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Transformation of an On-campus Course to an On-demand Course and Assessment

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Abstract

The category for this paper is Evidence-based Practice. In our university in the summer 2020 term, on-campus courses were changed to the remote instruction modality in response to the pandemic. Our university offered different options for conducting remote instruction either synchronized with the original course schedule or asynchronously. In response to the different needs of the students in that period of public health crisis, we tried an on-demand approach in our summer course Control of Machinery. In this approach, education was delivered through video lectures prepared weekly and stored in Canvas Studio that could be streamed to the students on demand. The students could either view these lectures during the class time in the course schedule or at some other time workable for them in the same week. Offering such flexibility could avoid the potential conflicts between the original class schedule and students' altered schedules during the public health emergency period. The video lectures were prepared using a versatile note-taking app S Note that supports integration of multimedia files. The app runs on an Android tablet. The lectures presented on the tablet were recorded by a screen recording app x-Recorder in the mp4 format that can be streamed online. Examination scores in the on-demand course were compared with those in the previous offering on campus. The scores of the on-demand course were not less than those of the on-campus course. Students evaluated the on-demand course regarding the communication of ideas and information, explanation of complex concepts and ideas, stimulation of critical and creative thinking, and whether the course was challenging. The student evaluation results were higher in the on-demand approach than in the previous offering on-campus.

Keywords

Remote instruction, face-to-face instruction, video lectures, distance learning, assessment

Background

Due to the pandemic, the summer 2020 offering of our Control of Machinery course was changed to the remote instruction modality. Some students preferred taking the course synchronously at the regular course schedule. Some other students preferred taking it asynchronously because of the possible changes in their responsibilities during the pandemic. We tried the new approach of delivering the education through video lectures prepared weekly and stored in the Studio of the learning management system Canvas that could be streamed to the students on demand. The students could either view these lectures during the class time specified in the course schedule or at some other time workable for them in the same week. In the previous offering of the same course in fall 2019, the course was delivered to the students in the on-campus, in-person modality at the time periods specified by the course schedule.

The Control of Machinery course is a senior level required course in the mechanical engineering department. This course covers the theory and design of linear systems and control techniques applicable to the control of machinery. Topics include design and implementation of control systems using conventional automatic controllers for linear systems, compensation techniques, and advanced topics in modern control theory. Simulation and/or hardware of modern control systems are also covered. The course learning outcomes, developed by the mechanical engineering faculty, are that at the successful completion of the course, students are able to:

- Analyze control systems in the time domain and in the frequency domain
- Design control systems in the time domain and in the frequency domain
- Apply knowledge of mathematics, science, and engineering to design systems with complex control actions including compensation techniques for control of physical systems
- Design solutions to control dynamic systems using state variable methods
- Apply knowledge of calculus-based physics with depth in the ability to apply advanced mathematics through multivariate calculus, differential equations, and linear algebra to design the control of a system or process to solve for desired needs

Transformation of an On-Campus Course to an On-Demand Course

We were aware of various options of online teaching methods[1,2,3] prior to making the transformation of the on-campus course to the on-demand course. Our on-demand approach bore some resemblance to the online modality. The following steps were taken in such transformation.

Revision of the course learning outcomes

In the transition from the on-campus, in-person course in fall 2019 to the online, on-demand course in summer 2020, the course learning outcomes for the in-person course were reviewed. In the review, we found that most of the outcomes could be transitioned to the on-demand course without modifications. For outcomes involving in-person, in-laboratory experiments, they were not feasible in that summer term due to campus closure. They were replaced by computer-aided control system design experiments that the students could perform in their places using Matlab. We provided the academic access codes for Matlab to the students. We also demonstrated laboratory experiments in pre-recorded videos prepared previously[4].

Reorganization of the course contents

After the revision of the course learning outcomes, we reviewed the topics and made changes to match the revised course learning outcomes. The changes were minimal. We organized the topics into six modules to match the summer schedule. The topics in these six modules are described as follows:

- Module 1: Mathematical modeling of mechanical systems by transfer functions. Proportional, integral and derivative control actions. Block diagram simplification and reduction techniques.
- Module 2: First- and second-order systems responses: rise time, peak time, settling time, peak value, and percent overshoot. Concept of dominant poles. Routh-Hurwitz stability test and BIBO stability.
- Module 3: Root-locus method: angle and magnitude criteria. Root loci on real axis, asymptotes, breakaway and entry points, angle of departure and angle of arrival, and intercepts on the imaginary axis. Lead compensator design. Lag compensator design.
- Module 4: Frequency domain analysis: Bode plots, Nyquist plots, gain margin, phase margin, and Nyquist stability criterion.
- Module 5: Mathematical modeling of control systems by state-space equations. Solution of state-space equation and introduction to the concepts of controllability, observability, and asymptotic stability.
- Module 6: One advanced topic in state-space control theory: the pole placement method and its application in the shaping of dynamic responses.

Some of the previous topics involving lengthy theoretical derivations, for example, root locus properties, were illustrated and computed by a computer-aided control system design software (Matlab Control System Toolbox) without the loss of rigor.

Development of the On-Demand Materials

The next step was to develop on-demand course materials for the topics in the six modules. One of the challenges in this summer offering was limited time to prepare course materials for the topics. We managed to produce the teaching materials within the limited timeframe. We did that by using technology already available and accessible at that moment to the instructor. That technology included a Samsung tablet with a stylus (S Pen), a versatile notetaking Android app S Note, and a screen recording app xRecorder with which the instructor had some exploratory experience before[3]. It turned out that the tools facilitated a smooth process of producing the lecture materials and the recording of the lectures in mp4 videos in the entire term.

S Note is a powerful and easy-to-use electronic notetaking app equipped with the following features. It provides various pen and brush types in a large collection of colors that users can write, draw, and paint on the tablet with an S Pen. The S Note app supports various photo, audio and video multimedia files. These multimedia files can be embedded into S Note documents. S Note has a built-in illustration art library. Users can insert any of the illustrations and shapes into an S Note document. The app permits layers that the users can overlay layers of drawings, graphics, photos, text and handwriting on any page. The app supports paginations. The contents in an S Note document are organized into pages that permit searching within the S Note document. S Note supports tags that permit search of contents among S Note documents. The app also supports sketch recording and the transformation of handwriting into text.

It was noticed that S Note was helpful in showing students the steps in solving problems. The solutions of the problems could be presented step by step in writing with graphical illustration and with verbal explanation simultaneously. This step-by-step writing process and the verbal explanation were recorded as mp4 videos by xRecorder. A screen shot of an example presented in S Note is shown in Fig. 1. It began with a blank page. The problem was described verbally. Every step along the way to the final answer was presented, explained, and recorded by xRecorder.

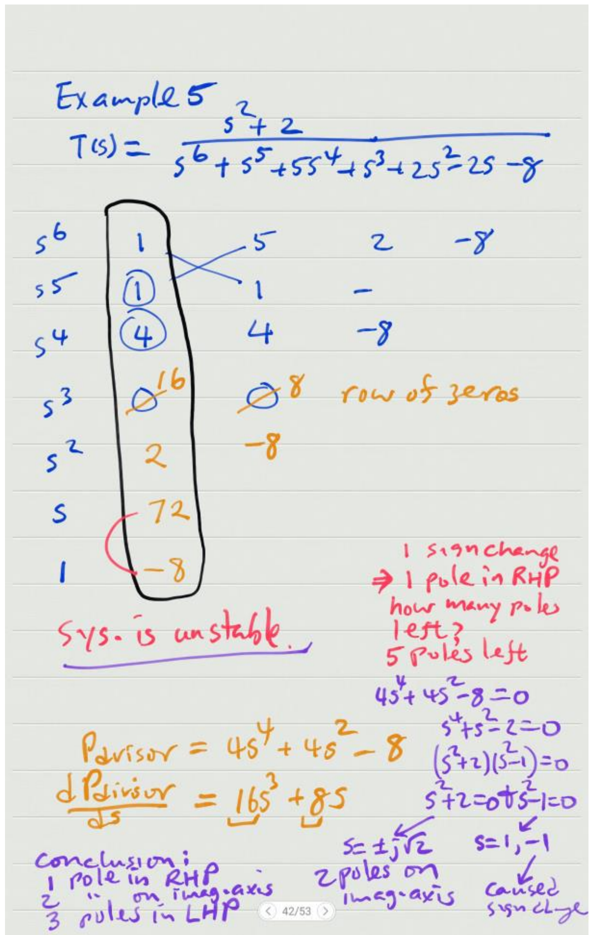


Fig. 1: a screen capture of S Note

These videos were dynamic contents that engaged students better than static contents like textbooks. The app xRecorder is a popular app for recording the screen of Android devices and their microphone inputs. The app is equipped with its own video editor that can be used for video cropping and for frame rate changing. In that summer term, we produced 42 videos of total size of 37.4 GB for the course delivered in the on-demand approach. The lengths of the videos ranged from 2 minutes for coverage of a short example to 90 minutes for a long lecture. The average length was about 50 minutes.

There are other notetaking apps in the market in addition to S Note, for example, Evernote, Microsoft OneNote, Apple Notes, Google Keep, etc. There are other tablets out there in the market too such as Apple iPads and Microsoft Surfaces in addition to the Samsung tablet that we used. These apps and tablets can also be considered in the development of the video lectures.

Demonstration of lab experiments

The workings of proportional, integral and derivative controllers in a position control plant were recorded in videos and viewed by the students. These experiments were developed in previous face-to-face courses[4]. The plant is shown in Fig. 2. The microcontroller and the associated signal conditioning circuits are shown in Fig. 3.

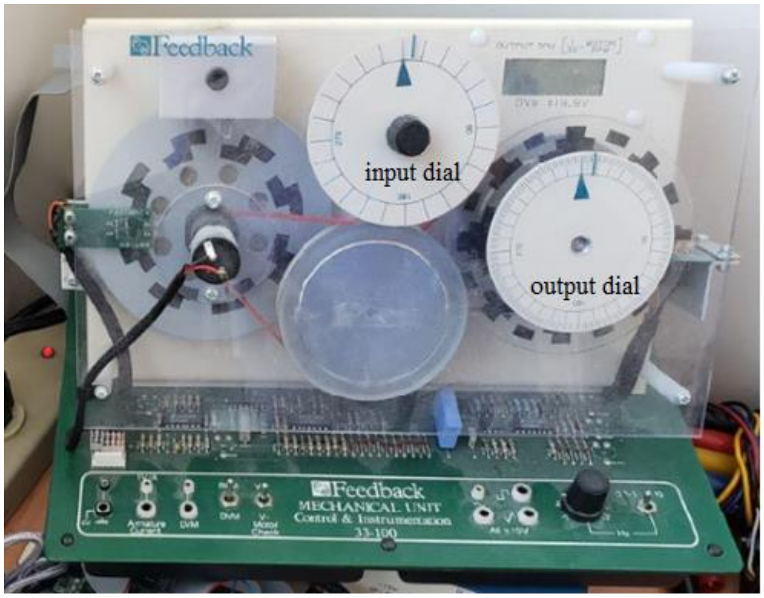


Fig. 2: photo of the position control plant

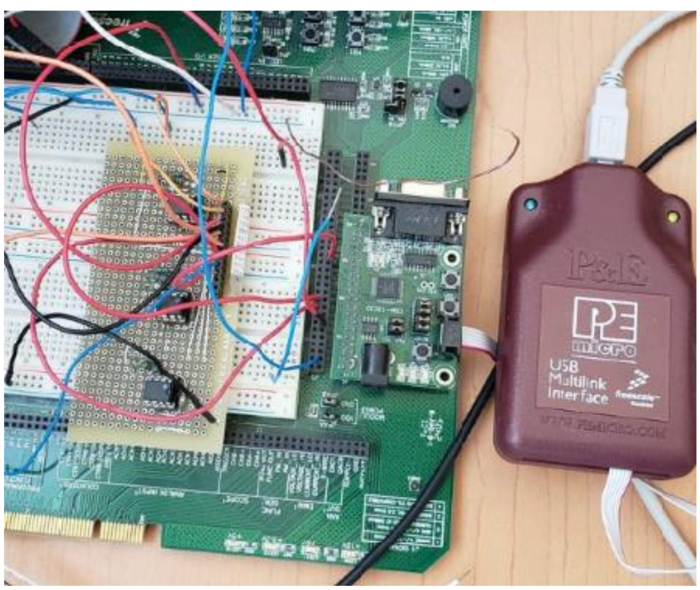


Fig. 3: circuits and microcontroller for driving the plant.

The application of the proportional controller in tracking the input dial by the output dial was demonstrated. There was ringing of the output dial in the tracking of the input dial and the students observed that in the videos. The input dial and output dial signal waveforms were presented as shown in Fig. 4. The effects of the proportional gains were also discussed and demonstrated.

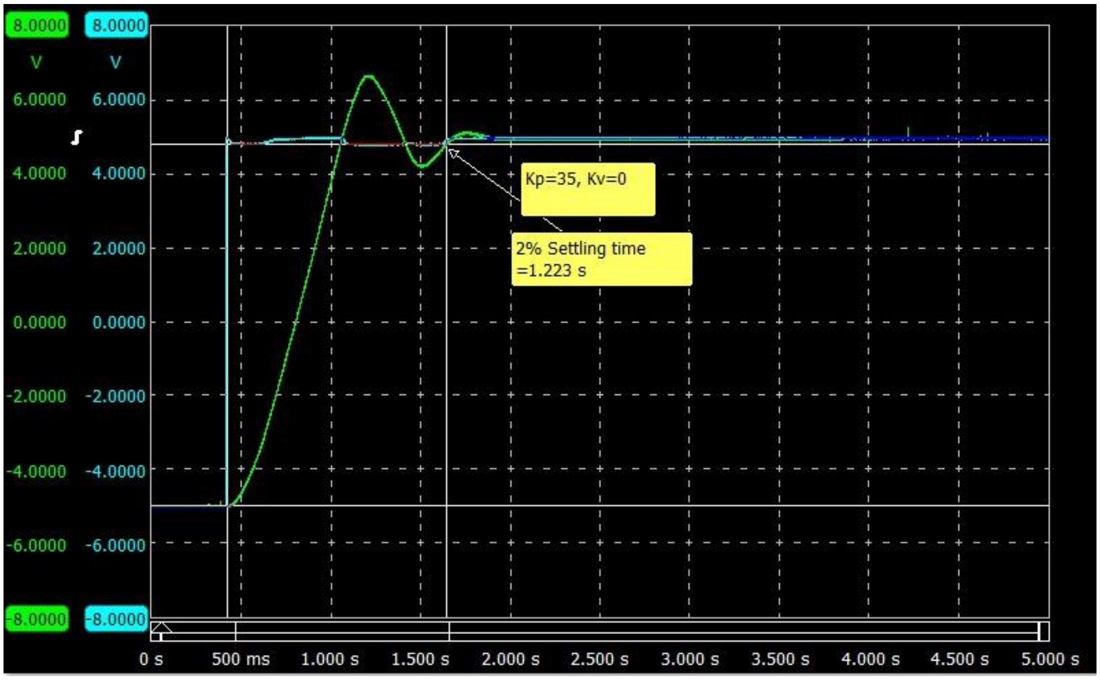


Fig. 4: proportional control (input signal in cyan and output signal in green)

The application of derivative control for removing ringing was demonstrated and the students observed no output dial ringing in the videos. The waveform, as shown in Fig. 5, with the ringing removed was presented and discussed in the videos.

The tracking of a triangular signal by a proportional controller was demonstrated also. The students observed in the videos that the output dial was moving fast and slow repeatedly in the tracking of the triangular signal. The output dial signal waveform was recorded and shown in the videos. Students observed ringing and steady state error in the output dial waveform. Integral and derivative controls were added to the proportional controller and demonstrated to the students that the ringing and the steady state errors were greatly reduced in the output dial waveform. The effects of the values of the proportional, integral and derivative gains on the output dial waveform were also demonstrated in the videos.

Solving control problems using computer-aided control system design software

Step-by-step Matlab commands for solving control design problems were presented in the video lectures. The problems include block diagram simplification, finding step response parameters, root locus plots, lag compensator design, lead compensator design, Nyquist plots, Bode plots, finding gain and phase margins, determination of stability, conversion between state-space equations and transfer functions, determination of controllability, observability, and asymptotic stability, and the shaping of dynamic responses.

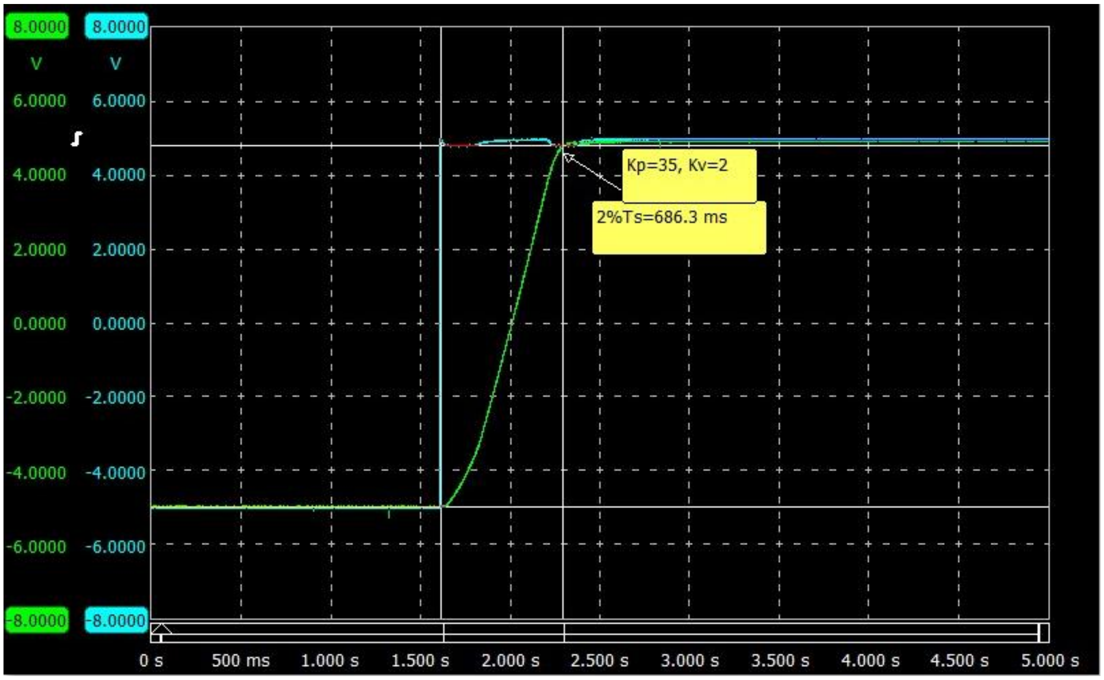


Fig. 5: derivative control, settling time=686.3 ms

Matlab procedures for solving these problems were documented as pdf files that were uploaded into Canvas for the students to download. Students used these notes in solving the computer-aided control systems design problems. Matlab was used extensively in this course. A sample of the notes for solving the shaping of the dynamic response problem is shown in Fig. 6.

Development of simulation assignments

Previous sets of computer-aided control system design problems were revised and new problems matching the revised course learning outcomes were developed. Solutions for the problems were prepared. Student submitted these assignments online. They were graded and solutions were posted online. Back of chapter problems matching the course outcomes were also assigned to students. Methods for solving these problems were presented in the lecture videos with examples.

Administration of the course

Weekly announcements were sent to the students informing them of the specific lecture videos to view for the week, the reading assignments, the computer-aided design problems, the homework problems, and ways to get help from the instructor. Lectures were prepared and recorded as mp4 videos weekly. These lecture videos were uploaded into Studio for students to stream to themselves at either the regular class time or at other times fitting their schedules. The reading assignments matched the contents of the lecture videos and offered extra information for those students interested in learning more about the topics discussed in the videos. The homework problems also matched the lecture videos. By solving the computer-aided design problems and the homework problems, students practiced what were taught in the videos and that refreshed their learning and improved their problem solving skills. Examinations were given to the students as a means of the assessment of learning for the whole class. An example of the weekly announcements is shown in Fig. 7.

Assessments

We evaluated various options for course assessments, e.g., exam proctored by online proctoring services such as Honorlock, written exam proctored by instructor through video conferencing software Zoom, group projects or individual research papers. The final choice was written exam proctored by instructor through Zoom. The examination results would be an indication of the attainment of the course learning outcomes.

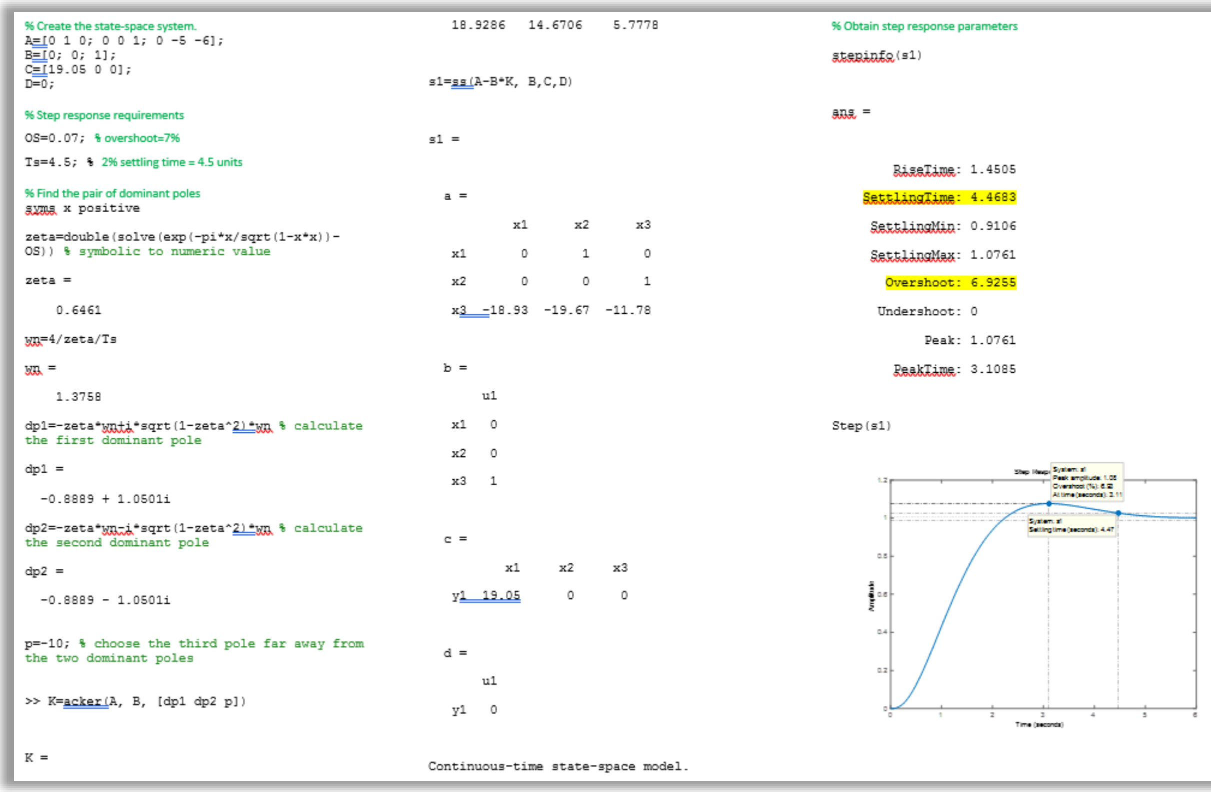
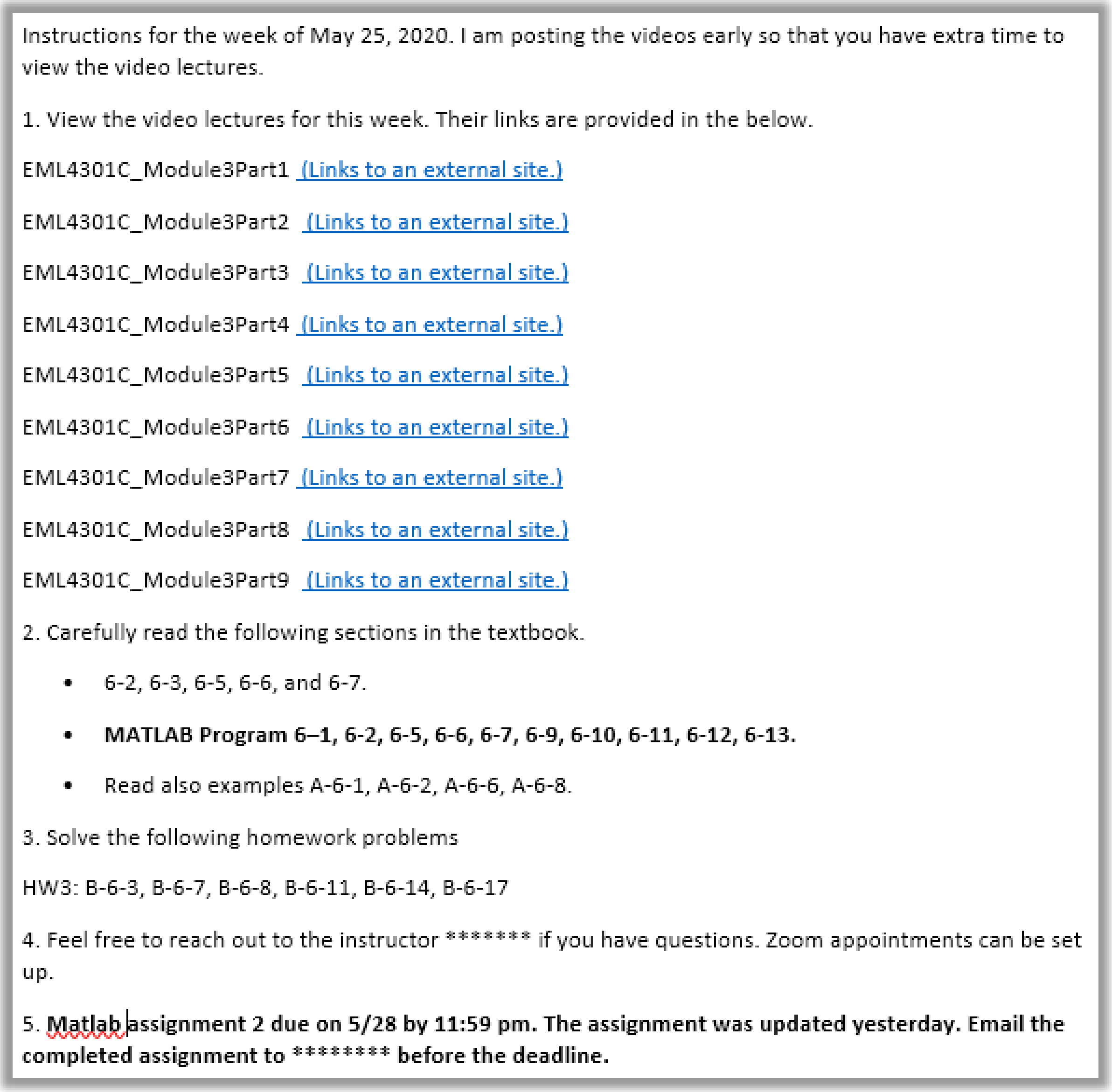


Fig. 6: a sample of the notes for solving the shaping of the dynamic response problem

The examination scores for the on-demand course in summer 2020 are shown in Table 1. Also shown in Table 1 for comparison purposes are the examination scores for the previous offering of this course on campus in fall 2019. In the table, Exam 1 covered the materials in Modules 1 and 2. Exam 2 covered the materials in Modules 3 and 4. Exam 3 covered the materials in Modules 5 and 6. The level of the exams in those two offerings were about the same.



Instructions for the week of May 25, 2020. I am posting the videos early so that you have extra time to view the video lectures.

1. View the video lectures for this week. Their links are provided in the below.

EML4301C_Module3Part1 (Links to an external site.)

EML4301C_Module3Part2 (Links to an external site.)

EML4301C_Module3Part3 (Links to an external site.)

EML4301C_Module3Part4 (Links to an external site.)

EML4301C_Module3Part5 (Links to an external site.)

EML4301C_Module3Part6 (Links to an external site.)

EML4301C_Module3Part7 (Links to an external site.)

EML4301C_Module3Part8 (Links to an external site.)

EML4301C_Module3Part9 (Links to an external site.)

2. Carefully read the following sections in the textbook.

- 6-2, 6-3, 6-5, 6-6, and 6-7.
- **MATLAB Program 6–1, 6-2, 6-5, 6-6, 6-7, 6-9, 6-10, 6-11, 6-12, 6-13.**
- Read also examples A-6-1, A-6-2, A-6-6, A-6-8.

3. Solve the following homework problems

HW3: B-6-3, B-6-7, B-6-8, B-6-11, B-6-14, B-6-17

4. Feel free to reach out to the instructor ******* if you have questions. Zoom appointments can be set up.

5. **Matlab assignment 2 due on 5/28 by 11:59 pm. The assignment was updated yesterday. Email the completed assignment to ******** before the deadline.**

Fig. 7: a sample of weekly announcements

The demographics for the fall 2019 offering was that 88% of the 44 students were seniors and 12% were postbac students. The GPA of 82% of students were greater than 3.0 and 17% between 2.0 and 2.99. The gender distribution was that 88% male and 12% female.

The demographics for the summer 2020 offering was that 100% of the 19 students were seniors. The GPA of 33% of students were greater than 3.0 and 67% between 2.0 and 2.99. The gender distribution was that 78% male and 22% female.

The averages of the scores of Exam 1 and 2 in summer 2020 were higher than those in fall 2019. Those for Exam 3 (the final exam) were roughly equal. This indicates that the on-demand approach did not decrease the performance of the students in the examinations. Among the two different groups of students taking the exams, those in fall 2019 their average GPA was greater than those in summer 2020. In the on-demand approach, course topics could be explained in deeper details in the videos because there was no restriction of the finite class time in the on-campus approach. More step-by-step solutions to problems were presented in the videos. That might have helped increasing the examination scores in that summer term.

Table1: comparison of exam scores

Control of Machinery course		Fall 2019 on campus	Summer 2020 on demand
Exam 1 score	Mean (out of 100)	82.0	92.2
	Standard deviation	7.7	7.1
Exam 2 score	Mean (out of 100)	71.4	86.5
	Standard deviation	11.2	9.1
Exam 3 score	Mean (out of 100)	75.7	75.2
	Standard deviation	15	12.2

University administered student evaluation of the course was conducted at the end of the summer 2020 term like that of the fall 2019 semester. The students evaluated the on-demand course in the following: communication of ideas and information effectively, explanation of complex concepts and ideas clearly, stimulation of critical and creative thinking, well-organized and provided a framework conducive to learning, and whether the course was set in high standards and challenging. The student evaluation results were higher for the on-demand course than the on-campus course in every item. The data are shown in Table 2. For the fall 2019 term, 39% of students participated in the student evaluation. It was 47% for the summer 2020 offering.

Table 2: university administered student evaluation results

Control of Machinery course	Fall 2019 on campus Scale from 0 to 5	Summer 2020 on demand Scale from 0 to 5
Communication of ideas and information effectively	3.24	4.67
Explanation of complex concepts and ideas clearly	3.12	4.44
Well-organized and provided a framework conducive to learning	3.65	4.78
Stimulated critical and creative thinking	3.82	4.56
Set high standards that challenged students in the course	4.18	4.89

The written comments for the on-campus course in fall 2019 are summarized in the following. Most of the comments were on the explanation of concepts and on the exam problems. On the explanation of concepts, some students commented that concepts were well explained but too much conceptual analysis and derivations. Some students were interested in using more Matlab.

In response to those comments, lengthy mathematical calculations and derivation by hand were done by Matlab instead when applicable in the on-demand offering in summer 2020. Matlab instructions were recorded in the video lectures. More Matlab assignments were prepared and given to student to increase their exposure to Matlab. Solutions to the new Matlab assignments were also prepared and posted.

On the examinations. While some students commented that the exams closely matched the materials taught and that the feedback on exam problems were excellent, other comments were the opposite. Many wanted the exams to be like the homework problems. In response to the comments, in the on-demand offering some of the exam problems were modified from the homework problems and the others were not.

The written comments for the summer 2020 offering are summarized as follows: on the explanation of concepts in the on-demand offering, students commented that the videos were very easy to understand and the assignments were applicable to what was taught. Some responded that the instructor did a great job of explaining the material and was quick to respond to questions. Some other comments summarized that the videos were doable but just not their preference. They would prefer in-person classes.

On the examinations, there was no comment from this group of students. There were some favorable comments about the structure and organization for this on-demand approach. Some commented that there was not a week that went by where they did not know exactly what to study and work on. Some others commented that the course was nicely organized and was made as enjoyable as possible. They also stated that the expectations of the students were clear.

To investigate whether the on-demand approach would affect the instructor's rating in the university administered student evaluations, the data from those two offerings were compared and are shown in Table 3 below. It is noticed from the table that the instructor's rating for the on-demand course was higher than that for the on-campus course.

Table3: the instructor's ratings

Control of Machinery course	Fall 2019 on campus Scale from 0 to 5	Summer 2020 on demand Scale from 0 to 5
Overall rating of instructor	3.31	4.63

Concluding Remarks

The transformation of an on-campus course to an on-demand course for meeting the needs of the students taking classes during the pandemic was briefly described. The process involved in the revision of the course outcomes, reorganization of the course contents, development of the on-demand materials, and other steps as described above. Students learned from the video lectures prepared weekly for the on-demand course. The video lectures covered the topics specified in the syllabus, demonstration of laboratory experiments, the step-by-step procedures for solving problems, and using computer-aided control system design software for solving control problems. The effectiveness of the on-demand approach was assessed through course examinations. The results indicated that the examination scores for the on-demand course were not less than that for the op-campus course.

University administered student evaluation on the course was also conducted. The evaluation indicated that the on-demand course received higher ratings than the on-campus course in the areas of communication of ideas and information, explanation of complex concepts and ideas, stimulation of critical and creative thinking, well-organized and provided a framework conducive to learning, and whether the course was set in high standards and challenging. The rating of the instructor was also improved in the on-demand course. Further investigation will be conducted to confirm these findings when the on-demand approach is applied to a different course.

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