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WIP: A Brief Introduction of Deep Learning and IoT to Freshman Engineering Students

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Abstract

In a recent survey conducted by American Society of Engineering Education (ASEE) Corporate Member Council, Artificial Intelligence (AI) and Internet of Things (IoT) are identified as areas where substantial skill gaps exist in recent engineering graduates meeting the industry demands. To get students exposed to these two important technologies, a pre-existing MATLAB workshop on deep learning and IoT developed by MathWorks is adopted in an Introduction to Engineering course for first year students from different engineering disciplines. Survey results show that the learning module on deep learning and IoT is effective in providing an introduction and raising awareness of the importance of these two topics among first year engineering students, especially female students.

Introduction

In the 2020 survey for skills gaps in recent engineering graduates conducted by American Society of Engineering Education (ASEE) Corporate Member Council [1], Artificial Intelligence (AI) and Internet of Things (IoT) are identified as areas, among others, that should be improved, with 81% and 70% responses expressing that they were inadequately prepared in the two respective areas. Therefore, there is a need to incorporate lessons into existing coursework to provide students with the most up-to-date training to help them keep pace with skills in demand beyond the classroom.

Artificial intelligence and Internet of Things, two technologies traditionally associated with electrical and computing disciplines, are now widely applied in all engineering fields and beyond. To attract students' interests in acquiring skills in these two technologies, a learning module on deep learning and IoT is integrated in a freshman Introduction to Engineering course, which is open to all engineering majors. The goal is to let students understand the importance of machine learning, deep learning and IoT, and encourage them to expand their knowledge in these fields throughout their undergraduate engineering degree program.

Instead of developing a new learning module, a pre-existing MATLAB workshop on deep learning and IoT developed by MathWorks [2] is adopted, due to its simplicity and ease of use. Students are able to perform the hands-on exercises in the module with very basic knowledge of MATLAB. No hardware and extensive programming knowledge is required of students, and minimal preparation is needed on the part of the instructor.

Two surveys are administered to evaluate the effectiveness of the module. A Situational Motivation Scale (SIMS) survey [22], a proven instrument to measure student motivation, is given at the end of the module, from which 77 student responses are collected. In addition, three questions related to the module are included as part of the End of Semester survey to collect additional student feedback regarding the module, to which 74 students submit their responses. Survey results show that first year engineering students, especially female students, are highly

motivated by the learning module, perceive the module as useful and want to learn more about deep learning and IoT in the future.

The rest of the paper is organized as follows. First, existing work on IoT and machine learning educational efforts are briefly reviewed in the background section, along with the MATLAB prerequisite. The MATLAB module on deep learning and IoT is described in detail next, followed by assessment and results. The paper ends with conclusion and future work.

Background

Existing Work

Internet of Things education has been incorporated in undergraduate engineering curriculum at module [3], course [4-6] and program levels [7, 8]. Specifically, for first year engineering students, an IoT lab module [3] is developed in a first year introductory C++ programming course. In [9], a project-based approach is adopted to teach programming and IoT concept at the freshmen/sophomore level. For all these developments, software programming on some microcontroller hardware is required to implement the IoT capability.

Similar to IoT education, machine learning is also getting incorporated more and more into undergraduate engineering curriculum. For example, machine learning concepts are integrated into existing courses such as an introductory computer science programming class in [10] and a data structure course in [11]. In [12], a new deep learning course is developed for junior and senior computer science students. In [13], computer science senior design teams are involved in machine learning research. All of these efforts [10-13] and many others are geared towards computer science majors. To teach deep learning concepts to students without extensive programming background, Excel is used in [14], and a Graphical User Interface (GUI) application is developed using MATLAB in [15]. To reach first year multidisciplinary engineering students, machine learning resource repositories are built, and students gain knowledge of machine learning through group projects in introductory MATLAB programming courses [16,17].

In contrast to the existing work described above, this paper focuses on discussing the experience and evaluation of teaching deep learning and IoT in a first year multidisciplinary Introduction to Engineering Course, in which most students don't have programming background [18] nor programming is the focus of the course. A pre-existing MATLAB workshop provided by MathWorks is adopted, with no development effort on the part of the instructor. In addition, no hardware and extensive programming background is required to use the module, only some basic knowledge of MATLAB is needed as will be described next.

MATLAB Instruction in Introduction to Engineering Course

MATLAB is taught in Introduction to Engineering, which is a freshman level 2-credit course that meets one hour and fifty minutes twice a week for 15 weeks. This course is a required course for students majoring in electrical engineering, mechanical engineering, aerospace engineering, and chemical engineering. Most students take it during their first semester in college. The course aims to give students an introduction to engineering through hands-on project work.

Although some engineering majors have their own dedicated introduction to MATLAB course, other engineering majors will benefit from a brief MATLAB introduction in their freshman year since many courses that students take in their degree program use MATLAB in their assignments, labs and projects. Due to this reason, MATLAB is introduced as a data analysis and visualization tool that helps solve engineering problems in the Introduction to Engineering course, in which developing the ability to analyze and interpret data is one of the course learning outcomes.

Three lecture periods are dedicated to MATLAB instruction in the curriculum. In order to make space for the new deep learning and IoT module, the original learning materials are compressed into two lecture periods and some are moved outside of lecture and assigned as homework. The content of the adjusted lectures is described as follows.

Before the first MATLAB class, students need to complete sections of the MATLAB Onramp tutorial [19] as a pre-lecture homework. This is to get students familiar with the MATLAB programming interface and introduce students to the MATLAB basics. Students get to try out in the web browser different MATLAB commands that will be taught in the lectures and receive instant feedback. The homework shifts easier part of the learning process outside of classroom, so that the lectures can be dedicated to more application-oriented exercises.

The first MATLAB lecture reviews the MATLAB basics that students have already learned in the pre-lecture homework. Specifically, students practice how to use MATLAB's command line interface as a calculator for mathematical operations, how to write and run a MATLAB script, how to define and access scalar, vector and matrix variables, and how to import data from a text file and draw 2D plots.

The second lecture reinforces the topics introduced in the pre-lecture homework and the first lecture by using MATLAB to solve problems from different engineering disciplines. For example, students are asked to import experimental data from text file and draw plots to investigate the relationship between input and output variables and compare different experimental conditions. Beyond reviewing and practicing the MATLAB basics, data analysis tasks that are essential to all engineering disciplines, such as curve fitting, interpolation and extrapolation are also introduced, and students practice them through examples.

The third lecture period is used to give students an introduction to machine learning, deep learning and IoT through MATLAB, which will be explained in detail next.

Deep Learning and IoT MATLAB Module

A workshop developed by MathWorks on Hands-on Deep Learning & IoT is adapted and used in the third MATLAB lecture. The workshop uses an image classification application to introduce deep learning and IoT.

To prepare to run the exercises in lecture, students are asked to bring a laptop and a webcam. They can also bring objects that they want the image classification algorithm to recognize. Students need to create a MathWorks account to use MATLAB Online, which they have already

completed when they go through the MATLAB Onramp tutorial as required by the pre-lecture homework. As the final preparation step, at the beginning of the lecture, students copy, via an URL link, a folder in which the exercise code provided by MathWorks resides, to their online MATLAB drive.

After all the preparations, the survey results from the 2020 ASEE Corporate Member Council survey for skills gaps in recent engineering graduates [1] are first shown to students. This is the only modification made to the workshop materials provided by MathWorks. The goal is simply to illustrate the unpreparedness of recent engineering graduates in the Artificial Intelligence and Internet of Things domains and to hopefully raise awareness among students.

Next, students are given a brief introduction of Artificial Intelligence, machine learning and deep learning including definitions, a brief history, and how they relate to each other. The difference between machine learning and traditional programming, i.e., the important characteristics of self-learning, is also emphasized. Students then run a hands-on exercise to utilize a pre-trained neural network to recognize objects using their own laptop camera. Specifically, the MATLAB script takes a snapshot using the webcam, then uses a pre-trained deep learning model AlexNet [20] to assign a classification label to the image. Figure 1 shows an object classified by AlexNet with its classification label and associated confidence score.

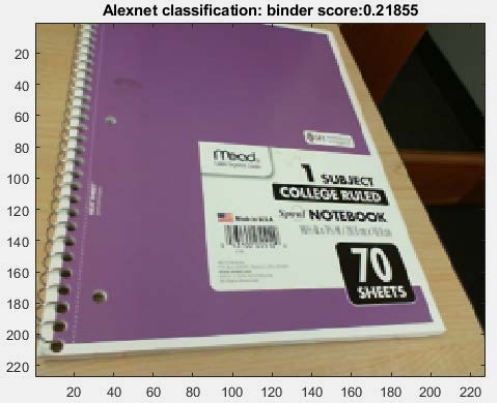

Figure 1. An object classified by Alexnet with its classification label and associated confidence score.

After the object-recognition exercise, Internet of Things is introduced including its definition, applications, and benefits. Students then perform the second exercise by sending the object classification labels obtained during their first deep learning exercise to a public ThingSpeak channel [21], which is MathWorks' IoT cloud platform, a free service for non-commercial small projects. As the object labels get aggregated from all students in the class in real time and sent to the cloud, students then run the third exercise to visualize the result as a histogram by retrieving the label data stored in the cloud ThingSpeak channel as shown in Figure 2.

As mentioned previously, MATLAB code in all three exercises are provided by MathWorks and are given to students at the beginning of the lecture period. The code is explained briefly before students conducting each exercise, and the MATLAB scripts are straightforward, concise and

easy to understand. Most students have no trouble running the exercises. The only caveat is that the pretrained neural network AlexNet used in the object recognition exercise is not very accurate and classify most objects wrong. This can be used as an opportunity to discuss challenges in the training and selection of models to use. The topic of transfer learning can also be introduced.

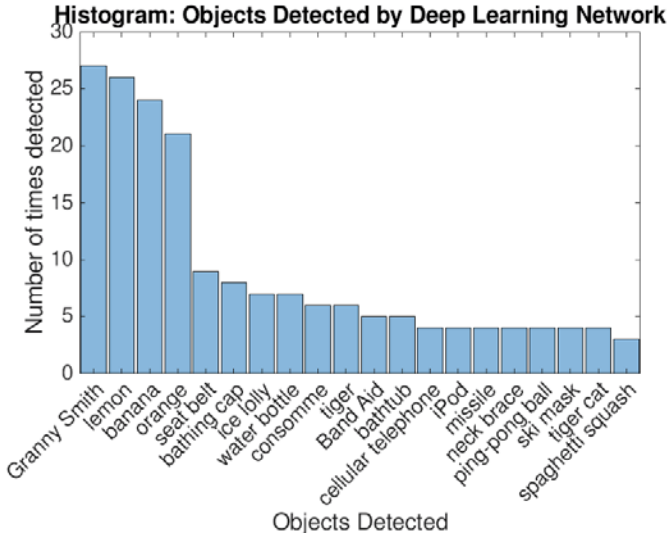

Figure 2. Retrieved object classification label histogram from ThingSpeak channel stored in the cloud

The instructor preparation for the module is minimal. All the exercises are pre-run to make sure they all work. The pre-created ThingSpeak channel by MathWorks is used in the exercises. It is also possible to create one's own public ThingSpeak channel, which is easy to do based on the tutorial provided at [21]. The only modification to the MATLAB script would be the ThingSpeak channel ID and the write key.

Assessment and Results

There is a total of 115 students enrolled in three sections of Introduction to Engineering in the fall semester of 2021, out of which 97 students consented to participate the research study.

A Situational Motivation Scale (SIMS) survey [22] is given at the end of the MATLAB deep learning/IoT lecture to measure student motivation. A self-determination index is calculated to measure students' overall motivation, with higher scores indicating greater self-determination.

In addition, three questions are included in the End-of-Semester Survey to further gauge student's perception of the deep learning/IoT learning module. The questions are Likert-type scale response questions with seven choices: 1 (corresponds not at all), 2 (corresponds very little), 3 (corresponds a little), 4 (corresponds moderately), 5 (corresponds enough), 6 (corresponds a lot), 7 (corresponds exactly).

Motivation

There are 77 Situational Motivation Scale (SIMS) survey responses received from students. The mean self-determination index, a metric of students' overall motivation, is shown in Table 1.

Table 1. Self-Determination Index (SDI) for the MATLAB deep learning/IoT lecture calculated for different demographics.
N is the number of survey responses, the ± range shows 95% confidence interval.

	Self-Determination Index (SDI)
Overall (N=77)	5.85 ± 1.02
Male (N=64)	5.51 ± 1.51
Female (N=13)	7.48 ± 1.96
White (N=44)	5.77 ± 1.26
Non-White (N=33)	5.96 ± 1.71

The overall self-determination index is quite high compared to SDI values calculated based on SIMS surveys collected from Introduction to Engineering students engaging in other course activities in previous years [18, 23, 24]. The table also shows female students demonstrate much higher self-determination compared to male students. It also shows non-white students' self-determination is slightly higher compared to white students.

End-of-Semester Survey
The three questions in the End-of-Semester Survey that are related to the MATLAB deep learning/IoT lecture are shown in Table 2.

Table 2. Survey questions for the MATLAB deep learning/IoT lecture.

Symbol	Question
Q1	The deep learning / IoT MATLAB lecture is useful.
Q2	The deep learning / IoT MATLAB lecture provides me with a good introduction of deep learning and IoT.
Q3	The deep learning / IoT MATLAB lecture makes me want to learn more about machine learning, deep learning and IoT in the future.

Table 3 shows the survey responses. It indicates overall students show positive response towards the MATLAB deep learning/IoT lecture, with over 70% of students corresponding at least moderately to the three survey questions. The survey result from Table 3 is consistent with the survey result from Table 1, with female students showing higher scores comparing with male students and non-white students showing slightly higher scores comparing with white students. Particularly, Table 3 shows female students seem to perceive the topic of deep learning and IoT as more useful compared to male students (Q1), therefore, they want to explore the topic further in the future (Q3).

Table 3. Survey responses to the MATLAB deep learning/IoT lecture survey questions from different demographics.

Seven choices for each question: 1 (corresponds not at all), 2 (corresponds very little), 3 (corresponds a little), 4 (corresponds moderately), 5 (corresponds enough), 6 (corresponds a lot), 7 (corresponds exactly).
N is the number of survey responses, the ± range shows 95% confidence interval.

	Mean (N=74)	Percentage of scores ≥ 4	Male Mean (N=61)	Female Mean (N=13)	White Mean (N=38)	Non-White Mean (N=36)
Q1	4.49 ± 0.37	73%	4.34 ± 0.40	5.08 ± 1.01	4.42 ± 0.53	4.56 ± 0.52
Q2	4.38 ± 0.35	74%	4.34 ± 0.39	4.58 ± 0.85	4.29 ± 0.49	4.47 ± 0.49
Q3	4.30 ± 0.37	72%	4.23 ± 0.39	4.67 ± 1.06	4.29 ± 0.51	4.31 ± 0.53

Conclusion and Future Work

A pre-existing MATLAB workshop developed by MathWorks on deep learning and IoT is adopted in a first year multidisciplinary Introduction to Engineering course. The module requires no additional hardware, little MATLAB programming background and minimal instructor preparation.

The survey findings show that first year engineering students are motivated after the MATLAB learning module. Female engineering students find the module particularly useful and are more willing to dive deeper and learn more about deep learning and IoT in the future. Due to its simplicity and ease of use, the learning module can serve as a lightweight introduction to deep learning and IoT in a wide range of engineering courses.

Future work includes trying out different pre-trained neural networks for image classification in the learning module to improve accuracy. Many students say in the free response questions in the surveys that they enjoy the module, however they wish the image classification algorithm could be more accurate. Additional feedback can also be collected by using the learning module to introduce deep learning and IoT to more engineering students. The additional feedback can help verify the findings in this paper, for example, whether or not female engineering students are motivated more by the learning module and why.

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