An Industry Sponsored Video Course for Control Engineering Practitioners

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Abstract: Video lectures are finding their way into education – there are numerous advantages and they can be used in different contexts within formal, non-formal and informal education. Control systems is a subject in formal education that can be viewed from a practitioner's angle. This paper describes a video lecture on control systems that is sponsored by ABB and available on YouTube. The lecture was developed by control practitioners for an audience that (1) does not have a strong engineering background and (2) have an engineering background but has not been shown the linkage to the real world. The difference between formal control systems lectures and this course are discussed.

Keywords: Control systems, education, process control, automation, video lectures, online.

1. INTRODUCTION

Control engineering is a subject usually taught at undergraduate level to electrical, mechanical, industrial, and chemical engineering students. Control systems take mathematical theory relating to feedback control and applies it to any dynamic process, from automotive to industrial production application. Control systems in education has been comprehensively described by, for example, Kheir et al., 1996.

In addition to formal education, non-formal education is becoming more and more important in a world of globalization and technical advancement. Globalization focuses on improved product and service quality, greater work responsibility and teamwork approaches (Merriam et al., 2012). A general decline in industrial labor stems from automation and competition from other countries with low labor costs. In addition, technology is advancing quickly in all areas. This together puts an emphasis on training in automation by corporates companies in a non-formal education form.

Non-formal education can be of a supplementary nature, which means that it is "a quick reaction to educational, social and economic needs because formal education is too slow in response (if it does in fact decide to respond) to those needs" (Brennan et al, 1997). The course described in this paper is non-formal and supplementary, that is, many aspects are not covered by control systems courses taught at university level.

With the advance of internet technologies – it is estimated that 40% of the world population has an internet connection today[1] – video lectures have become widespread for use in the classroom. Recently, the concept of the flipped classroom has been introduced. Herreid et al. (2013) explain the essence of the flipped classroom model: What is normally done in class and what is normally done as homework is switched or flipped. Often, the flipped classroom experience is equated with the use of internet technology in general and videos specifically.

Videos are sometimes 'copies' of the normal lecture. Wieling and Hofman (2010) showed that attending either the lecture in person or view the videos results in better performance of the students. Further benefits of video lectures in the engineering context have been reported (Liu & Kender, 2004; Mason et al., 2013).

The quality and content of videos available online, most dominantly on YouTube , varies significantly. These online videos can be grouped according to the following criteria

- Realization: Filmed lectures, presentations with voice overs, animations, or a combination thereof.
- Designation of presenter: Academic institution, industrial institution, private person.
- Technical quality: Sound, camera.

There are several obvious benefits and disadvantages of online lectures. The key benefit is that the learner can view the video lecture at a preferred time, place and most importantly at her own pace. Videos allow pausing and re-playing which is crucial for effective learning. A key disadvantage is that the learner cannot interrupt the lecture to

[1] http://www.internetlivestats.com/internet-users/

ask questions and discuss the lecture with peers during class breaks. However, these difficulties can be easily overcome with the flipped classroom.

In this paper, we will review the video lectures available in control engineering which act as a support for control engineering courses. In addition, we will investigate material available to control engineering practitioners in continued education and training-on-the-job. The main contribution of this paper is to describe the purpose, contents and methodology of the online video lectures presented by an industrial supplier and which describes control engineering education from the practitioner’s point of view. The technical realization of the videos and the targeted audience are also discussed. Lastly, the differences between control engineering for undergraduate students and control engineering for practitioners used in training-on-the-job are discussed.

2. VIDEO LECTURES IN CONTROL ENGINEERING

Videos explaining the fundamentals of control are ubiquitous but vary dramatically in quality. However, in this day and age with internet search functions available, helpful material can be easily identified. Tab. 1 gives a list of undergraduate control courses that enjoy a popularity and which will be referred to when comparing the industry sponsored video lectures described in this paper. Screenshots of the videos are shown in Fig. 1 to give a feeling of the presentation type. Three of these four courses are by academic lecturers who made their material available online while the most successful lectures – in terms of views – is produced for the purpose of video lectures only by an extremely talented and successful control practitioner. It is noteworthy that all video lectures in Tab. 1 have been placed online in the last three years. This is in accordance with the trend to move higher education to YouTube and social networks (Gilroy, 2010).

Table 1. Control systems fundamental video series available on the internet. The videos can be found on YouTube by searching for the names of the presenters, adding the search item ‘control’.

No	Presenter	Affiliation	Description	Year	Views
1	Brian Douglas	Planetary Resources, USA	Designed video lectures with pen tables for drawing text and images and Photoshop software	2012	2,000-100,000
2	Benjamin Drew	University of the West of England, UK	Filmed lecture with projector style presentation	2014	100-300
3	James K. Roberg	MIT USA	Filmed lecture with chalk on board presentation, produced professionally in 1985	2013 (1985)	3,000-50,000
4	Anthony Rossiter	University of Sheffield, UK	Power point lectures with voice over, built on university course offering (Rossiter, 2013; Rossiter, 2014).	2013	300-4,000

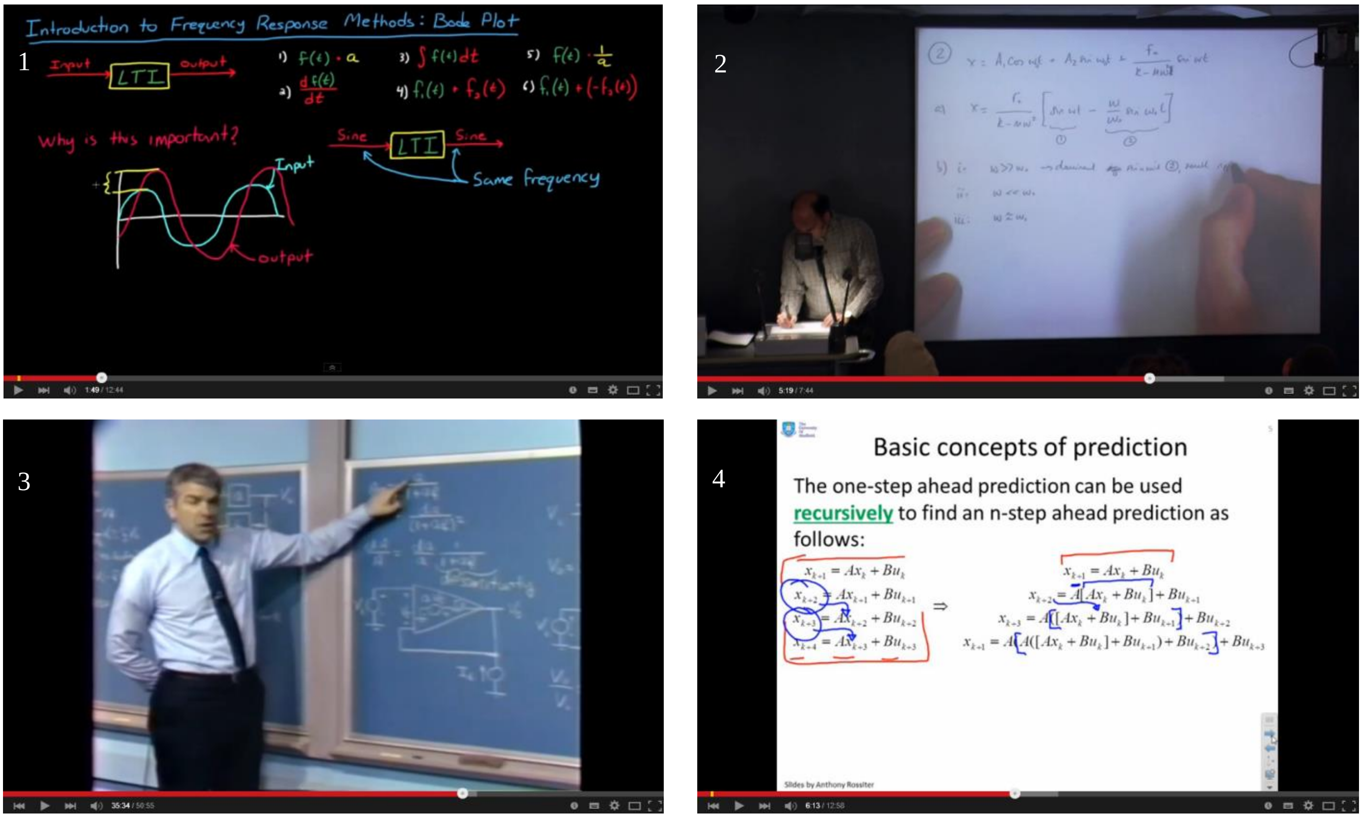

Fig. 1. Example screenshots of control systems courses of Tab. 1.

The abundance of online material which is freely available speaks for the concept of the flipped classroom to be used in control engineering education. Also, any undergraduate student with access to the internet cannot blame ‘poor lecturing skills’ for not understanding parts of the subject.

3. NON-FORMAL CONROL ENGINEERING EDUCATION

In education, there are two strong movements observed in recent years (Jarvis et al., 2003): (1) from theoretical to practical and (2) from single discipline to multidisciplinary to integrated knowledge. The latter is particularly true for control engineering, as described by Murray and co-workers (2003): “Increasingly, the modern control engineer is put in the role of being a systems engineer, responsible for linking the many elements of a complex product or system. This requires not only a solid grounding in the framework and tools of control, but also the ability to understand the technical details of a wide variety of disciplines, including physics, chemistry, electronics, computer science, and operations research.”

Control engineering is taught at undergraduate level within almost exclusively engineering disciplines, most commonly within electrical, mechanical, chemical and industrial engineering. Because of these traditional department structures of today, control is typically only a small aspect of any curriculum. It is usually difficult to change the contents and structure of control courses so that necessary changes that are required by the two movements cannot be accommodated.

Because of the shift from theory to practice and the integration of knowledge, teaching control systems by practitioners has a different flavour as well as urgency. Engineering in general and control engineering in particular is tightly bound to applications and practice.

All in all, it is important to tailor control courses to an experienced audience who have domain knowledge but no necessary previous exposure to control systems. Sometimes, engineers and technicians may have attended a control course as part of their first education many years ago. In some cases, this experience may have had a negative connotation. All three authors of this paper are control engineering educators and have found that even technically inclined professionals may view control systems as intimidating. Or as one lecturer states at the beginning of the course: ‘Control engineering is not for the faint-hearted’.

4. INDUSTRY SPONSORED CONTROL SYSTEMS VIDEO LECUTRES

Large and small control engineering companies alike recognize the need to train and further educate their own staff as well as potential customers. Many companies offer courses to their customers and clients which are held by experienced staff and practitioners. ABB for example, provides ABB University which is a platform that trains customers mainly on ABB products both online and in courses help by ABB experts.

Distinctively, generic topics such as control engineering are also offered by ABB as taught courses and recently also as online lectures. These video lectures originate from taught courses which the principal author of this paper started giving in the 1990s. Since then, the content has been changed, expanded and refined. Originally, the lectures were held based on and supported by a book of the same title that proved to be extremely popular with the course attendants. The book is broken down into chapters that target tuning aspects.

The video lectures are all presented by the principal author of this paper, Kevin Starr and were produced with the support of a team of control engineering experts. The videos are part of a larger series produced by ABB Service that include other automation topics such as lifecycle services, optimization and statistical analysis. Nevertheless the course as such forms an entity.

The motivation for the videos was 1) make the course content available to a wider audience 2) make the course content available to the attendants of the training who wanted to refresh their experience. As a result, the intended audience is as broad as the platform YouTube – basically anyone with an interest in automation. This can range from an undergraduate student wanting to know about the industry relevant bits of control to a process operator with the motivation to understand loop tuning.

4.1 Course contents

The course deals with control systems but is very different from control systems taught at undergraduate level. It fills in a gap between the control theory taught at university level and the “real” world found where – at least most of the time – no process models are available, processes are slow and nonlinear and step tests are out of the question. The linkage from theoretical to practice is often missed. The course is based on 25+ years of experience in control tuning, deployment and design. It addresses challenges that are encountered by people working in control in the process industries.

The table of contents of the course is listed in Tab. 2. There are 14 video lectures in total which cover nine chapters. Each of the 14 videos had been watched several hundred times within the first six months. There’s a decline in views after the original chapter, possibly because these interest most and capture the widest audience but probably also because the attention span and perseverance of an online audience is somewhat limited.

The course is structured like many undergraduate courses. After the introduction to control problems and terminology the course covers process identification or modelling, feedback control and tuning. It then deals with common problems encountered in the real world such as dead time, oscillation cycles and process nonlinearities.

Although the course syllabus is similar to many academic lectures the course itself is very different. For one, most

Table 2. Table of content of video lectures

No	Chapter	Content	Views[2]
1	Contents	Preface	687
2	Chapter 1	Control introduction	967
3	Chapter 2	Control terminology	650
4	Chapter 3	Process Identification Part 1	852
5	Chapter 3	Process identification Part 2	399
6	Chapter 4	Feedback controllers Part 1	285
7	Chapter 4	Feedback controllers part 2	260
8	Chapter 4	Feedback controllers Part 3	204
9	Chapter 4	Feedback controllers Part 4	212
10	Chapter 5	Control tuning	302
11	Chapter 6	Tank level tuning	339
12	Chapter 7	Dealing with dead time	204
13	Chapter 8	Cyclic Reduction	167
14	Chapter 9	Control loop nonlinearity	142

control academics would agree that control systems is a subject which involves many mathematical equations. Looking at the screenshots of the online video lectures in Fig. 1 shows that mathematical formulas are everywhere. The video lectures focus on concepts and explain the impact of equations. The mathematical formulations are 'blurred out'.

It is important to highlight that the content is geared towards an audience wanting to apply control to the process industries. This means that the presenter can focus on process control and relevant methodologies.

In the following, we will explain the difference between a practitioners approach to learning and an academic approach three examples taken from the video lecture, namely process modelling or identification, the feedback loop and tuning. This comparison is used to explain the gap between theory and practice and discussed in Section 5.

4.2: Example 1: Process identification

Process identification which in most academic courses is referred to as process modelling. First principles are excluded, instead the focus is on practical methods that work in industry. Process identification or modelling is about the response of the process to a likely input such as the change of an actuator.

The course leads up to tuning PID control loops and this is stressed throughout the videos. For example, knowledge of the process dynamics is required to find correct tuning settings. Again, dynamics are explained without any mathematical description but with a visual representation of possible step responses, see Fig. 2. A person trained in control systems would be able to write down the equations in the time and Laplace frequency domain but this rather distracts from the concept to be conveyed. Process related application examples are given for the process dynamics, such as a tank being filled for the integrating behavior (fifth curve from the top).

[2] As of June 20, 2015.

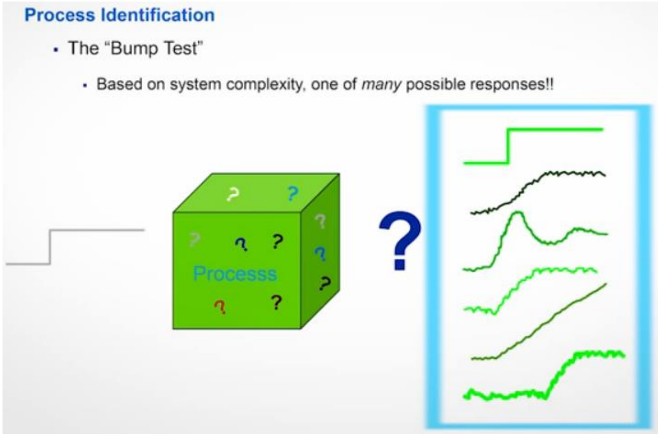

Fig. 2. Modelling or process identification using a step test or "bump test" for practitioners.

The second important aspect of process identification is to consider whether the process is self-regulating or non-self regulating. In most textbooks this is referred to stability. Considering that regulating and control are closely related terms it becomes evident that self-regulating systems will be easier to control.

4.3: Example 2: Feedback loop

Since more than 90% of the industrial control loops are feedback controllers the course mainly deals with those. In most textbooks on feedback control, the control loop is represented as shown in Fig. 3 (a). In the control video course, the starting point is the process as shown in Fig 3 (b) which lies on top of the controller which takes centre stage.

Somewhat unusually, the starting point of the feedback controller is the 'attribute of an error' of a step change. This

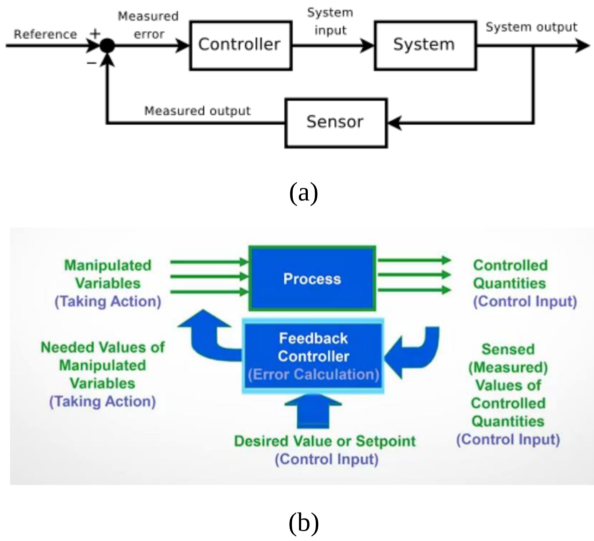

Fig. 3. Feedback control loop as (a) described in textbook (Source: Wikipedia) and (b) in the video lecture described in this paper.

makes a lot of sense for the practitioner because in practice, the controller acts on the error and the error usually arises when a step change is applied to the setpoint. Attributes here are the magnitude of the error, the duration of the error and the rate of change of the error. All these attributes are used to define the PID controller.

4.4 Example 3: Tuning

In the tuning section, the purpose of the course becomes most evident: The aim is not to understand control fundamentals but to apply it and use it. It starts off by saying that for a desired first order, no overshoot closed loop response the direct synthesis tuning method should be applied. Helpfully, it is pointed out that this method is also referred to as lambda tuning or pole placement tuning. If a one quarter wave decay response is desired, then Ziegler-Nichols tuning is advisable. This procedure is made for a person who actually has to tune the control of a system and issues such as doing bump tests on open and closed loop systems are carefully discussed.

The course evolved in this way because people were tuning by feel, basically guessing, then hoping the loop would stop oscillating. Some plant engineers and managers, however, will not allow to “tune” their system by this approach. The requirement is that the system cannot be touched until a prediction on how the tuning parameters will impact on the process is made. This request gave the motivation to link theory and practice and helps the audience to quickly setup and commission control systems.

4.5 Technical realisation of online videos

The videos were made for an intranet, that is, company internal online channel called ABB TV. The videos were sub sequentially released on the online video platform YouTube between August and December 2014. The videos can be found by, for example, searching for ‘kevin starr abb’ on YouTube or Google.

All videos are presented in the same fashion with the principal author, Kevin Starr, on the right and the presentation on the left. Intermittently, the presentation is blended in as full screen, see Fig. 5.

To produce the videos a mix of prosumer and basic video equipment was used. To be specific, the shoots were done with a Sony FS100, Rode shotgun microphones, LED light panels and mix of basic materials like a green screen and tripods. The majority of the video presentations are done in front of a green screen and edited in post-production to give the effect of being in a studio. No professional studio was used but instead the most was made of the office space available, such as using an open conference room. Enough space is needed to fit a green screen, lighting and sound equipment. However many interviews are done where ever space is available.

All post production was done on a high end HP editing computer with Adobe Premiere Pro. A professional videographer was engaged who has produced YouTube

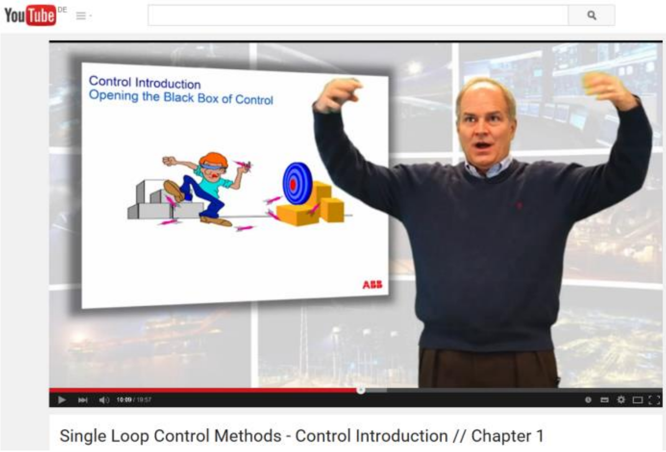

Fig. 4. Screenshot of online video lecture.

sports videos with well over 10million viewers. This combination of technical knowledge and production skills and insights enable telling technical stories with video very effectively.

The majority of the videos are based on presentations that have been presented before so adapting them to a video came quite naturally. In this sense, the course corresponded to most of the filmed lectures listed in Tab. 2.

5 CONCLUSIONS

In this paper we described video lectures that cover a practitioners approach to control systems.

The course is aimed at an audience with some experience in control – either from a theoretical view point through control systems fundamentals or as a practitioner who had to deal with control but has no formal education in control. The course therefore describes non-formal education that ordinarily would have taken place at a corporate training facility. The mathematical formulas are kept to an absolute minimum.

For students with a background in control fundamentals the course fills the gap between theory and application. The focus is on process control for which key terminology is introduced. It therefore forms the basis of the arguably most important part of automation, the control of the process. The course can therefore be a valuable addition to formal control engineering education to prepare graduates for the work place. This could be achieved by flipping the classroom and letting the students watch the video course in their own time, then discussing the course in class.

All authors of this paper have taught control engineering to several hundred people over the years. In the authors’ experience it is true today that students at college and university use Google and YouTube as their main resource of learning. If something is not available on these platforms, most students will not discover it on their own. The video lectures are a valuable resource that can be accessed by anyone with an interest in control systems.

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