RETHINKING TEACHING PRACTICES FOR SIGNAL PROCESSING EDUCATION

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ABSTRACT

There are three fundamental components of teaching a course: course content plan, delivery, and assessment. While teaching methodologies have evolved vis-à-vis all the above components, signal processing domain has itself evolved significantly over the past few years. It would not be wrong to say that the signal processing domain has redefined itself in the past few years and has also evolved rapidly creating a need to devise innovative teaching practices. Learning habits of students have also become diverse and are considerably different compared to those of students of the late 20th century. In this paper, we present the changing landscape of signal processing theory and discuss some of the teaching practices that may prove more helpful in this fast-changing era of technology.

Index Terms— Innovative teaching techniques, student learning, signal processing

1. INTRODUCTION

The desired objective of signal processing education is to impart deep understanding of its concepts along with the skills to use these theoretical concepts in solving real life problems. Signal processing domain has evolved substantially over time. It has become more and more interdisciplinary covering a wide spectrum of theoretical areas and applications. For example, although optimization theory was always taught to engineering students, this mathematical topic, today, constitutes the backbone of sparse signal recovery, compressive sensing based signal recovery, and machine learning. There have been advancements in theoretical areas as well as expansions of their utility in interdisciplinary application areas ranging from genomics to internet-of-things (IoT). Hence, it is now imperative to provide both the conventional as well as contemporary signal processing knowledge to students so that they become thorough with the concepts and are able to apply them in real world problems. This ever evolving landscape of theoretical concepts adds challenges in structuring a degree curriculum as well as structuring the plans of corresponding courses consisting of theory, analytic derivations, and coding assignments.

At the same time, delivery of courses has also changed substantially over time. From only 'Chalk-and-Board' style, teaching now includes newer styles of flipped classroom and online course delivery such as MOOCs (massive open online courses) as well. In the context of evolving concepts, it is important to adopt varied course delivery methods, within a course and across courses, that are apt for any particular subject and match with the learning abilities of students.

One fundamental component of teaching a course is assessment of students which facilitates the instructor to check their progress and evaluate their learning. It is either formative or summative [1]. While earlier only summative assessment was used, formative assessment is very popular today. The goal of summative assessment is to evaluate student's learning at the end of an instructional unit by comparing it against some standard such as a final exam or project. It focuses more on the grades achieved by students rather than overall learning. On the other hand, the goal of formative assessment is to gain an understanding of what students know (and don't know) in order to make responsive changes in teaching and learning [2]. Performance of students is continuously monitored by assignments, classroom discussions, project works, and examinations. It involves feedback to teachers for them to recognize and address the areas where students are struggling. It also involves feedback to students helping them identify their strengths and weaknesses, and motivating them to work on their weaker areas.

Thus, there are efforts to improve student learning via instruction style and course assessment, while newer courses are added. In fact, both course delivery and assessment are being adapted, keeping in view, the change in the learning habits of students. In this paper, we briefly review the teaching practices and discuss some of the innovative practices of teaching with this changing landscape of signal processing.

2. EVOLVING LANDSCAPE OF SIGNAL PROCESSING

Signal Processing has evolved exponentially over the last few years encompassing numerous domains of science and technology. The digital world we live in, which includes computers, cell phones and smart TV, is completely enabled by signal processing. Applications of signal processing are enormous ranging from biomedical signal processing to financial signal processing. Different applications of signal processing

*Thanks to UGC, Govt. of India for UGC-Junior Research Fellowship. We gratefully acknowledge the research funding support (Grant: EMR/2016/006183 and DST/ICPS/CPS-Individual/2018/279(G)) from the Department of Science and Technology, Govt. of India for this research work.

in the health include handling waveforms, images or video sequences available diverse forms such as tracking of electrocardiograms (ECG) or heartbeats, localization of epileptic sources in the brain via analyzing electroencephalogram (EEG), echography, or magnetic-resonance imaging (MRI).

Another highly interdisciplinary application of signal processing is the field of genomic signal processing [3]. Next generation sequencing technology has shortened the time taken to sequence the complete DNA of a person that contains vast amount of information and is targeted towards personalized medical therapy. This big data is being analyzed today by advanced signal processing methods of machine learning/deep learning, network science, and Bayesian statistics. Today, computational biology and biomedical engineering are two significantly major fields, where signal processing researchers are working actively. However, to be able to work effectively in these applications, it is required to gain sufficient knowledge of biomedical field.

Graph signal processing, network science, machine learning, deep learning, optimization theory, sparse signal recovery, compressive sensing, and collaborative filtering are some of the key theoretical developments that have made significant impact in varied applications, cutting across many disciplines of engineering. Internet of Things (IoT), natural language processing, smart cities, smart vehicles, healthcare, big data analytic, financial data analytic, robotics, communication engineering of 5G and beyond, unmanned vehicles, and assistive technologies are a few applications being benefited by the advancements in signal processing.

One key change is that these areas have become relatively more interdisciplinary. For example, graph signal processing is being benefited by the individual developments in both signal processing and graph theory. As a consequence, developments in graph signal processing are fast and its methods are being applied in varied fields as medical imaging, social network data analysis, and big data analytic. Similar interdisciplinary growth is true for many theoretical developments in signal processing, particularly, in machine/deep learning. Although this is redefining signal processing with more applicability across disciplines, this evolving landscape is adding challenges from the point of view of imparting signal processing education. Students require to learn the deep theoretical concepts of both the traditional and contemporary theory, learn application domains (say Biology), and require to have both analytical and coding skills.

3. TRADITIONAL AND MODERN TEACHING PRACTICES

One of the most fundamental component of teaching a course is delivery of course content to students. Traditional teaching practices involve 'chalk-and-board' based teaching. It is more like a demonstration of theoretical concepts to students with comparatively less emphasis on the practical aspects of the same. This style is instructor-centric and may not be always appropriate to meet individual student's needs. In general, this style of teaching is preferred with signal processing courses requiring mathematical rigor and derivations. Here, instructors often assume that students are more or less at the same level of understanding. Traditional assessment is largely summative through assignments, mid semester examinations, and final semester examinations rather than the evaluation of students' performance throughout the semester. There is a limited choice of courses to students. Students rely on textbooks and notes for knowledge. Curriculum is often rigid and every student is expected to follow the same.

While 'chalk-and-board' is the earliest technique of delivering a lecture, inclination has shifted towards PowerPoint-based teaching because it provides an opportunity to the instructor to clearly communicate the contents in written, graphical, and visual format [4]. However, there are certain disadvantages of PowerPoint style. Often, important derivations are not communicated properly to students. As a consequence, students may not get an in-depth understanding of the content. A study [5] suggests that all engineering subjects do not benefit in terms of effective student learning with PowerPoint style of lecturing. A refined and balanced 'chalk-and-talk' lecturing style is proposed in this study [5], which inherits the advantages of traditional 'chalk-and-board' teaching, while being complemented with an appropriate use of modern lecture theater technology.

Teaching practices have progressed considerably over the years and innovative methods of teaching have been adopted. Modern teaching practices have shifted focus from being instructor-centric to student-centric. Flipped classroom and MOOCs are examples of modern teaching practices used today. Flipped classroom is a type of blended learning that delivers instructional content outside the classroom and moves interactive activities like group discussions inside the classrooms. Contents are delivered online either by sharing relevant video lectures from global experts or having instructors prepare their own video lectures. Thus, active learning is ensured in the classroom via discussions with the instructor and the fellow students. Also, the initial learning of contents outside the classroom via videos provides an opportunity to students to learn at their own pace by repeatedly watching difficult topics. Flipped classroom style of teaching has been reported to be attempted first in an economics course in 2000 [6]. Since then, it has been adopted by educators in many courses including Biology [7], Business Management [8], Industrial Engineering [9] and Computer Science [10].

Of late, MOOCs have emerged as important online course learning option with open registration at free or nominal costs [11]. Courses are based on widely accepted curriculum with stated outcomes [11]. MOOCs are provided by teaching platforms such as Udacity, MITx, EdX, Coursea, Udemy, and NPTel. These are very famous with students now a days. MOOCs can be integrated with classroom courses to enhance the learning of students [12]. Theoretical knowledge is in-complete in signal processing unless blended with practical skills. Hence, signal processing courses are often supplemented with projects to enhance the understanding of students and, to help them bridge the gap between the mathematical theory and its practical implementation. Workshop style programming tutorials are conducted to provide hands-on experience towards the practical aspects of signal processing. There are various blackboard sort of online discussion forums and DSP portals where students can exchange their ideas. Varied study materials are available online such as on Wikipedia or through online textbooks, say OpenStax [13].

Assessment has also changed from summative to formative assessment style. Students' performance is evaluated throughout the semester via course projects, assignments, quizzes, and semester examinations collectively. Credit based system has been adopted at many places where a sequence of courses is recommended to students. Students can select courses according to their areas of interest. In this manner, students can design their own curriculum to build knowledge and skills depending on their interests, but within the realm of the degree program. In sum, modern teaching practices provide a relatively easy access to knowledge, flexibility in learning contents, and facilitate designing of self-interest curriculum.

4. CHANGE IN LEARNING HABITS OF STUDENTS

Before initiating discussions on innovative styles, we require to understand the learning habits of students of today. In fact, course delivery and assessment methods are continuously been modified to match to learning styles of students. Earlier students had good note-taking and writing habits inside the classroom. Hence, they used to study from textbooks and, rely on the books and their handwritten notes for learning. However, today's generation is more addicted to multimedia tools such as laptops and tablets. Often, students prefer taking notes on their laptops. This reduces the note-taking ability, particularly, in signal processing subjects that require mathematical derivations. PowerPoint teaching style reduces this further because the pace of content delivery is generally a bit faster compared to the chalk-and-board teaching.

In order to adjust to students' learning habits, more content is made available through multimedia, say via sharing of online resources available through videos, lecture slides, etc. However, these in turn enhance their dependence on laptops. Although lecture slides and videos tend to impart learning in a more dynamic manner, longer hours with these multimedia modes often results in loss of concentration among the [5]. Further, since online videos are readily available, students prefer to watch these compared to studying from the text books and their own notebooks. Due to lack of their own handwritten notes, students are unable to revise concepts quickly as and when required, thereby, affecting their retention power [14].

Solution manuals of good text books are uploaded globally. Thus, a large number of students do not solve problems themselves and depend heavily on internet for answers to their problems, rather than thinking and solving themselves. This leads to gaps in learning and adversely affects their problem solving and analytical skills. Also, this hampers their power of critical thinking and reasoning.

Another notable change is an increased shift towards coding. Coding itself is important because it helps in building problem solving skills and help students with system designs. Although coding has become an integral part of learning, it is a bit addictive. Students tend to remain engrossed in coding for long hours and lose track of time. This adversely affects their reading time and concentration.

In sum, today's student is spending less time and effort in self-learning, in understanding concepts, and in solving problems. They are largely glued to the multimedia tools that are both good and bad with reference to their intellectual growth. While the availability of online study material makes them self-sufficient in gaining knowledge and saves them time, it is hindering the development of their critical reasoning.

5. SOME PROPOSED INNOVATIVE METHODS

In this section, we discuss briefly a few innovative methods that may enhance learning of students in signal processing. First, we discuss some innovative methods with reference to teaching style and later with reference to the assessment of courses.

Course content plan may be modified regularly such that approximately 20% or so weightage is given to the contemporary research. Contents should include relevant real-world applications, where signal processing is currently being used. This will have many benefits. First, it will inspire them more because they can better relate to their surroundings. Secondly, they will be better prepared for the job market. Lastly, these graduates will be able make valuable contributions to society by working on contemporary problems of need.

Since most students in higher education learn more by hands-on training rather than only theory, courses should be supported with collaborative industry-institute workshops and projects of practical applications encompassing various domains of signal processing. It will help to bridge the gap between the theoretical concepts learned in the classroom and the practical utility of those concepts. One of the thoughtful ways of doing this could be to encourage multi-disciplinary diversity inside the classrooms and small student project groups involving students from varied backgrounds, such as electronics and computer science students, are formed. This will facilitate exchange of skills, learning styles, and ideas among students. It will allow strengthening of their complementary skills. For example, electronics students can help computer students in signal processing theoretical concepts, while computer science students can help electronics students in improving their coding skills.

Tutorials should be conducted on mathematical concepts as well as on programming questions to impart a good balance between analytical and coding skills. Although tutorials are generally conducted regularly for some basic courses such as Signal and Systems or Probability theory and Random Processes; these may also be conducted for advanced courses such Compressive Sensing, albeit a bit irregularly and in different forms such as short-duration workshops, etc. Tutorials on coding should be organized in a workshop manner thereby providing hands-on experience to students.

Visual presentations help students better in understanding and learning theoretical concepts. Although slides are an efficient mode of transmitting knowledge pictorially, important derivations are, often, not communicated properly through lecture slides, thereby, hampering the overall in-depth understanding of the subject. Therefore, lecture slides should be supplemented with proper step-by-step derivations on board wherever required. Lecture slides of theoretical concepts should be mixed with coding lab results to facilitate better understanding of concepts. Techniques like flipped classroom or MOOCs can be made a part of curriculum within courses and across courses. Students may be shared relevant video or online lectures of global experts with appropriate balance with regular lectures to keep students motivated during the entire course. These can be used as resources for strengthening the pre-requisite requirements of courses.

Apart from lecture slides, relevant video presentations delivered by industrial experts and academicians in top-notch conferences, related to signal processing, may be shared with students so that they are able to relate better with the course. Listening to the same concept from different people in different settings can definitely help in bridging gaps in understanding. Although guest lectures from experts are commonly held in departments, they may also be arranged within the course to inspire students. Talks by faculty members of same or related departments may be organized so that students are able to understand signal processing concepts in interdisciplinary setting and in relation with other courses. This will help them contemplate a bigger picture of the concepts. For example, faculty in circuits and robotics can be invited to deliver special emphasis on the application of Laplace transform in circuits or control circuitry design of robots, respectively.

Game styled interactive short quizzes may be conducted to liven the classroom environment and hence, motivate the students to learn better. Signal processing involves a lot of mathematics as well as coding. Hence, assignments should contain a good balance of both theoretical questions and coding questions. Learning should be imparted such that it covers the entire spectrum of fast learners to slow learners. Varied resources can cater to both the population. Likewise, extra tutorials can be conducted that allow slow learners to keep pace with others. Besides, the grade weightage of different assessment components such as assignments, minute papers, projects, quizzes, examinations, and technical paper presentations should be appropriately balanced so that every student is able to demonstrate his/her proficiency. Bonus questions may be provided for quick paced students to keep them motivated. Group as well individual exercises should be given in right balance to students. Group exercises provide a platform to students for discussing their ideas with each other. These discussions and studies help transfer of skills to each other. On the other hand, individual exercises help in developing critical thinking and problem solving skills among the students. Course projects may also be supervised along with industry professionals and/or with different faculty of same or different department.

Students should be encouraged to inculcate a right of balance of learning via multimedia resources and studying from text books. They should not fall in trap of having a loss of reading concentration owing to excessive usage requirement of multimedia tools. Group study habits should be recommended to increase pen-and-paper style of study habits, doing derivations and solving numerical problems by self.

6. CONCLUDING REMARKS

Efforts should be made in proposing curriculum with varied sequence of courses that provide expertise to a student in a particular area as well as provide breadth of knowledge with core fundamentals. Blended learning with MOOCs, online resources, Powerpoint and chalk-and-board teaching with theoretical derivations, tutorials, workshops, guest lectures are important for delivering the fast paced technological contents. Efforts should be made to make students aware of working out numericals and studying from text books, as well as being skilled in both the theory and coding. Signal processing professionals' preparedness in both theory and coding helps them in working with ease with interdisciplinary community. Efforts should be made to bring awareness among them of these potential benefits of working in signal processing.

Today, signal processing has actually faded the boundaries between different disciplines of sciences. Most of the interdisciplinary domains of science have become an integral part of signal processing with varied applications in different walks of life. It has been rightly defined as the "science behind our digital life" by IEEE Signal Processing Society. It is at the heart of the modern world, powering today's entertainment and tomorrow's technology.

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