

Impact of Flight Simulators on Teaching and Learning Simulink in an Aerospace Engineering Course*

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This paper presents the results of investigating two teaching approaches to students studying a course on Numerical Simulation in Aerospace Engineering. In one approach a group of students used Simulink only and in the second another group used Simulink and a physical flight simulator. The impact on students' motivation and academic achievement was assessed by the use of hierarchical clustering and linear discriminant analysis. There were 42 undergraduate students split into two groups. The conclusion is that by using a flight simulator students enjoy to a larger extent the learning process and thus are more motivated and eventually obtain better marks.

Keywords: flight simulator; rubric; education; Simulink; linear discriminant analysis

1. Introduction

Simulation software provides high flexibility and integration capabilities for designing and testing aerospace prototypes [1]. Hence, Aerospace Engineering students need to learn how to design models and develop simulations by means of some specific software, such as Matlab/Simulink [2]. Some works have shown the utility of virtual environments to improve the learning process [3] and also proved that improving the motivation of students usually leads to an increment of the number of students that would choose further learning after the course is finished [4, 5].

Simulation software has been used pervasively in engineering education. From electric circuits [6] to nuclear engineering [7] a broad range of fields: diesel engines [8]; refrigerating cycles [9]; wireless sensor networks [10]; programming [11]; computer architecture [12]; vibration and noise [13]; management [14, 15]; hydrodynamic bearing design [16], plastic injection [17]; robotics [18]; to name a few, have employed simulations to further improve the learning process.

Nevertheless, despite the importance of using simulation software, we have observed that aerospace engineering students in general do not like

using such software and prefer handling real systems instead. As a consequence, their learning results are usually not as good as expected. Therefore, our goal is to enhance those learning results by means of improving the motivation and the interest of the students in the simulation subject. The use of flight simulators, which are close to real systems, provides the tool to achieve this goal as several authors have used Matlab/Simulink in order to control the performance of simulated aircrafts [19–21]. Hence we developed two simple lab assignments for students of Aerospace Engineering at the University of León (Spain) and used the X-Plane¹ based simulators of the Flight Simulation Centre Leon (SAULE). This simulation centre offers the possibility of connecting Simulink to three different aircrafts: Cessna 172, Beechcraft Baron 58 and Boeing 737. We evaluated the results of the learning process with the help of a rubric and a survey, and used hierarchical clustering and linear discriminant analysis [22] in order to see the impact of using flight simulators in the students' results.

The rest of this paper describes the X-Plane I/O data package in section 2, while 3 and 4 show our two simple models that will be used as lab assign-

¹ X-Plane is a commercial tool developed by Laminar Research.

ments; finally, section 4 details the case study we carried out with our students. Conclusions and future work are stated in section 5.

2. X-Plane I/O data

X-Plane is a Flight Simulation software that allows the user to select flight parameters in order to both, show their values on screen and to exchange them with a computer via User Datagram Protocol (UDP) [23, 24]. Flight parameters appear grouped into fields with up to eight values that are somehow related (e.g. values of pitch, roll and headings appear in the same field). X-Plane assigns to each field an identifier, Field-Id [10].

Data packets always have the same structure (Fig. 1). If we select N fields of data to be exchanged then X-Plane creates a UDP structure that consists of a vector of the following $(5 + 36 \cdot N)$ bytes:

1. The first 5 bytes make a header of four ASCII characters, ['D', 'A', 'T', 'A'], plus one byte for internal use.
2. The other bytes correspond to the N fields that consist of 36 bytes each.

Each of the fields that contain information of a group of parameters consists of:

1. One Field-Id of 4 bytes that contains the field number
2. Eight values of 4 bytes each that contain the real values of the transmitted parameters codified using the standard IEEE-754. If the involved field consists of less than eight values, the other fields are also included although their values are discarded.

3. Receiving data from X-Plane

As a first assignment, students have to develop a Simulink model that receives from X-Plane the data

corresponding to the pitch, roll and altitude. Pitch and roll are the first two parameters of field 17, while the aircraft's altitude in feet above the mean sea level (ftmsl) and the altitude in feet above the ground level (ftagl) are the third and fourth parameters of field 20. This model consists of five stages that first read the data stream, then isolate the fields in the stream, select the values in the fields and converts them into real; finally, the received parameter values are displayed. The fourth stage is a subsystem, Bytes2Real, we have developed in order to take into account the Network Byte Order.

4. Sending data to X-Plane

The second assignment consists of setting the value of the flight simulator throttle command. This is the first and only parameter of field number 25, so X-Plane will discard the values of the other seven parameters (whose values we set to 0 although any other value could have been used). Our simple solution to this assignment makes the header and appends to it the 36 bytes field. These 36 bytes include the Field-Id (4 bytes), the throttle value (4 bytes), and seven discarded parameters (28 bytes). Finally, the model sends the whole packet to X-Plane. In order to handle the Network Byte order, we also need to make a specific subsystem, Real2-Bytes.

5. Experiments and results

We have tested the benefits of our approach with the students of aerospace engineering at University of Leon. Concretely, the involved students are enrolled in 'Numerical Simulation in Aerospace Engineering', a subject that is taught during the 7th semester, which corresponds to the last academic year of that degree. In order to assess the impact of the flight simulators, we have divided the students into two groups of 21 students each. The students were

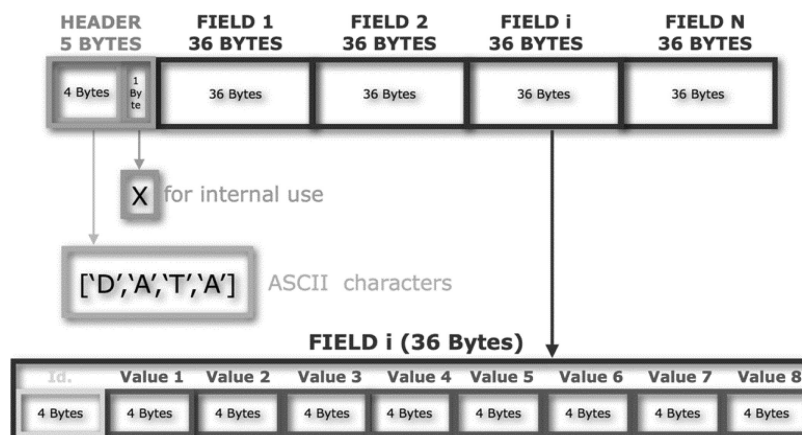


Fig. 1. Example of data packet structure sent to X-Plane.

Table 1. Rubric used for the evaluation of the students

Category	2 points	1 points	0 points
Problem Solving	Actively looks for solutions to the problems and develops models correctly.	Develops and test models although some failures are still present.	Tries to solve the problems but the solutions are useless.
Use of external help	Never requires the assistance of the teacher or class mates.	Sometimes need to ask for help.	Cannot find any solution without help.
Contributions	Uses subsystems or/and improves the solutions provided in the assignments.	Tries to improve the solutions, although with lack of success.	Does not make any contribution to modify the designs.
Working with Others	Almost always listens to, shares with, and supports the efforts of others. Tries to keep people working well together.	Often listens to, shares with, and supports the efforts of others, but sometimes is not a good team member.	Rarely listens to, shares with, and supports the efforts of others. Often is not a good team player.
Attitude	Always has a positive attitude.	Often has a positive attitude.	Sometimes has a negative attitude.

assigned to each group irrespectively of their previous knowledge or grades. One group (A) would use Simulink and SAULE flight simulators, which run under X-Plane software. This group would develop the two models described above in order to receive/send flight parameters from X-Plane and test their models connecting them to the simulators available in SAULE. The other group (B) would only work with Simulink. This group would work in a regular lab sending/receiving data between two computers, that is, without using any flight simulator. In both cases, the students had to develop the same models and carry out the same testing.

In order to establish the impact of our approach on the learning results, the students were evaluated with the help of an evaluation rubric (Table 1). In addition, we carried out a student satisfaction survey on both groups, A and B, about the following items: (a) 'I find Simulink interesting and useful for engineers'; (b) 'I have learnt modelling and simulation with the lab assignments'; (c) 'I am going with

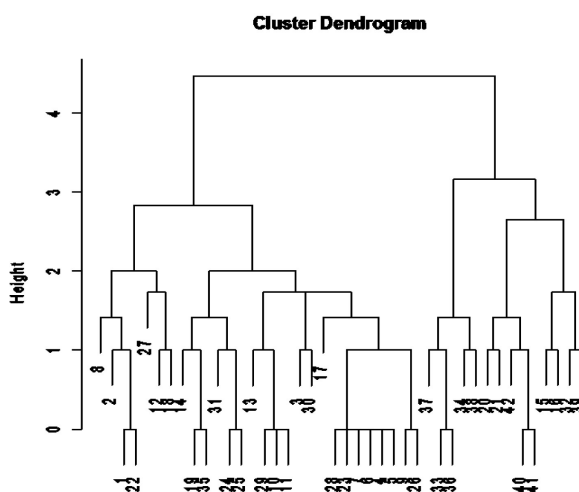
further simulation learning subjects'; (d) 'I enjoyed carrying out the lab assignments'.

The data set recorded will provide the opportunity to extract conclusions from a fact-based approach, as recommended by ISO 9000 principles. These conclusions will be useful in order to make decisions on the design of future courses. In order to reveal the underlying knowledge, tools and techniques from the Data Mining area will be used. In particular, cluster analysis and a multidimensional scaling technique such as linear discriminant analysis will prove useful for such purpose, even though the cardinality of the data set is only 42 observations. Five of the features of this data set are related to the rubric while the remaining four correspond to the satisfaction survey.

5.1 Results

Common exploratory data analysis techniques, such as hierarchical clustering analysis, suggested the presence of two different data generating populations (Fig. 2). Regardless of our experimental design consisting of two groups using different methodologies, this fact might not be reflected on the results; had the different treatments shown similar behaviours the exploratory analysis might have provided overlapping results. Moreover, more than two different behaviours could have been detected, but that was not the case.

Table 2 shows the relationship amongst the clusters revealed by the dendrogram and the two different methodological approaches—groups A and B. It can be clearly seen that those students

**Fig. 2.** Dendrogram of the rubric results showing two main classes.**Table 2.** Relationship between groups A & B and clusters 1 & 2

Reality	Classified as	
	Cluster 1	Cluster 2
Group A	17	4
Group B	11	10

Table 3. Change of basis matrix corresponding to the LDA applied to the rubric features on groups A & B

	LD1
Problem solving	23
External help	16
Contributions	5
Working with others	17
Attitude	39

belonging to group A lay in their majority in Cluster 1. Group B consists of a mixture of Clusters 1 and 2.

The profile of Clusters 1 and 2 shows a significant difference on their grades. The average grade for cluster 1 is 7.6 while the average grade for cluster 2 is 3.3. Thus, group A, which is the group using the flight simulators has in its numbers students with better results. Group B, on the other hand, is expected to have lower results. So as to identify the causes of this difference, multidimensional scaling, and in particular, linear discriminant analysis might shed some light. Thus, a linear discriminant analysis is performed using groups A and B as the two different classes. This provides a projection of the data set on a single dimension, as shown in Fig. 4-a. This projection shows the presence of two classes though strongly overlapped, which is completely coherent with Table 2.

Table 3 shows the change of basis matrix corresponding to the LDA applied to the rubric features. The values of the scaling are represented in percentage to ease their interpretation (larger absolute values have greater influence on the process of discriminating between both groups). From those values, it can be established that the 'Attitude' is the feature with larger impact on the difference of the

two groups, and thus the main cause on their different rate of success.

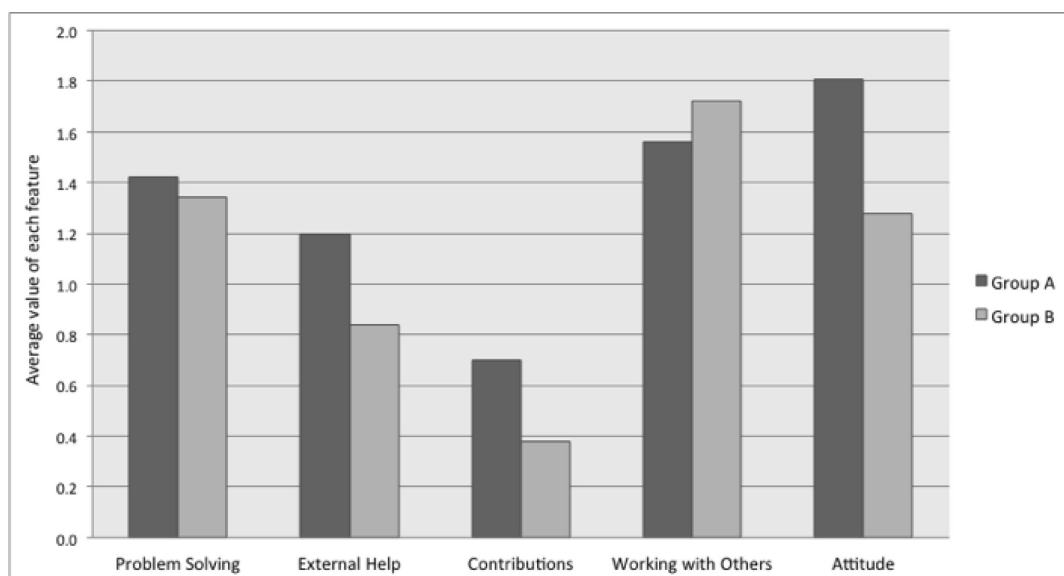
The average value of the grade for those students belonging to group A is 6.7 while the average value for group B is 5.6. Fig. 3 shows the average value of each feature for groups A and B. It can be seen that students from group A have higher marks in every feature but 'Working with others'. This reflects the fact that using the flight simulator makes the work of the student less dependent of the help of other members of the group. Besides, the attitude is the feature where a larger difference exists between the two groups, as already identified by the LDA change of basis matrix.

A similar analysis was performed on the Survey features. Fig. 4-b shows the LDA projection corresponding to groups A and B on these features. In this case, a clearer distinction between the two groups is found. The change of basis matrix shows (Table 4), in this case, that the 'Joy' feature is the predominant cause in the difference between the two groups. It might be interesting to highlight the tiny value for the 'Learnt' feature, which shows that the students feelings about what they have learnt is similar regardless the group they are in.

The linear discriminant analysis of the Test and Survey data let us remark that the use of flight

Table 4. Change of basis matrix corresponding to the LDA applied to the Survey features and groups A & B.

	LD1
Usefulness	33
Learnt	3
Further learning	21
Joy	43

**Fig. 3.** Profile of the two groups according to the Rubric features on groups A & B.

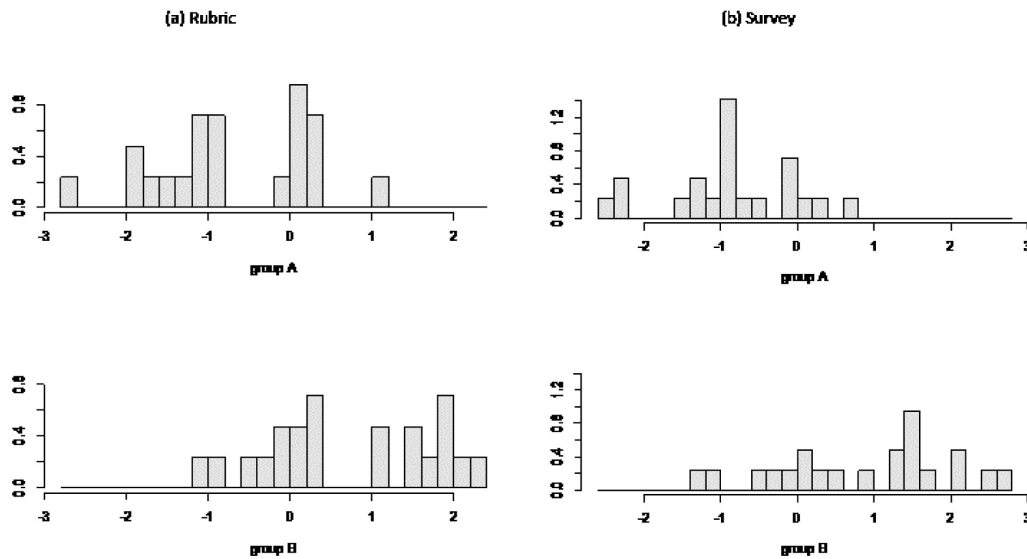


Fig. 4. LDA analysis of the Rubric (a) and Survey (b) features on groups A & B.

simulators is clearly a useful tool for motivating students, and it does not only improve their feelings about learning modelling and simulation but also their chances of achieving better learning results.

6. Conclusions and future work

We have developed two simple lab assignments so that Aerospace Engineering students can learn the basics of model Simulation with Simulink. In order to look for a better way of improving the learning results, we have carried out a case study to compare the results provided by a group of students using a combination of flights simulators and Simulink, and another group of students that only used Simulink to develop their assignment. In order to assess the learning results a rubric was designed and implemented while a survey was conducted to measure the satisfaction degree of the students.

A preliminary hierarchical clustering analysis of the data suggested the presence of two main clusters of students where difference in their marks was significant. Both clusters contained students from groups A and B, but group A, the one that used the flight simulators, had a larger proportion of students belonging to cluster 1, the one with higher marks. As the students were assigned to the groups irrespectively of their previous background, this result suggests that the use of the flight simulator enhances the performance of the students. On the other hand, the use of what proved to be a less attractive methodology made no difference on the motivation and performance of the students belonging to that group.

A linear discriminant analysis, using the information collected on the rubric features and the A and B

grouping, showed that the results of the students from both groups overlapped in the central area while substantial differences appeared on the tails of the distributions. The predominant factor in the difference of groups A and B turned out to be the 'Attitude'. This result is not a surprise according to the experience witnessed by the instructors. This improvement in the attitude and motivation is associated to the fact that the students from group A obtained better marks. The impact of the 'Attitude' factor on the boost of performance is indeed strong (39%).

Further work on the survey features showed a clearer distinction on the behaviour of the two groups A and B. This highlights the fact that even though differences existed on success ratios, even larger differences existed on the student's satisfaction and the degree at which they enjoyed the learning experience. The LDA analysis provides a measure of 43% for the impact of the 'Joy' feature on the boost of performance. Both the improvement on the 'Joy' of the experience and the improvement on the 'Attitude' stands to reason to be associated and linked, jointly boosting the students performance.

The main conclusion from this work is that by using flight simulators the students enjoy to a larger extent learning numerical simulation and the use of Simulink and thus are more motivated and eventually obtain better marks.

As future work we will develop more complicated lab assignments that include control over flight parameters. We will also assess the impact on the learning process of this addition of difficulty in order to evaluate whether the use of flight simulators is still useful when complexity increases.

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