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Teaching control courses online during the covid-19 pandemic: some experiences at the University of Brescia

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Abstract In this paper we present the experience of online teaching of some control courses during two years of covid-19 pandemic at the University of Brescia. Different (undergraduate and postgraduate) courses are considered and a survey has been conducted with the students to evaluate pros and cons of the new way of teaching. A specific initiative employed in the second year to increase the student engagement has also been evaluated. It is believed that the results of the survey can help in discussing and learning best practices to apply during the pandemic and when this will be finished.

Keywords: Control education, online teaching, covid-19, student engagement.

1. INTRODUCTION

The covid-19 pandemic has affected significantly the lives of people all over the world. In particular, in order to reduce the number of infected, online teaching has been used in universities and this has represented a real novelty in many cases, for both students and instructors. For this reason, the advantages and disadvantages of online teaching with respect to the face-to-face one has been analyzed in many countries (see, for example, (Peytcheva-Forsyth and Aleksieva, 2021; Verde and Valero, 2021; Kaur et al., 2021; Martínez et al., 2021)). It turns out that this difficult situation might also represent an opportunity to improve the effectiveness of educational activities (Makarova et al., 2021) in many disciplines, including engineering (Revilla-Cuesta et al., 2021). In fact, new tools should be used appropriately to improve the quality of teaching, to engage the students more effectively, and to make them acquire those soft skills that are important for their career (Chen et al., 2021; Wang et al., 2021; Ramírez-Hurtado et al., 2021; Bumbalauskas and Vyas, 2021).

It is therefore interesting to investigate how to improve online teaching with respect to control courses (Ma, 2020; Lee et al., 2021), which have their specific features, as it is important for the student to learn fundamental concepts but also understand the practical issues related to a control system.

In this paper we present the experience of teaching four courses online at the University of Brescia in 2020 and 2021. The courses involve students of different years, that is, both undergraduate and postgraduate students, and they deal with different topics. In particular, one course is given at the bachelor level and the students have to learn fundamental concepts as they will attend other control courses subsequently. One of these subsequent courses is given at the first year of the master program and it deals with control systems technologies, mainly related to industrial process control. A laboratory course is then given in the last year and it consists in a motion control problem to be solved by the students in order to be familiar with practical aspects in the design of a control system. Finally, the fourth considered course is given as a unique control course for postgraduate students, so that its aim is to drive students to understand the power and relevance of feedback loops (Rossiter et al., 2020) and how they can be implemented for motion control systems. All these courses have been always taught in a traditional face-to-face mode before the pandemic.

The city of Brescia has been one of the first cities hit by the coronavirus in Italy and, unfortunately, it has been one of Italian covid-19 epicentres for many months. Indeed, face-to-face lectures have been unexpectedly forbidden in February 2020 just after one week from the beginning of the semester, so that both teachers and students were taken by surprise and university courses have to be rearranged to be given online very quickly.

On the other hand, one year later in 2021, although there was the hope to going back to normal life, the educational system in general was prepared better and, in any case, both students and instructors were more familiar with online teaching.

It is worth stressing here that students are not required to attend lectures in order to pass the final exam and there are no mandatory tasks for them during the semester so that they are fully free to decide how much they are involved in the educational activities proposed by the instructor.

In order to evaluate the advantages and disadvantages of the online teaching experience, a survey has been conducted with the students. The results, although the limited context has to be taken into account, might represent a starting point of a discussion about how to improve the online control education in case the pandemic will be still present in the next year or, hopefully, how to improve the teaching of control courses in case people will be allowed to be present in the classrooms.

The paper is organized as follows. In Section 2 a description of the courses considered in the analysis is given and the online teaching modalities that has been applied are presented. The survey filled out by the students is described in Section 3. A summary of the results is then given in Section 4 and discussed in Section 5. Finally, conclusions are drawn in Section 6.
2. CONSIDERED CONTROL COURSES AND ONLINE TEACHING MODALITIES

The analysis carried out in this paper involves four different control courses given at the University of Brescia for different kind of students. Their content and the teaching modalities are described in the following subsections.

2.1 Fundamentals of Control Systems

This course is the first control course taught to students attending the second year of the Industrial Automation Engineering program. It is therefore an introductory course related to control systems for students who will then attend other courses related to control. It consists of 90 hours of lectures. After an introduction to feedback control, the content includes linear systems and transfer functions. Both time domain and frequency domain analyses are treated. Then, the design of a control system is considered by using both loop shaping (by means of Bode plots) and analytical methods. State space modelling is then explained by addressing structural properties (stability, controllability and observability) before presenting state-feedback control.

Before the pandemic, typical lectures were given in the classroom by using the blackboard, including exercises where problems were solved by the instructor. In addition, about 24 hours of computer exercises were done by the students with Matlab/Simulink. At the end of each lecture, the instructor provided a simple online survey to the students asking the topics of the lectures that needed to be better clarified. A (short) new explanation related to them were then done in the subsequent lecture.

In the first year of the pandemic the lectures have been done online (using the Microsoft Teams platform) applying exactly the same methodology (that is, by using an electronic blackboard). Indeed, lectures were done live in the days and time according to the program timetable. However, lectures were recorded and made available to the students who could access them at any time. The same approach has been used in 2021 but in this case, a quiz with some questions related to the topics of each lecture was proposed to the students with the aim to engage them more and to make them aware if everything was clearly understood before taking the next step. They could consult any means to understand better if the concepts were assimilated by the students.

2.2 Control Systems Technologies

This course is given to postgraduate students attending the first year of the master program in Industrial Automation Engineering. It consists of 90 hours of lectures. In half of them the teacher explains the concept by using slides and the blackboard. The other half of the classroom hours are devoted to the solution of problems (related to the topics considered in the frontal lectures) by the students themselves with Matlab/Simulink. The content is mainly related to industrial process control systems, including PID controllers (and their tuning), system identification, control structures, model predictive control, fuzzy control. There have been no significant differences in the teaching approach before and during the pandemic. Lectures and computer exercises were transferred online and lectures were given live, recorded and made available to the students.

2.3 Laboratory of Control Systems

This course is attended by students attending the second (final) year of the master program in Industrial Automation Engineering. After 36 hours of frontal teaching, students are required to design and implement a motion control system for a mass connected to an electrical motor with an elastic transmission. The controller has a cascade PID structure and exploits an observer to estimate the position of the load. Before the pandemic the implementation was done by using an experimental setup but in 2020 and 2021 students were required to perform only simulations. Face-to-face lectures were substituted with asynchronous learning. Videos were recorded by the instructor and made available at any time to the students who could in any case ask for clarifications during the official hours of the timetable.

2.4 Control Systems

This is a unique control course (of 60 hours) given to postgraduate students attending the master program in mechanical engineering. The content includes an introduction to feedback control, fundamental concepts of linear systems, PID control and motion control systems. Traditional frontal learning with theory and exercises (with both blackboard and Matlab/Simulink) were used before the pandemic. In 2020 and 2021 asynchronous learning was mainly applied. In fact, some exercises were done live (by using Microsoft Teams) in order for the students to be easier to ask questions and, as a consequence, for the teacher to understand better if the concepts were assimilated by the students.

3. SURVEY

The same survey has been conducted with all the students who have attended the courses at the end of it. After some background information (average mark, availability of an efficient internet connection and of a quiet room where the student can avoid any distraction), the following questions (with the related possible answers) have been asked.

(1) Advantages of online lectures are:
   (a) I do not waste time in travelling from home to the university (disagree/partially agree/fully agree)
   (b) I have no problem to find a comfortable seat in the classroom (disagree/partially agree/fully agree)
   (c) I can see again the video of the lecture if some explanation is unclear (disagree/partially agree/fully agree)

(2) Other advantages of online teaching are: (textual comment)

(3) Disadvantages of online lectures are:
   (a) I miss a direct relationship with my mates (disagree/partially agree/fully agree)
   (b) I miss a direct relationship with the instructor (disagree/partially agree/fully agree)
   (c) It is more difficult to ask questions to the instructor (disagree/partially agree/fully agree)

(4) Other disadvantages of online teaching are: (textual comment)

(5) My favourite teaching modality is: (synchronous learning provided that the lectures are recorded and made available / synchronous learning in any case / asynchronous learning)
(6) In case I prefer synchronous learning, this is because:
   (a) I can ask clarifications to the teacher immediately (yes/no)
   (b) I am forced to attend a lecture at a given time (yes/no)
   (c) Other advantages of synchronous learning are: (textual comment)
(7) In case I prefer asynchronous learning, this is because:
   (a) I can better organize my time (yes/no)
   (b) I can move forward with the course at any time (yes/no)
   (c) Other advantages of asynchronous learning are: (textual comment)
(8) With respect to face-to-face lectures, in my opinion,
   (a) I have learned better the topics of the course (disagree/partially agree/fully agree)
   (b) I have learned to be more autonomous (disagree/partially agree/fully agree)
   (c) I have improved my soft skills in general (disagree/partially agree/fully agree)
   (d) It has been harder attending the course in general (disagree/partially agree/fully agree)
(9) With respect to face-to-face lectures, I have consulted
   (a) my mates (less frequently / same / more frequently)
   (b) web resources (less frequently / same / more frequently)
   (c) textbooks (less frequently / same / more frequently)
   (d) the teacher (less frequently / same / more frequently)
   (e) specific resources of the courses (for example, specific exercises) (less frequently / same / more frequently)
(10) With respect to face-to-face lectures, I have spent more
    time for studying (disagree/neutral/agree)
(11) How many times do I have watched the video of the
    lecture more than once? (never/sometime/often/always)
(12) In case it is possible to go back to face-to-face lectures:
    (a) I prefer that all the lectures are face-to-face (disagree/neutral/agree)
    (b) I prefer that all the lectures are online (disagree/neutral/agree)
    (c) I prefer that all the lectures are face-to-face by they are recorded and the videos are made available (disagree/neutral/agree)
(13) In case it is possible to go back to face-to-face lectures but
    lectures are recorded:
    (a) I would always attend the lecture in person (yes/no)
    (b) I would sometime attend the lecture in person (yes/no)
    (c) I would never attend the lecture in person (yes/no)

Finally, for the undergraduate students of Fundamentals of
Control Systems, a specific question has been added in 2021
in order to evaluate the usefulness of the quizzes at the end
of each lecture to motivate them to constantly learn the subject:

(14) How do you evaluate the use of the quizzes at the end of
    the lecture?
    (a) They have been useful to understand better the topics of
        the lecture (disagree/neutral/agree)
    (b) They have motivated me in attending the lectures and
        studying the topics each time (disagree/neutral/agree)
    (c) They have request too much time with respect to the
        benefits I received (disagree/neutral/agree)

4. RESULTS

The main results of the surveys are summarized hereafter (the
number of participants are shown in Table 1 for the consid-

| Course                        | 2020 | 2021 |
|-------------------------------|------|------|
| Fundamentals of Control Systems | 46   | 31   |
| Control Systems Technologies  | 17   | 30   |
| Laboratory of Control Systems | 15   | 18   |
| Control Systems               | 17   | 24   |

ered courses). There are not significant differences in the re-
sponses from the students of the different courses and, more
importantly, from 2020 to 2021. The few relevant ones will be
highlighted.

- Attending the lecture without going to the university allows
  a significant saving of time (which can be employed for learning better
  the content of the course) and of money (which might imply an increas
  of the number of students enrolled in a given program), see Figure 1.
- However, the main perceived advantage of online teaching
  is that the students can watch the video of the lecture as many
time as they like and at their favourite pace (namely, they
can stop the video in order to think better about a concept or in order to look for additional resources useful for
their comprehension), as shown in Figure 2.

Indeed, almost all the students have watched the videos
again after the lectures, which means that their availability
is really useful (Figure 3).
- A clear perceived disadvantage of the online teaching is the
  poor relationship with the other students and with the
  teacher (Figures 4 and 5).
- Further, it is more difficult to be focused on the lecture
  being in front of a screen for a long time. However, with
  asynchronous learning, the student can pause the video at
  any time when he/she is tired.
- Students appear to be happy whatever (synchronous or
  asynchronous) mode is selected by the instructor (Figure
  6). Indeed, each mode has its own pros and cons. Students
  might prefer live lectures because they can stop the in-
tstructor in case something is not clear, they can interact
  with the other students immediately and they are forced
to keep a tight schedule in their educational activities.

On the other side, asynchronous learning enables the stu-
dents to manage their agenda according to their specific
needs, to learn faster if possible, and minimize possible
3 temporary problems with the internet connection.
- Students, in general, feel that online learning is harder
  than traditional learning (Figure 7).

Nevertheless, the students of Control Systems have re-
sponded that they have saved time with the online lectures
(Figure 8). A possible reason for this is the relatively
short length of the course, the introductory content for
which there are not a lot of mathematical details and the
asynchronous model that has allowed students to learn fast
(considering that they are “experienced” postgraduate stu-
dents and considering also the time saved by not travelling
to go to the classroom).
- There are different viewpoints about asking questions to
  the instructor. Some students think that online it is easier
to ask a question because they cannot be criticized by the
rest of the class. Indeed, this is an opinion that is expressed
more by undergraduate students, while postgraduate ones
think that it is easier to ask a question directly to the
teacher when you are in person in the classroom. Thus, it
appears that an important task of the instructor is to make
students comfortable with asking for clarifications during the online lecture or to dedicate specific time intervals for them in case of asynchronous learning.

- During the online learning experience the students have consulted more web resources (Figure 9), which can be a positive result since they have become more autonomous, but they have consulted less their mates (Figure 10). This is a quite obvious drawback of the online experience because students becomes less familiar with team working skills and they lose those social activities that are in any case essential for their growth.

They have consulted the teacher more or less as usual (Figure 11), which means that, event if talking through the internet represents a barrier for a close relationship, this does not prevent students to ask clarifications to the teacher.

- As shown in Figures 12–14, the use of the quizzes at the end of each lecture has been evaluated very positively by the class of Fundamentals of Control Systems. In fact, they have helped most of the students in making them aware if a topic had been well understood and in engaging them in the course day by day.

- Almost all the student have responded that, even in case frontal lectures will be recovered, they would like to have the lecture recorded and available for watching it again in case they have missed something. If this is done, the great majority would in any case attend the lecture in person, some students would go to the classroom frequently but not always while only a few of them would prefer to only attend online (asynchronously).

Online teaching has had a great boost because of the pandemic and it will not be sensible to go back to the traditional face-to-face only teaching. In fact, students have perceived some clear advantages of the online teaching (most of all, having the possibility of watching the video of lecture as many time as they like and reducing the travelling time and costs) and these should be kept also when the presence of the students in the classroom will be allowed.

Actually, it has to be realized that the increased availability of video lectures and web resources at a very large scale can facilitate a new learning paradigm where the students select by themselves courses based on their own needs and also based on their preferences (for example, a teacher who explains a topic in a clear way with the required level of details). On the one hand, this personalized education might be beneficial for a person who can select his/her best path for the career but, on the other hand, there is the clear risk to lose those soft skills (like being able to work efficiently in a team) that can be acquired only having in-person social activities. Indeed, universities have a key role in the society also because they implicitly promote such a kind social activities who contribute to the people well-being.

One of the next challenges in control education will be therefore the development of a new organization of control courses (for example by suitably mixing face-to-face and online lectures) that incorporates the advantages of online teaching in the traditional educational approach in order to exploit the new technologies to make the overall education more efficient and sustainable for the students (it is worth noting that a similar reasoning is done regarding the organization of control conferences, where the discussion is about in person, online or hybrid mode).
Almost all the students have responded that, even in case of asynchronous learning, that the lectures are recorded and made available.

During the online learning experience the students have preferred to attend online (asynchronously). Some students would go to the classroom frequently but not always while only a few of them would prefer to only attend the lecture in person, in the case essential for their growth.

The increased availability of video lectures and web resources at a very large scale can facilitate a new learning paradigm where the students select by themselves courses based on their own needs and also based on their preferences (for example, a teacher who explains a topic in a clear way with the required level of details). On the other hand, there is the clear risk to lose those soft skills (like and reducing the travelling time and costs) and these should be kept also when the presence of the students in the classroom will be allowed.

Online teaching has had a great boost because of the pandemic during the global lockdown. During the lockdown, some students have realized that the traditional educational approach in order to exploit the new technology and to modernize the educational contents, where the discussion is about in person, online or hybrid (for example by suitably mixing face-to-face and online learning). In fact, students have perceived some disadvantages such as the internet represents a barrier for a close relationship, the lecture recorded and available for watching it again in synchronous learning in any case essential for their growth.

In any case, the lecture recorded and available for watching it again in synchronous learning provided that the lectures are recorded and made available.

Figure 5. Answers related to question 3(b).

Figure 6. Answers related to question 5.

Figure 7. Answers related to question 8(d).

Figure 8. Answers related to question 10.

Figure 9. Answers related to question 9(b).

Figure 10. Answers related to question 9(a).

Figure 11. Answers related to question 9(d).
6. CONCLUSIONS

In this paper we have presented the results of a survey about online teaching between students who have attended control course at the University of Brescia in 2020 and 2021 during the covid-19 pandemic. Although the context is actually limited (different responses could be obtained for other courses, universities, and countries), the obtained results help in reflecting on how online teaching can be improved and, most of all, on how a new teaching paradigm with the advantages of both frontal and online lectures can be built. In fact, it is believed that the experience gained in this period should be fruitfully exploited in the future.

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