ON THE APPLICATION OF AN ASSIGNMENT-CENTERED METHODOLOGY TO A SYSTEMC MODELING COURSE

E. JUAREZ[1], C. SANZ[1], M. J.GARRIDO[1], AND J.M. MENESES[2]
[1]*Departamento de Sistemas Electrónicos y de Control. Escuela Universitaria de Ingeniería Técnica de Telecomunicación (EUITT). Universidad Politécnica de Madrid (UPM).*
[2]*Departamento de Ingeniería Electrónica. Escuela Técnica Superior de Ingenieros de Telecomunicación (ETSIT). Universidad Politécnica de Madrid (UPM).*

In this paper, an assignment-centered course on SystemC modeling is presented. Course objectives are discussed in detail. Moreover, an overview of the applied methodology and course content is introduced. As far as the course assessment concerns, three different modes have been proposed. In addition, a survey has been conducted to obtain student feedback. Course goals have been completely achieved and positive student feedback has been received.

1. Introduction

System-level specification language courses have been traditionally introduced in graduate programs using a theory-based approach. Unlike hardware description language (HDL) courses, practical applications are not usually presented as part of the course material. To resolve this deficiency, an assignment-centered course on SystemC modeling has been prepared for a graduate program of the Universidad Politécnica de Madrid (UPM).

The SystemC course has been embedded within a graduate course named *Microelectronic and Electronic Design: Architectures for Video Coding*. This course has consisted of 40 hours and has been organized into two blocks. The former is composed of five lectures of two hours each on topics related to video coding technology while the latter is formed of ten lectures on digital system modeling. As far as the digital system modeling block concerns, one of the lectures has been devoted to discuss technological alternatives to design digital systems and the other nine lectures have been dedicated to discuss SystemC modeling. Knowledge of the C programming language and a hardware description language has been assumed as a prerequisite. No previous C++ experience has been required. Although some time has been devoted to traditional lecturing, teaching has been basically focused on assignments.

2. Course Objectives

The aim of the course has been to provide the basic concepts and skills needed to model real, complex digital systems using SystemC [1]. This main goal has been divided into the following objectives: to understand the differences between hardware-oriented models of computation (MoC), i.e. register-transfer-level (RTL), and functional-level MoCs used in system modeling, i.e. Kahn processes networks; to establish connections between C++ concepts [2] and SystemC language structures; to provide a hands-on experience on SystemC modeling based on assignments; to introduce modeling concepts such as hierarchical channels and dynamic sensitivity that appear in SystemC but are not included in traditional HDLs.

3. Course Overview

Eight students have been enrolled in the graduate course. Lectures and hands-on exercises have been given in the laboratory. The Cygwin Linux-like environment for Windows has been installed in each computer to run the GCC 3.3.3 compiler. XEmacs has been used to edit, debug and compile SystemC specifications. No particular integrated development environment (IDE) has been used.

The SystemC course has been structured into nine lectures of three hours each and each lecture has been organized as follows. Session beginning is devoted to outline the main ideas discussed in previous sessions. Then, due assignments are checked and the session is followed with a brief lecture on new concepts. Finally, new assignments are proposed. Students work them out in couples in each computer for at least half of each session. Assignments have mainly consisted of incomplete or erroneous code that needed to be completed or debugged. The goal has been to focus on understanding the characteristics of previously introduced concepts.

The sessions have been scheduled in the following way. One session is dedicated to give a SystemC overview and an introduction to basic C++ ideas. Assignments related to C++ fundamentals are due. Then, two sessions are dedicated to introduce C++ concepts such as inheritance, polymorphism, virtual methods, dynamic binding and composition. Assignments concerning operators, inheritance and virtual methods are due. Afterwards, one session is dedicated to introduce the SystemC module structure. An assignment related to video coded traffic modeling is due. Interfaces, primitive channels, processes and static sensitivity are explained in next two sessions. Assignments related to functional modeling of FIR filters are due. At last, three sessions are dedicated to explain hierarchical channels and dynamic sensitivity. Assignments related to the specification of a bus as a hierarchical channel and that of a primitive FIFO channel with two thresholds are due.

4. Course Assessment

Three different modes have been proposed to assess the course. Notice that participation has been compulsory. No final exam has been due. In the first mode, only assignment completion has been required. Besides this point, a guided final project has been demanded in the second mode. At last, freedom has been given to present a research project in the third mode. Student grades depend on the chosen mode. Five students have selected the first mode, two students have selected the second mode, and one student has worked on a special research project.

5. Student Feedback

A survey has been conducted to obtain the student course feedback. The goal of the survey has been to evaluate the whole graduate course. There was no obligation to fulfill the survey. Only 6 out of 8 students answer the questions.

5.1 Survey outline

The survey conducted among the students has consisted of two parts. As will be discussed later more in detail, the former has been designed to rate course lectures and the latter has collected their views about topics such as course material, balance between lecturing and assignments, and options available to assess the course, among others.

As far as the course lecture rating concerns, two criteria have been selected. Students have rated lectures against topic interest and applied teaching method on a scale from 0 to 10. In particular, a table with the following entries has been provided for the interest criterion:

Entry Number	Lecture Topic
1	Video coding fundamentals
2	Video coding standards
3	Video coding architectures
4	Adaptable architectures for multi-standard video coding
5	IP data broadcasting over DAB/DVB networks
6	Technical alternatives in digital system design
7	Digital systems modeling in SystemC
8	SystemC assignments

Table 1. Table to rate course lectures against the interest criterion

As can be seen in Table 1, the idea has been to rate the whole graduate course. Note that only entries 7 and 8 in Table 1 reference the lectures and assignments related to the embedded SystemC course. For the applied teaching method criterion, a similar table has been provided to the students. Nevertheless, as shown in Table 2, entry 8 has been divided into three different items to separate assignments rating from that of their solutions. Moreover, the rating of the material supplied for the proposed assignments (entry 8.2) has been split from that of the corresponding explanations (entry 8.3)

Entry Number	Lecture Topic
8.1	Proposed C++/SystemC assignments
8.2	Solutions to the proposed C++/SystemC assignments
8.3	Explanation of the solutions to the proposed C++/SystemC assignments

Table 2. Detail of the entries provided to rate the 'SystemC assignments' topic

The second part of the survey has consisted of four sections. In section 1, student opinion about lectures that might be extended, shortened or eliminated has been asked for. Next, particular concerns about the course material have been solicited in section 2. It is worth noting that the SystemC course material has been completely written in English. In section 3, comments about the SystemC lectures have been requested. In particular, student opinion about the balance between theory and assignments, the equipment available at the laboratory and the lecture structure has been required. At last, section 4 has solicited general comments about the course.

5.2 Survey results

As performance metric to draw conclusions from the survey results, the sample mean (or estimated average of the rating process) has been used. In addition, the theory of confidence intervals is applied. We assume that the discrete-time rating random process associated to each table entry is a sequence of independent and identically distributed random variables with a common probability density function which can be appropriately fitted with a normal distribution.

In order to produce statistically significant statements from the survey sample means, non-overlapping confidence intervals have been employed. For entries 1 to 6 in Table 1, the confidence level to produce non-overlapping intervals has been found to be as low as 12%. Although for entries 7 and 8 in Table 2 the confidence level is slightly better, to derive significant conclusions the value has been found to be as low as 40%. Hence, the degree of believe (or likelihood) of any statement produced from the survey data is significantly low, especially for the first part of the graduate course. In order to obtain greater confidence levels, new runs of the graduate course are needed.

Figure 1 provides the sample mean of the lectures previous to the SystemC course with 90% confidence intervals. As can be seen, independently of the criteria, the sample means are greater than 7.5 for all the lectures. However, the resulting confidence intervals totally overlap. Figure 2 shows the same sample mean sequence with 12% confidence intervals. Notice that the ordinate axe in Figure 2 is scaled from 6.5 to 9.5. The lecture on technical alternatives in digital system design (entry 6) has been ranked at the top for both criteria. On the other hand, the smallest sample mean for the interest criterion corresponds to the lecture on video coding standards (entry 2), while entry 3 (lecture on video coding architectures) is equally significant than entry 2 for the method criterion. The differences between the worst and the best rated lectures are smaller than 16% and 11% for the interest and method criteria, respectively. Registered student inclination for practical aspects of digital system design could be probably the cause of the current lecture ranking.

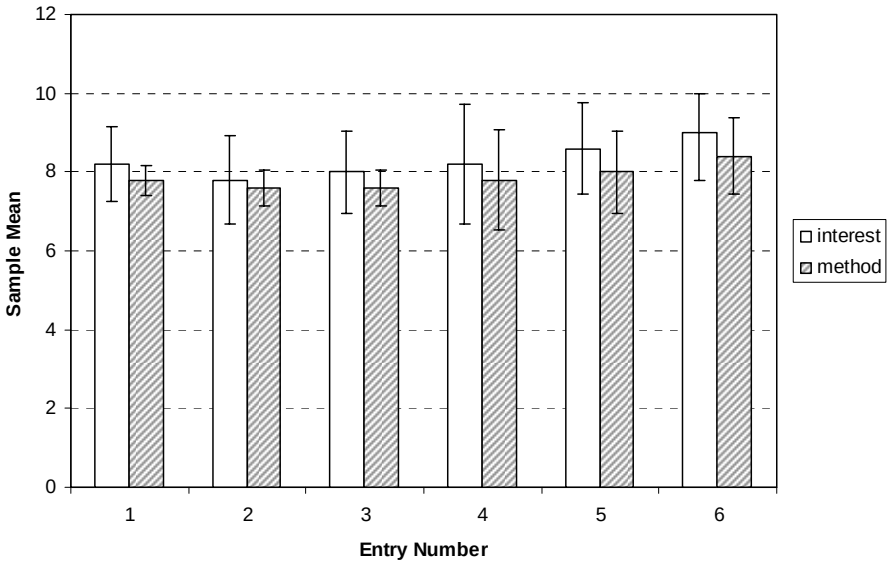

Figure 1. Sample mean of entries 1 to 6 in Table 1 with 90% confidence intervals

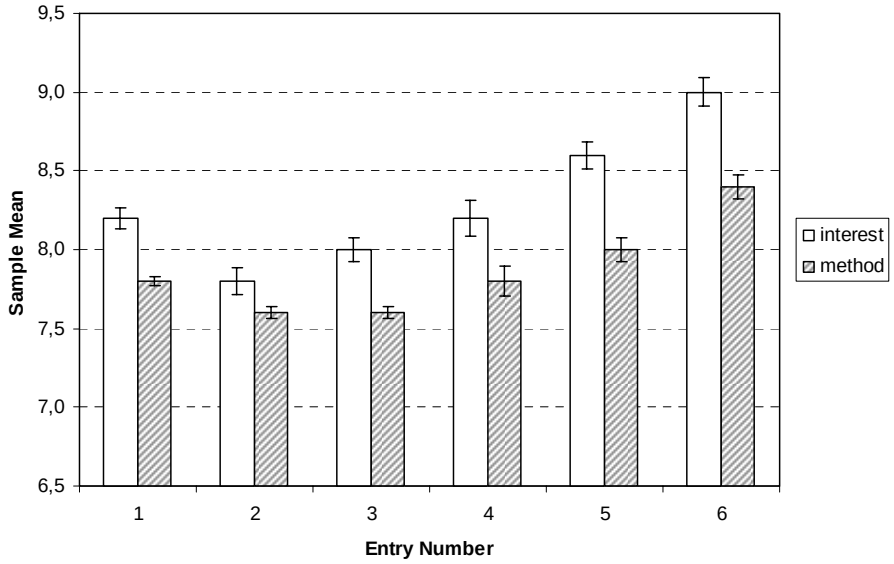

Figure 2. Sample mean of entries 1 to 6 in Table 1 with 12% confidence interval

Table 3 summarizes the main statistics and the confidence interval accuracy of the sample means for entries 1 to 6 in Table 1. The confidence interval accuracy columns measure the relative size of the increment (decrement) experimented by the sample mean at the upper (lower) endpoint of the corresponding confidence intervals. Notice that although the initial sample size is 6, since one of the students has provided no answer for entries 1 to 6, the values under the corresponding column are always 5. As can be seen, in most cases the accuracy is greater than 10% at a 90% confidence level. On the other hand, the accuracy is upper-bounded at 1.5% at a 12% confidence level. It goes without saying that higher confidence interval accuracies (or smaller percentage values) would have been obtained if the sample size would have been greater.

Entry number	Sample mean		Sample standard deviation		Sample size	12% confidence interval accuracy		90% confidence interval accuracy	
	Interest	Method	Interest	Method		Interest	Method	Interest	Method
1	8.2000	7.8000	0.9798	0.4000	5	0.86%	0.37%	11.39%	4.89%
2	7.8000	7.6000	1.1662	0.4899	5	1.08%	0.46%	14.25%	6.15%
3	8.0000	7.6000	1.0954	0.4899	5	0.99%	0.46%	13.05%	6.15%
4	8.2000	7.8000	1.6000	1.3266	5	1.40%	1.22%	18.60%	16.22%
5	8.6000	8.0000	1.2000	1.0954	5	1.00%	0.99%	13.30%	13.05%
6	9.0000	8.4000	1.2649	1.0198	5	1.01%	0.87%	13.40%	11.57%

Table 3. Statistics, 12% and 90 % confidence interval accuracy of entries 1 to 6 in Table 1.

Figure 3 shows the sample mean of the SystemC course lectures (entries 7 and 8 in Table 2) with 90% confidence intervals. As can be seen, a lower bound of the sample mean is 8.0 for all lectures and criteria. However, no statistically significant statements can be derived from the results because the confidence intervals totally overlap. Figure 4 gives the same sample mean sequence with 40% confidence intervals. Notice that, similarly to Figure 2, the sample mean axe in Figure 4 is scaled from 6.5 to 9.5. From the interest point of view, the lectures on digital systems modeling in SystemC and their assignments are statistically indifferent. However, the method employed with the proposed SystemC assignments is top-ranked. Consequently, it is likely that students appreciate a learning pace based on assignments.

Table 4 presents the main statistics and confidence interval accuracy of the sample mean of the entries in Table 2. As can be seen, in most cases the accuracy is greater than 6% at a 90% confidence level. On the other hand, the accuracy is upper-bounded at 2.6% at a 40% confidence level. The higher accuracy (or lower percentage value) of the results in Table 4 at 90% confidence level with regard to those in Table 3 is mainly due to the greater sample size and smaller sample standard deviation of the SystemC course survey.

Entry number	Sample mean		Sample standard deviation		Sample size	40% confidence interval accuracy		90% confidence interval accuracy	
	Interest	Method	Interest	Method		Interest	Method	Interest	Method
7	9.0000	8.3333	0.8165	0.9428	6	2.07%	2.58%	7.46%	9.31%
8 / 8.1	9.1667	9.0000	0.6872	0.5774	6	1.71%	1.47%	6.17%	5.28%
8.2	-	8.5000	-	0.9574	6	-	2.57%	-	9.27%
8.3	-	8.6667	-	0.7454	6	-	1.96%	-	7.07%

Table 4. Statistics, 40% and 90% confidence interval accuracy of the embedded SystemC course

In the following paragraphs, the results of the four sections of the second part of the survey are summarized.

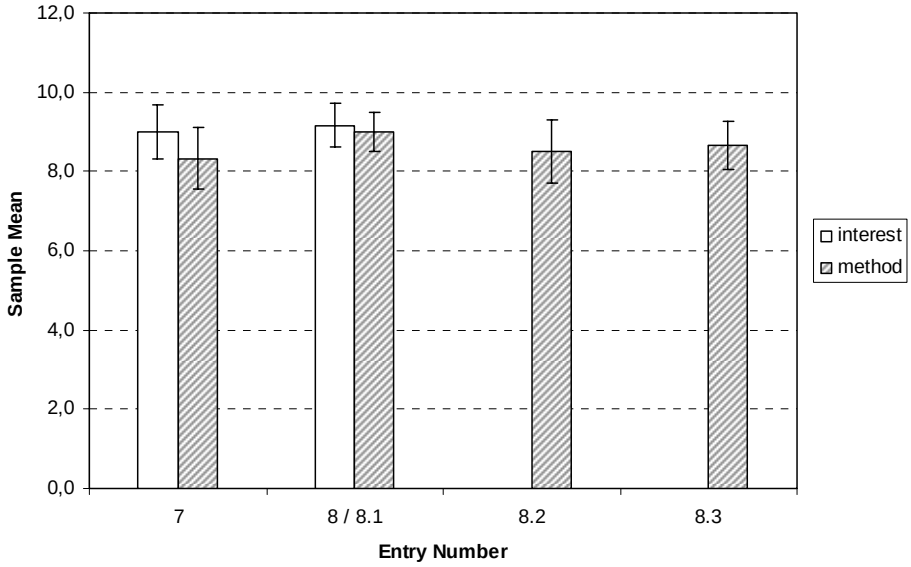

Figure 3. Sample mean of the embedded SystemC course entries in Table 2 with 90% confidence intervals

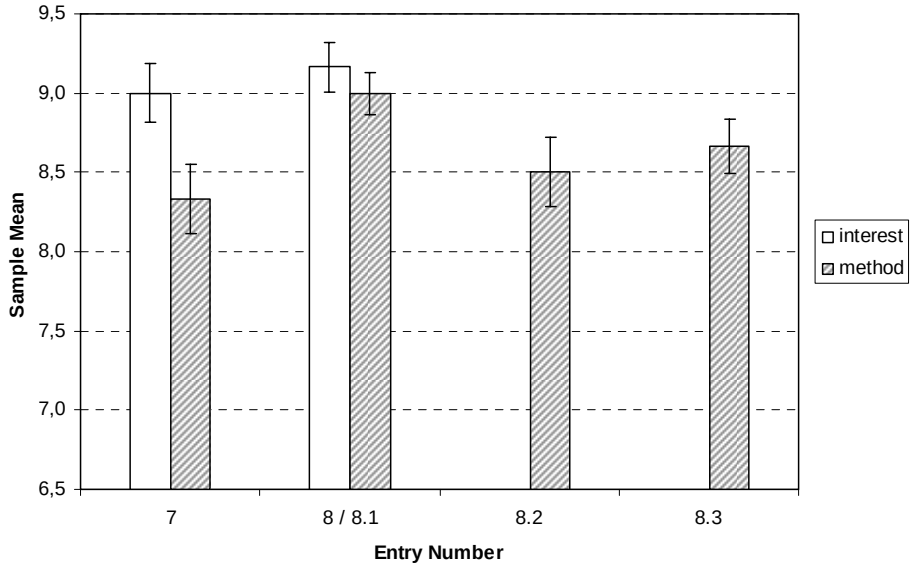

Figure 4. Sample mean of the embedded SystemC course entries in Table 2 with 40% confidence intervals

In section 1, student opinion about the lectures that might be extended, shortened or eliminated has been asked for (Table 5). As can be seen in Table 5, from the students' point of view, the SystemC course should be extended. In particular, 50.0% of the students would like to lengthen the time devoted to SystemC. Moreover, 33.3% of those who want to have the SystemC course expanded would like to expend more time with their assignments. In addition, 16.7% of the students consider that the topic on technical alternatives is very interesting. Finally, 16.7% of the students indicate that a more theoretical approach to the lectures previous to the SystemC course would be more convenient.

Comments	Number of students
“The lectures previous to the SystemC course have been taught from material which comes from projects where the lecturers were involved. A more theoretical approach would have been more appreciated”	1
“More time is needed for SystemC assignments”	1
“Because of its interest, more time should be devoted to the SystemC course. The lecture on technical alternatives in digital system design is also very interesting because of the general view given on the available tools and devices ”	1
“Lectures on video coding standards should be shortened and expend more time with the SystemC course”	1
No answer	2

Table 5. Comments on potential lectures to extend, to shorten or to eliminate

In section 2, concerns about the course material have been solicited. Table 6 presents the answers about the quality of the course material. The first point to highlight is that 66.6% of the students consider that the material is at least suitable. Furthermore, 16.7% of the students who support this statement have rated as “very good” the SystemC course material. However, 16.7 % of the students think that the material is not particularly good. Since the SystemC course material has been totally written in English, students have been asked on its convenience. Table 7 summarizes the answers. In particular, 50.0 % of the students indicate that the English language is not an inconvenient to follow the lectures. Furthermore, more than 66.6 % of these students consider that is preferable to have the material in English. Nevertheless, 16.7 % would like to have the documentation in Spanish.

Comments	Number of students
“The material is quite good”	1
“The material is suitable. The SystemC course has a very good one”	1
“The material is average”	1
“The material is appropriate”	2
No answer	1

Table 6. Comments on the quality of the graduate course material

Comments	Number of students
“It is not an obstacle at all. In fact, I like to have it in English”	1
“It is not an impediment. I prefer to have the material in English”	1
“An English material is not an inconvenient to follow the course”	1
“A basic documentation is Spanish would have been more convenient, although no especial problem have been found to follow the English material”	1
“Since the material is provided in technical English there has been no problem. However, more problems would have appear with a material in colloquial English”	1
No answer	1

Table 7. Comments on having the SystemC course material in English

In section 3, comments about the SystemC lectures have been requested. Table 8 provides the answers to the question on the suitability of the balance between theory and assignments. Particularly, 83.3 % considers that the balance between theory and assignments is suitable. However, 16.7 % of the sample has the opinion that more time should be devoted to assignments. Table 9 indicates that the students consider that the laboratory equipment employed with the SystemC course is good enough, although 16.7 % of the students would have preferred a windows-based operating system environment. Table 10 presents the comments on the organization of the SystemC course. Almost all students (83.3 %) have considered that the organization is good. However, 16.7 % of the students have thought that it would be more interesting to provide the assignment solutions when they are explained. Notice that the organization used has been the following: the solutions to the assignments of a lecture have been provided to the students at the end of the lecture. The assignments have been usually explained in the next lecture and, occasionally, several assignments have been explained together.

Comments	Number of students
"Yes, it is appropriate"	3
"The SystemC lectures have been undoubtedly the best ones, including those of other PhD courses. The assignments are essential and very well formulated "	1
"This kind of courses always need more exercises"	1
"I think that the method followed is quite good: theoretical explanations followed by a block of assignments.	1

Table 8. Comments on the suitability of the balance between theory and assignments of the SystemC course

Comments	Number of students
"Yes"	5
"Yes, although I would have preferred a windows-based environment	1

Table 9. Comments on the laboratory equipment of the SystemC course

Comments	Number of students
"Yes, very good and interesting"	1
"Very good. This is the only course which has provided a documentation that enable future self-study for system development in SystemC"	1
"A better idea could be to give the assignment solutions when they are explained and not before"	1
"I agree, it is good"	1
"I like it"	1
"It is the best method"	1

Table 10. Comments on the organization of the SystemC course

Section 6 has collected the following comments: "I think this a good experience and I hope that I will be able to use what I have learnt within the course"; "As part of a program related to digital electronic design and video coding, the SystemC course is very interesting". "As far as the assignment solution concerns, I think more attention should have been paid to the solution basis". In other words, there is a comment that considers very interesting to add some theoretical explanations in relation to the solutions.

6. Conclusions

Course objectives have been completely achieved. All the enrolled students have passed the course. No student has dropped out. In general, assignments have been finished successfully. Assignment solving in the laboratory has encouraged student participation. The likelihood of any statement produced from the survey data is significantly low, especially for the first part of the graduate course. In order to obtain greater confidence levels, new runs of the graduate course are needed. On the other hand, the SystemC course methodology has been a success from the student point of view. Consequently, it is likely that students appreciate a learning pace based on assignments. In addition, from the students' point of view, the SystemC course should be extended.

References

[1] T. Grotker, S. Liao, G. Martin, and S. Swan. *System Design with SystemC*, Kluwer Academic Publisher, June 2002

[2] F. B. Brokken, *C++ Annotations*, University of Groningen, http://www.icce.rug.nl/documents/, last visited on 03/10/06