SIMULATION OF ACADEMIC PERFORMANCE RATES. ESTIMATION OF INDICATORS OF SUBJECTS AND OF A COMPLETE DEGREE.

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The purpose of this paper is to present a program written in *Matlab-Octave* for the simulation of the time evolution of student curricula, *i.e*, how students pass their subjects along time until graduation.

The program computes, from the simulations, the academic performance rates for the subjects of the study plan for each semester as well as the overall rates, which are a) the efficiency rate defined as the ratio of the number of students passing the exam to the number of students who registered for it and b) the success rate, defined as the ratio of the number of students passing the exam to the number of students who not only registered for it but also actually took it. Additionally, we compute the rates for the bachelor academic degree which are established for Spain by the National Quality Evaluation and Accreditation Agency (ANECA) and which are the graduation rate (measured as the percentage of students who finish as scheduled in the plan or taking an extra year) and the efficiency rate (measured as the percentage of credits which a student who graduated has really taken).

The simulation is done in terms of the probabilities of passing all the subjects in their study plan. The application of the simulator to Polytech students in Madrid, where requirements for passing are specially stiff in first and second year subjects, is particularly relevant to analyze student cohorts and the probabilities of students finishing in the minimum of four years, or taking and extra year or two extra years, and so forth. It is a very useful tool when designing new study plans.

The calculation of the probability distribution of the random variable "number of semesters a student has taken to complete the curricula and graduate" is difficult or even unfeasible to obtain analytically, and this is even truer when we incorporate uncertainty in parameter estimation. This is why we apply Monte Carlo simulation which not only provides illustration of the stochastic process but also a method for computation.

The stochastic simulator is proving to be a useful tool for identification of the subjects most critical in the distribution of the number of semesters for *curriculum vitae* (CV) completion and subsequently for a decision making process in terms of CV planning and passing standards in the University.

Simulations are performed through a graphical interface where also the results are presented in appropriate figures.

Keywords: Accreditation, Quality Processes, Curriculum Design.

1 STOCHASTIC SIMULATOR

The purpose of the project is the development of a student curricular path simulator which provides a computation of academic performance indicators of a degree as a whole and of each subject of the study plan individually.

The academic indicators incorporated into the curricular path simulator have been defined by either the Universidad Politécnica de Madrid, the National Quality and Accreditation Agency (ANECA) and the General Secretariat of the College Coordination Council.

The official degree, for which the stochastic simulator has been developed, is the Bachelor in Industrial Engineering Technologies currently in order in Universidad Politécnica de Madrid at the ETSII [1]. It has four courses in a semester structure, with 240 credits (ECTS). From the sixth

semester on the students have to choose one of the eight possible majors or track subjects: Automatic Control and Electronic, Electrical Engineering, Construction Engineering, Mechanical Engineering, Materials, Industrial Engineering, Industrial Chemistry, Environmental Engineering and Energy Technology.

For each individual subject the student has two ordinary and one extra chance to take exams. Dates depend on the semester the subject is taken and appear in the Academic Organization Project.

However, the curricular path simulator may be adapted to any other degree with a different schedule, and the specific performance indicators may also be computed.

1.1 Hypothesis implemented into the stochastic simulator.

To generate the sample paths of student curricula we assume the following hypotheses for the stochastic model:

1) The probability that a student passes a subject is, for each simulation of, say, typical cohort for the year of 450 students, a value selected at random from within the confidence interval obtained from the data of previous years of the University.

2) The students behave independently, *i.e*, the passing probability of any student in a given subject is independent of whether any other student has passed it (or any other subject).

3) Within the sample path of a given student, future behaviour is independent of the past, i.e., how many trials he/she needs to pass a subject does not depend on how many he/she needed to pass previous subjects.

4) The probability of passing a subject increases as the student takes the exam more and more times (obviously unsuccessfully). The increase in passing probability has been set to 30% in each trial but could be modified and incorporated into the set of sensitivity parameters after collection of sample evidenced along time.

5) It is considered that the student always takes the exam whenever allowed by the credit thresholds.

6) To be more specific on hypothesis 5) the student will always take any exam of a subject he/she failed previously as well as any new subject such that he/she does not accumulate more than 30 credits (ECTS) in a given exam period (semester). This number (30 credits) is also a sensitivity parameter.

7) The order of choice of new subjects is fixed rather arbitrarily by the program and could of course be altered if convenient.

8) For the second half of the *curriculum vitae* (CV) (so called second cycle) the students are alloted to the different majors (track subjects in the Spanish academic jargon) in accordance with its distribution along previous years.

1.2 Sensitivity parameters of the stochastic simulator.

These are parameters whose value may be modified and has to be specified to generate the curricular paths.

- **Probability of passing for each subject.** It is based on the success rate defined as the ratio of the number of students passing the exam to the number of students who not only registered for it but also actually took it.
  For each new simulation, new values are generated for the passing probability of every subject, within their confidence intervals computed from real data of success rates of previous years. This interval may be modified and thus the range of value for the passing probability.
- **Total number of students per year and distribution among majors.**
  It has been established that the number of freshmen at first course is 450 which are sorted out by the algorithm among the different majors in accordance with data of previous years.

- **Increase in probability of passing a subject as the number of trials accumulates.**
  The probability of passing a subject is increased each time the student takes the examination, this is a sensitivity parameter which can be adjusted in accordance with data from previous years.
- **Máximum number of credits a student takes per semester**. This is one of parameters with a strongest impact on the rates. It is established by the registering rules of the University but its influence may be evaluated with the simulator.

2 PERFORMANCE INDICATORS

2.1 Performance indicators for the official degree as a whole.

They have been defined by the ratio of Agencia Nacional de Evaluación de la Calidad y Acreditación. (ANECA) (Agency for Quality and Accreditation) [2]. The stochastic simulator incorporates two obtained from the student curricula path:

Graduation rate: Proportion of students graduating in the number of semesters as specified in the study plan or taken and additional academic year.

Computed as follows: the denominator is the total number of students who registered for the first time for a degree in the academic year c. The nominator is the number of students within those of the denominator who graduated (d) as scheduled or a year later (d+1).

$$\frac{Number\ of\ students\ graduated\ in\ d\ or\ 'd+1'(out\ of\ those\ who\ registered\ in\ 'c')}{Total\ number\ of\ students\ registered\ in\ year\ 'c'}x100$$

Efficiency rate: Proportion of the number of credits which the students would have taken if they had passed the first time in every subject (theoretical figure) with respect to the number of credits actually taken. .

It is computed as follows: The nominator (theoretical figure) is obtained from the number of credits times the number of students who have graduated. The denominator, as defined above, is the number of credits actually taken by the joint set of students

$$\frac{Number\ of\ theoretical\ credits\ of\ the\ study\ plan\ x\ Number\ of\ graduates}{Total\ number\ of\ credits\ really\ taken\ by\ the\ graduates}x100$$

This indicator may convey a false quantification of efficiency if there is a large number of students with credits transferred from other universities.

2.2 Performance indicators for each subject.

They are adapted given the definitions established by ANECA. They may be defined just for each semester call or for the full academic year.

Efficiency rate: it is the proportion of students who have passed the subject with respect to those who registered.

$$\frac{Number\ of\ students\ passed}{Number\ of\ students\ registered}x100$$

Success rate: It is the proportion of students which have passed the subject with respect who those who took the exam.

$$\frac{Nnumber\ of\ students\ passes}{Number\ of\ students\ registered} x100$$

Absentism rate: it is the proportion of students who have not taken the exam with respect to those who registered for the subject.

$$\frac{Number\ of\ students\ registered - Number\ of\ students\ that\ took\ the\ exams}{Number\ of\ students\ registered} x100$$

It is to be expected that, under an adequate regulation of registering, and the increase in tuition fees, this rate decreases significantly.

3   SOFTWARE

The simulator is written in *Matlab Octave*. The input data are given in an EXCEL file where the subjects of the study plan are specified along with the semester where they are scheduled, the number of credits, and the corresponding passing probabilities obtained initially from real recent data. This file is incorporated in the software to start program execution.

The simulator uses an interactive dynamic graphical interface which is user-friendly and provides an instant visual feedback leading to an intuitive understanding of results.

The main page of the program is shown in Figure 1. From here on it is possible to proceed with *New Simulations* (Nueva Simulación) and to calculate the different performance indicators. Additionally, there exists a *Tutorial* (Ayuda) where information about the program and the performance indicators is included.

Figure 1: Main Page

New simulations may be run just clicking on a button on this display to obtain new student curricula paths from which the corresponding academic performance indicators are calculated by pressing the appropriate button; the results are subsequently displayed.

Under the *Subject Rates* (Tasas Asignatura) in the main page, it is possible to select one in of the common subjects of the degree and to display its performance indicators as well as its time evolution (Figure 2).
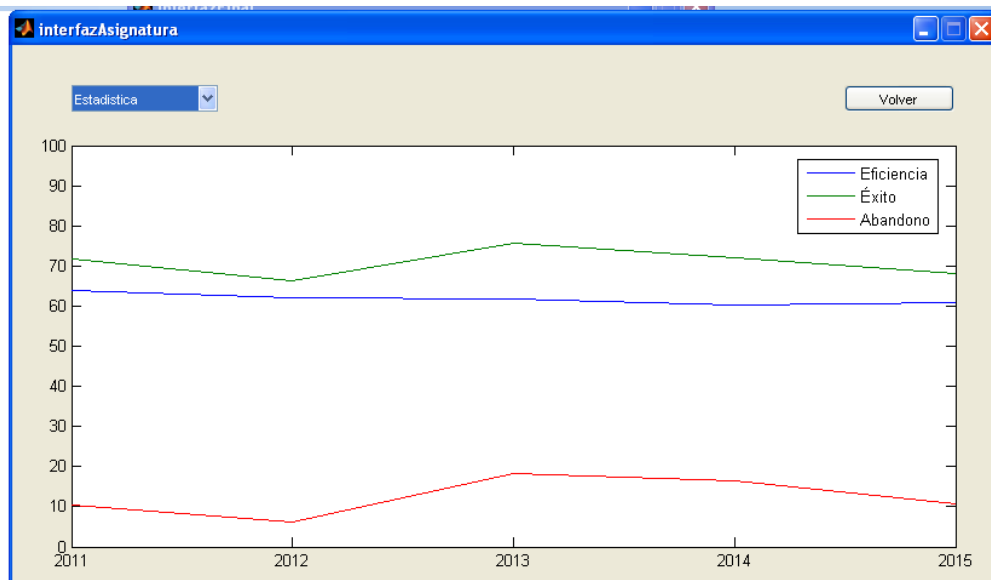

Figure 2: Evolution of the indicators for a given subject

Under *Semester Rates* (Tasas Semestre) we show the time evolution of the indicators for the subjects scheduled in the same semester of the degree.   This graph is very useful to perform comparative analysis (see Figure 3).
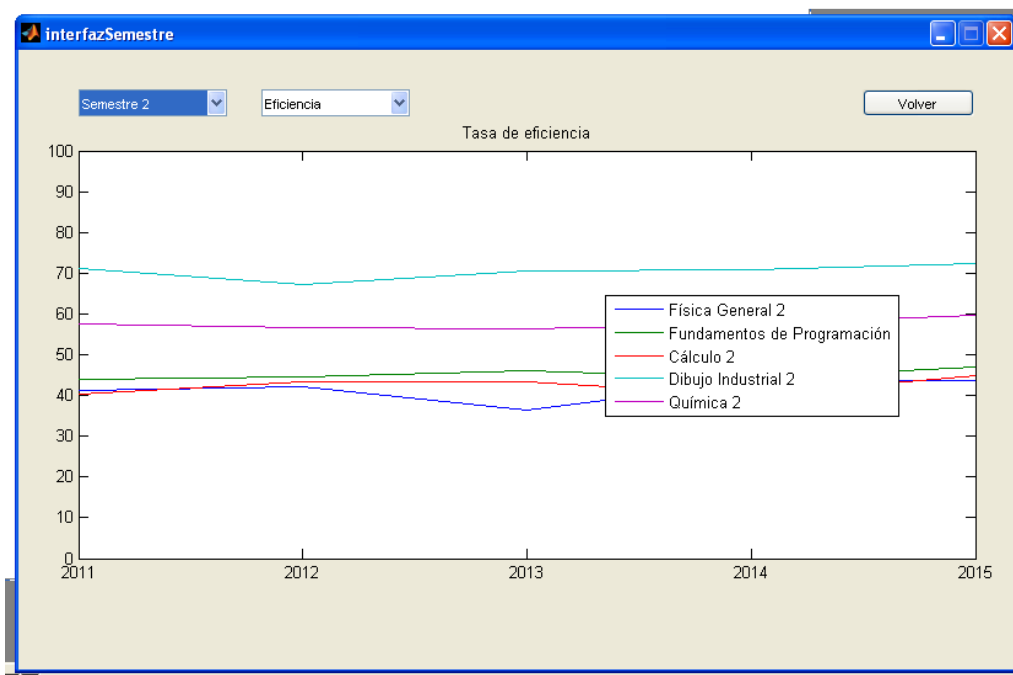
Figure 3: Performance indicator evolution for subjects of the same semester.

Within the Full Rates (Tasas Completas) option, two graphics are presented (Figures 4 and 5).

Figure 4 shows the joint representation of all the subject indicators for a given semester, and also, if desirable for a given major. They correspond to a single path, not to the time evolution.
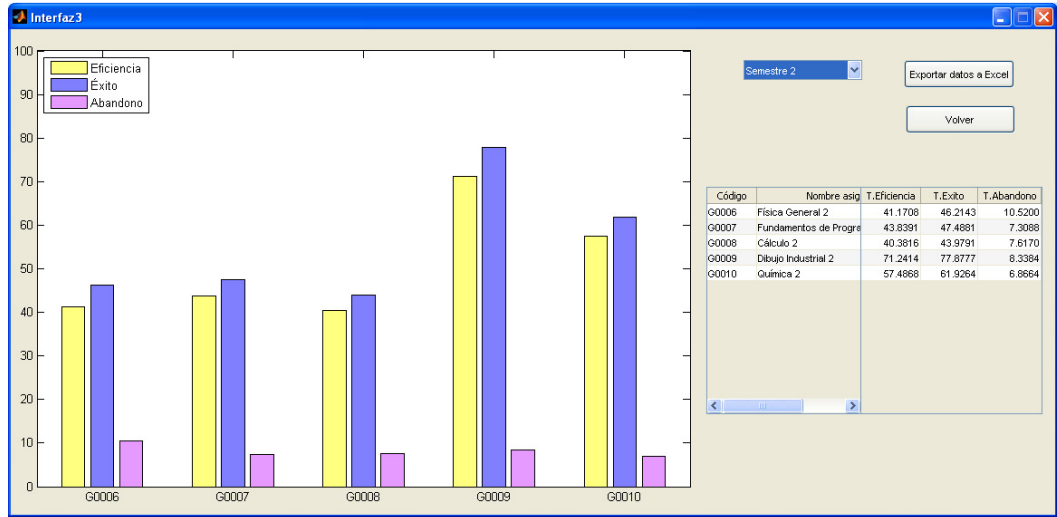

Figure 4: Performance indicators for a given semester.

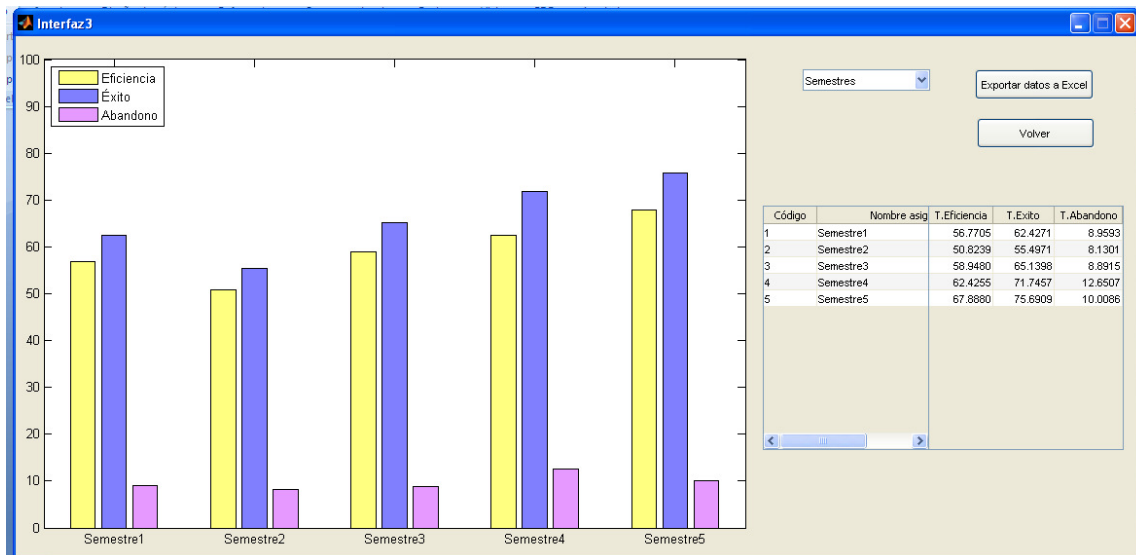Figure 5 compares performance indicators for common semesters, those taken before choosing a major.

Figure 5: Indicators for common semesters.

The program also allows for showing jointly the values of the indicators for all subjects common to the official degree (Figure 6). The data from Figures 4 through 6 can be exported to EXCEL for further analysis if desired.
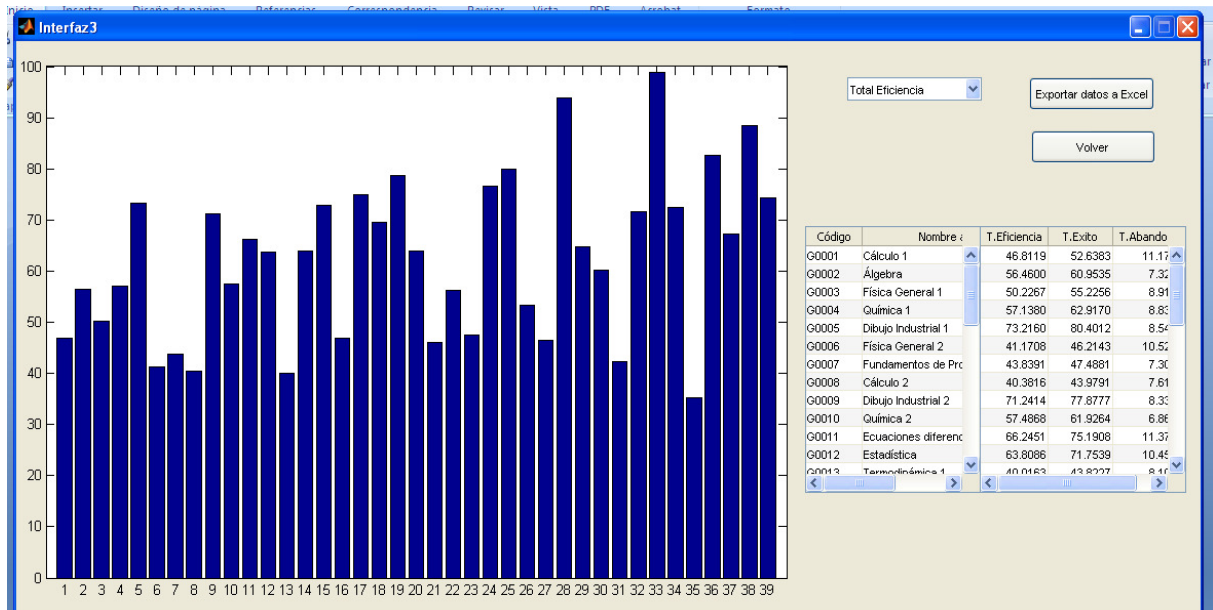
Figure 6: Performance indicators for all common subjects.

Finally, under *ANECA rates* in the main page (Tasas Aneca), performance indicators for the official degree as a whole, as defined in subsection 2.1, are calculated. Figure 7(a) shows the time evolution of the *Efficiency Rate* and the *Graduation Rate*. The values for different years are obtained from different simulations.
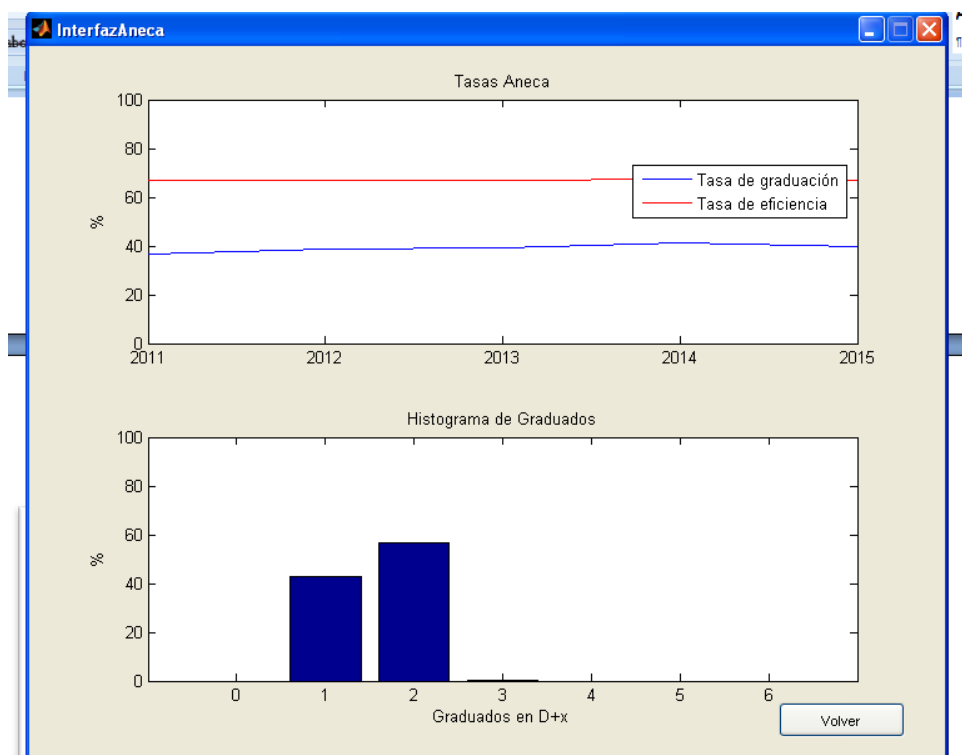

Figure 7: (a) and (b) ANECA Performance rates.

Figure 7(b) shows the histogram of the distribution of the number of students graduating as scheduled (*d+0*) or a year later (*d+1*) and so forth. Those graduated in (*d+0*) and (*d+1*) are those used in the

calculation of the Graduation Rate. For instance in the graphics 7(b), one can see that more than half the students take one or two extra years to graduate.

4. CONCLUSIONS

A stochastic simulator has been developed to simulate curricular paths and from which one can estimate performance indicators of student curricula in Madrid Polytechnical University. A stochastic (Monte Carlo) algorithm is necessary because analytical computation is unfeasible.

The simulator can be adapted to other degrees.

The simulator is proving to be a very useful instrument for decision making, particularly what changes could be made in the University to increase success rates and optimize resources.

REFERENCES

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