Engaging First-Year Engineering Students with Deep Learning and IoT

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Outline

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Motivation

• In the 2020 survey for skills gaps in recent engineering graduates conducted by American Society of Engineering Education (ASEE) Corporate Member Council,
  – 81% responses expressed that they were inadequately prepared in the area of Artificial Intelligence (AI);
  – 70% responses expressed that they were inadequately prepared in the area of Internet of Things (IoT).
Motivation

• 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.

• Most existing work requires
  – Students of extensive programming background, and/or
  – Microcontroller hardware, and
  – Instructor time and effort to develop new course materials.
Innovative Approach

• Introduce machine learning and IoT to freshman engineering students in a “Introduction to Engineering” course
  – A freshman level 2-credit course that meets one hour and fifty minutes twice a week for 15 weeks.
  – 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.
  – A hands-on project course.
MATLAB Instruction in the “Introduction to Engineering” Course

• Taught as a data analysis and visualization tool using three lecture periods.
  – Use Onramp tutorial as pre-lecture homework.
MATLAB Instruction in the “Introduction to Engineering” Course

• 1st lecture: command line interface, mathematical operations, script, defining and accessing scalar, vector and matrix variables, data import from a text file and 2D plots.

• 2nd lecture: engineering problem solving, e.g., data visualization, curve fitting, interpolation and extrapolation.

• 3rd lecture: an introduction to machine learning, deep learning and IoT through MATLAB.
Deep Learning and IoT MATLAB Module

- A workshop developed by MathWorks on Hands-on Deep Learning & IoT is adapted and used in the 3rd MATLAB lecture.
- The workshop uses an image classification application to introduce deep learning and IoT.
- Students can perform the hands-on exercises in the module with very basic knowledge of MATLAB.
- No hardware and extensive programming knowledge is required of students.
- Minimal preparation is needed on the part of the instructor.
Module Implementation

• Prerequisites
  – Bring a laptop with webcam and objects to classify.
  – Create a MathWorks account to use MATLAB Online.
  – Copy, via an URL link, a code folder to online MATLAB drive.

• Introduction
  – A brief introduction of Artificial Intelligence, machine learning, deep learning and Internet of Things is given.
Module Implementation

- Exercise 1: take a snapshot using the laptop webcam, then use a pre-trained deep learning model AlexNet to assign a classification label to the image.
**Exercise 1**

### Connecting to the camera

```matlab
camera = webcam(1); % Connect to the camera
```

### Loading the neural net named: Alexnet

```matlab
net = alexnet; % Load the neural net
```

### Capturing & classifying image data

#### Take a picture

```matlab
picture = snapshot(camera);
```

#### Resize the picture

```matlab
picture = imresize(picture,[227,227]);
```

#### Classify the picture and obtain confidence score

```matlab
[label,scores] = classify(net, picture);
```

#### Sorting scores in descending order

```matlab
[sorted_scores,indices]=sort(scores,'descend');
```

#### Show the picture with the label

```matlab
imshow(picture);
title(['Alexnet classification: ', char(label), ', score: ', num2str(sorted_scores(1))]);
clear camera
drawnow;
```
Module Implementation

- Exercise 2: send the object classification labels obtained during Exercise 1 to a public ThingSpeak channel.
## Exercise 2

### Connecting to the camera

```matlab
camera = webcam(1);
```

### Loading the neural net named: Alexnet

```matlab
mnet = alexnet;
```

### Capturing image data

```matlab
picture = snapshot(camera);
```

### Classifying image data

```matlab
picture = imresize(picture,[227,227]); % Resize the picture
[label,scores] = classify(mnet, picture); % Classify the picture and obtain confidence score
[sorted_scores,indices] = sort(scores, 'descend'); % Sorting scores in descending order
image(picture); % Show the picture
title([''Alexnet classification: '';char(label), 'score:','...
num2str(sorted_scores(1))]); % Show the label
```

### Aggregating label data to open IoT platform

```matlab
try
    thingSpeakWrite([1318077],cellstr(label),'WriteKey','LRB2KUM6QKDC0LV')
catch
    pause(randi(5))
extend
```
Module Implementation

- Exercise 3: visualize the result as a histogram by retrieving the label data stored in the cloud ThingSpeak channel.
Exercise 3

Reading aggregated label data for the last 2 hours from ThingSpeak

```plaintext
readChannelID = 1318077;
LabelFieldID = 1;
readAPIKey = '';

dataForLastHours = thingSpeakRead(readChannelID, ...'Fields', LabelFieldID, 'NumMinutes', 120, ...'ReadKey', readAPIKey, 'OutputFormat', 'table');
```

Visualizing data using a histogram

```plaintext
if (isempty(dataForLastHours))
  labelsForLastHours = categorical(dataForLastHours.Label);
  numbins = min(numbel(unique(labelsForLastHours)), 20);
  histogram(labelsForLastHours, 'DisplayOrder', 'descend', ...'NumDisplayBins', numbins);
  xlabel('Objects Detected');
  ylabel('Number of times detected');
  title('Histogram: Objects Detected by Deep Learning Network');
  set(gca, 'FontSize', 10)
end
drawnow
```
Assessment and Results

- Situational Motivation Scale (SIMS) survey given at the end of the module:

<table>
<thead>
<tr>
<th>Group</th>
<th>Self-Determination Index (SDI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall (N=77)</td>
<td>5.85 ± 1.02</td>
</tr>
<tr>
<td>Male (N=64)</td>
<td>5.51 ± 1.51</td>
</tr>
<tr>
<td>Female (N=13)</td>
<td>7.48 ± 1.96</td>
</tr>
<tr>
<td>White (N=44)</td>
<td>5.77 ± 1.26</td>
</tr>
<tr>
<td>Non-White (N=33)</td>
<td>5.96 ± 1.71</td>
</tr>
</tbody>
</table>
Assessment and Results

• End of Semester Survey: Three questions (score 1: corresponds not at all - 7: corresponds exactly)
  – 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>
<thead>
<tr>
<th></th>
<th>Overall (N=74)</th>
<th>Percentage of scores ≥ 4</th>
<th>Male (N=61)</th>
<th>Female (N=13)</th>
<th>White (N=38)</th>
<th>Non-White (N=36)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1</td>
<td>4.49 ± 0.37</td>
<td>73%</td>
<td>4.34 ± 0.40</td>
<td>5.08 ± 1.01</td>
<td>4.42 ± 0.53</td>
<td>4.56 ± 0.52</td>
</tr>
<tr>
<td>Q2</td>
<td>4.38 ± 0.35</td>
<td>74%</td>
<td>4.34 ± 0.39</td>
<td>4.58 ± 0.85</td>
<td>4.29 ± 0.49</td>
<td>4.47 ± 0.49</td>
</tr>
<tr>
<td>Q3</td>
<td>4.30 ± 0.37</td>
<td>72%</td>
<td>4.23 ± 0.39</td>
<td><strong>4.67 ± 1.06</strong></td>
<td>4.29 ± 0.51</td>
<td>4.31 ± 0.53</td>
</tr>
</tbody>
</table>
Conclusion

• 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 hardware, little MATLAB programming background and minimal instructor preparation.
• Many students find the module interesting and cool.
• The module can serve as a lightweight introduction to deep learning and IoT in a wide range of engineering courses due to its simplicity and ease of use.
Acknowledgement

• Special thanks to Ms. Gaby Arellano-Bello from MathWorks for providing the MATLAB workshop materials and technical support needed for the in-class implementation.

• Also, thanks to Anoush Najarian, Shruti Karulkar, and Louvere Walker-Hannon, who are the authors of the workshop.
More Information

• MathWorks newsletter article:

• ASEE conference paper:

• Contact me at chao.wang.6@asu.edu if you have any questions.