoring of the student. Thus a blended learning method (b-learning) was implemented in SA, through which the virtues of the traditional education were potentiated with those of the e-learning tools in benefit of the learning process.

To incorporate the b-learning techniques to the educational system it was necessary to obtain a computer tool which could transmute the daily practice made in the classroom into electronic practices that could be remotely developed and self-assessed. It was necessary a tool that could incorporate the following capabilities:

- Auto-correction: it should allow the students to correct their all-year exercises.
- Automatic correction: the tool should automate the correction process given the large number of students and practices to be accomplished.
- Continual assessment: the tool should have the capability to include a very large number of practices due to the daily tests that the student has to complete.

There are many computer applications that satisfy those requirements. The implantation at an institutional level by the Technical University of Madrid of the Moodle platform eases its election between the different possible options.

As Moodle is an open platform it was possible to develop applications to improve its performance and to adapt it to the needs and particularities of the SA. First, an application that allowed the customization of each exercise, assigning different values to its variables, was developed. However it was not possible to use the generic Moodle techniques for that personalization as exercises of SA have an important graphic component, which was necessary to customize with the rest of data for each exercise. The purpose of personalization was focused to minimize the possible student scam that could be originated by the on-line resolution of a single exercise, and, at the same time, to compare the different results obtained by some students in the face-to-face lessons to provide some valuable knowledge about the variation of the final result in relation with the initial values of the problem. In order to acquire this last knowledge the rank value should be carefully calibrated, so that the values do not deviate from the real possible cases extracted from its technical approach and/or of the previous experience of the building structures construction.

From the first semester once the system was implemented, it was positively received by the students and a measurable improvement in the results of SA teaching was observed.
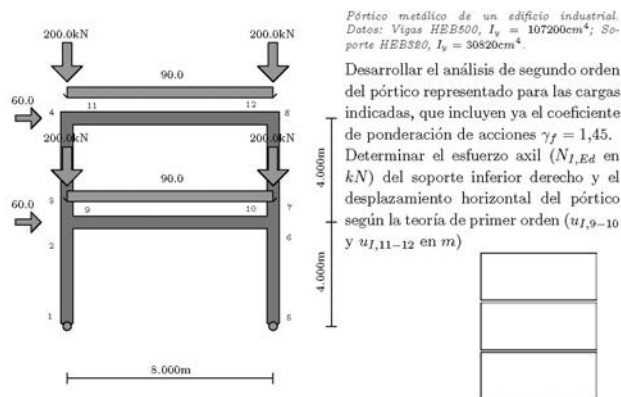
The great acceptance of the system turned into an extra motivation of the students, who, stimulated by the immediate answer of the system, increased considerably the time spent on the subject. A proof of this is the considerable number of attempts in solving the exercises that were made by the students. While some students just needed a few tries to solve correctly the exercise, others needed a large amount of them. A detailed explanation of this first experience can be found in (Aznar & Hernando, 2011) and (Aznar et al, 2012).

Once the success of the developed system and the adequacy of the e-leaning tools for evaluation were verified, we thought about the possible risk of losing the perspective of the whole picture of the structural behavior. In the Structural Analysis classic treatises the study of the graph of internal forces was imperative allowing the study of the

behavior of the structure as a whole, opposite to the local and detailed description that is achieved by a pure numerical description. To take advantage of all benefits of the b-learning method it was necessary the evaluation and verification of the graphs geometry that represent the structure internal forces, and not just some (or many) numerical values. Unfortunately, as Moodle platform did not included such possibility, we had to develop the application described below.

2. Development

In order to achieve the previous mentioned targets it was necessary to find again an e-learning platform where we could develop them. The choice of Moodle was the most suitable. The main reasons that made us opt for it was the more than two experience years we had with it, and the request of not losing the targets already achieved. Among others: a) the possibility of an automatic correction; b) the option of an immediate answer to the students; c) the possibility of answering the same question many times in case the answer is not correct; d) the freedom of schedules; e) the proven Moodle's capability of storing in an efficient way the huge amount of data necessary to elaborate SA practices. This subject involves a complexity technical part, including bibliography, regulations and technical documentation, and, mainly, graphical documentation (architectural plans, structure plans, structure detail plans, structural models, forces schemes, etc.), without which there is the risk of reducing the Structural Analysis to a simple academic entertainment. On the other hand it was neither found the wanted tool in any other computer application.

Figure 1. (a) Partial view of a SA practice. (b) Example of the developed question type.

Once the Moodle platform was selected, a study of its performance was made in order to find the most efficient way of achieving the pursued targets. It was decided to develop a new "question type", to be added to the ones

already offered by Moodle. This new question type was named "graph of internal forces", "diagrams" in its short version.

Fig. 1 shows an example of the developed question type. In this example the students has to draw the graph of internal forces on the structural model.

It was sought that the professor, relying on Moodle capabilities, would be able to introduce question of the type "diagrams" in the course exercises in a quick and easy way. Likewise, the students should be able to answer, graphically, as any other question of the test. To develop "diagrams" and make it compatible with the platform and its usual use, a study of several standard Moodle question types was made.

3. Operation

In order to develop the new question type several basics requirements were specified:

3.1. Definition of the question wording

The questionnaires development should be quick and easy. It must be ease to the professor the introduction of the question formulation data, its solution, as well as the allowed error margins and other specific parameters of "diagrams", such as scale factors or sign criteria.

3.2. Student's answer.

The students should be able to answer in an easy and enjoyable way, and essentially by graphic means: drawing straight lines, parabolas or combinations of them.

3.3. Bidirectional communication with the database.

Moodle stores all the information about the questions, such as values, solution, error margins and other parameters from the question formulation, as all the answers (attempts) provide by the student, in a relational database. All Moodle question types allow a bidirectional communication with the database to implement the yearned automatic and continuous correction. It was obvious that "diagrams" should also have this property.

3.4. Feedback.

With data introduced by the professor in the definition of the question and answer given by the student, Moodle should be able to validate the student's answer. At the same time, attending to the parameters established by the professor, it should show the student the mark of its answer, its graphical correct answer, or to allow the student to continue searching for the right answer if he has not yet reached the highest mark, etc. All Moodle standard questions had these properties, and thus "diagrams" should inherit them.

3.5. Flexibility.

Because of the large tradition of the Structural Analysis, plenty of approximations coexists. Thus, flexibility was an imperative premise in "diagrams" as we would not want to limit its use just to SA and even, just to the particular vision of a SA professor.

4. Implementation

In order to experiment without the risk of causing collateral damages, a local version of Moodle 2.4 was installed in a network isolated computer. Once defined the basic requirements, pointed out in the previous section, and with the "safe" Moodle version available the development of the new Moodle question type was initiated.

The code for "diagrams" was written in *php* language, as it is the standard code for all the Moodle question types. Attending to the indications in the Moodle manual we started from the basic structure of the "short answer" standard question, which we modified up to transforming it into "diagrams". A portion of this code is represented in Fig. 2.

```
 * The diagrams answer question type.
 *
 * @copyright  2013 Jose Ignacio Hernando García, Miguel Martínez Pañeda
 * @license    http://www.gnu.org/copyleft/gpl.html GNU GPL v3 or later
 */
class qtype_diagrams extends question_type {
    public function extra_question_fields() {
      return array('question_diagrams', 'answers', 'topology', 'graphofinternalforces', 'width'
    }

    public function questionid_column_name() {
        return 'question';
    }

    public function move_files($questionid, $oldcontextid, $newcontextid) {
        parent::move_files($questionid, $oldcontextid, $newcontextid);
        $this->move_files_in_answers($questionid, $oldcontextid, $newcontextid);
        $this->move_files_in_hints($questionid, $oldcontextid, $newcontextid);
    }

    protected function delete_files($questionid, $contextid) {
        parent::delete_files($questionid, $contextid);
        $this->delete_files_in_answers($questionid, $contextid);
        $this->delete_files_in_hints($questionid, $contextid);
    }

    public function save_question_options($question) {
        global $DB;
        $result = new stdClass();

        $context = $question->context;

        $oldanswers = $DB->get_records('question_answers',
                array('question' => $question->id), 'id ASC');
```

Figure 2. Portion of the code of "diagrams" question type

Even though writing the code of the different *php* files (which form the structure of the question and their interaction with the database) had its difficulties, the biggest hurdle was encountered when creating the application that would allow the students to draw the answer. A *javascript* application was designed that accompanied the *php* files, and to which they refer. In the designed application the students can, through a command panel with different options, draw in a canvas the structural answer of the internal forces graph of the set out structure.

After many verifications the question type was finally installed in the Moodle of the Technical University of Madrid. After three semesters of an intensive use of "diagrams", in which it has been subjected to limit situations that had forced to improve some of its aspects, it is confirmed that the question type is fully operational.

5. Performance

The premise of making the new question type as simple as possible was adopted to develop the data entry by the professor and the introduction of the results by the student.

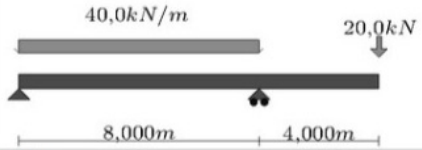Fig. 3 shows an example of the professor form has to complete to elaborate one of these new question types.

Figure 3.View of the professor´s form to complete a "diagrams" question type

Once installed the Moodle question type "diagrams"4 the professor can select it directly from the question type list that shows up when a new question is created in the "question bank". To the standard options that are shown to the professor when writing a new question like "name of the question", "text of the question", etc. the specific ones for "diagrams" are added. From the particular options of "diagrams" stand out, first, the input in which the geometry and the topology of the structural model must be defined, and on second place the input where the diagram of internal forces of each bar which form the structure is defined. The geometry and the topology is defined through the coordinates of the structural model bar ends, in a similar way as in any designing structural commercial program, so therefore it is supposed to be familiar for a SA professor. The definition of the diagram of internal forces is not difficult either, as, for the usual forces in buildings the diagram is formed by straight lines or quadratic polynomials. In the case of straight lines the professor has to define the value of the diagram in two points, in the second case he has to introduce the value of three random points. The diagram of a bar could be formed for several stretches (formed by straight lines and/or second order curves). The professor should define each of this different stretches separately as in the previous cases. Other offered parameters can be seen at Fig. 3.

Once concluded the data input, the professor can see the formulation of the question and the diagram of internal forces as shown in Fig. 4.
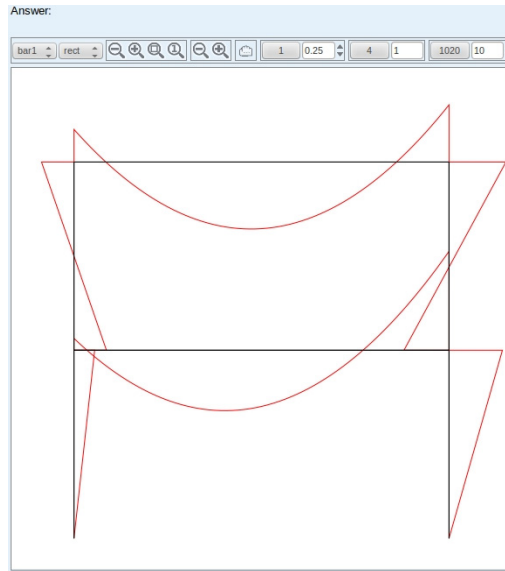
Figure 4. Preview of the question, just available to the professor

The "diagrams" question is shown to the student as another typical question inside the Moodle form. Next to the formulation of the question (that could include graphics, as any other Moodle question) it is displayed a small tool bar and a canvas where the drawing of the diagram of internal forces of the structure can be made just with the mouse. Its working is similar to a CAD application, so it does not suppose any difficulty for any student of architecture of the 21st century (Fig. 5).
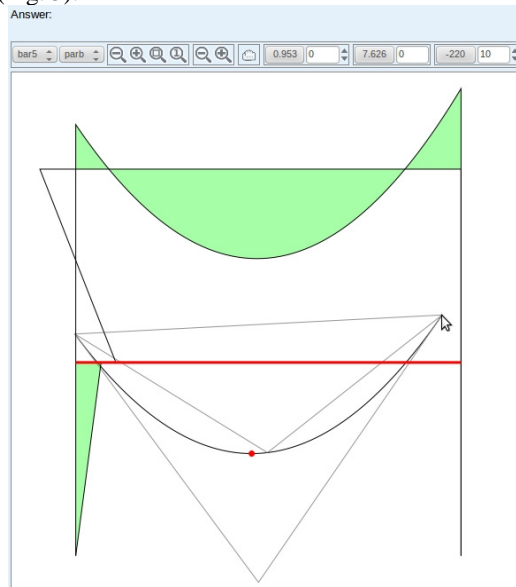

Figure 5. Student's answer snapshot.

Figure 5 shows the internal forces diagrams of bars already answered and validated by the application on green and diagrams already answered but not validated by the application on black. Also, the diagram that was being answered at the time the snapshot was taken is shown next to the cursor.

6. Results

This work includes the methods developed for the incorporation of a new type of question in the Moodle platform. This new question type, which enriches the use of ICT, has been fully operational amongst the standard Moodle question types for three semesters in the network of the Technical University of Madrid. Since its implementation it has been used by the students of several structural subjects of the University of Architecture.

The operation of this new question type (figure 5) has not brought about any problem since its installation. It has been excellently welcomed by students, overflowing the most optimistic previsions, reaching almost an addictive use.

Thanks to this new application the drawing of the graph of internal forces of a structure is covered through the ITC, one of the targets of the SA subject, overcoming the limitations that the Moodle platform offered a priori. The benefits for the students are manifest, according to the enquiries made to the SA professors and to the success evidenced in the final tests results. These tests have proven a much more complete learning than before the implementation, with an evident settlement of concepts.

7. Conclusions

Students profit of all the benefits of the b-learning method through the developed computer application system of continuous automatic correction and an automatic evaluation system for the diagrams of internal forces. The development of this informatic questionnaire type offers new tools in contrast with the traditional student qualification characterized by very subjective component. Using this tool objective qualification of a major part of the subject, the diagrams of internal forces, is achieved together with other advantages as the professor is released from mechanical duties.

Thanks to it, this self-correcting application has improved considerably the learning of SA between the students proved in the evaluation results. Student motivation has also been increased, due to the graphic input of results and the quickness of the system feedback. This high motivation has resulted in an unattainable level of comprehension through other techniques. The tool makes also viable the correction of the daily practices in a time impossible without the ICT, which allows the professors to focus their efforts on others tasks as the direct attention to the students reflected in a much better exploitation of the learning process. The professors also turn out benefited as the work of evaluation and monitoring of students is considerably improved, with the additional advantage of having a number of qualifications formerly impossible at any time.

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