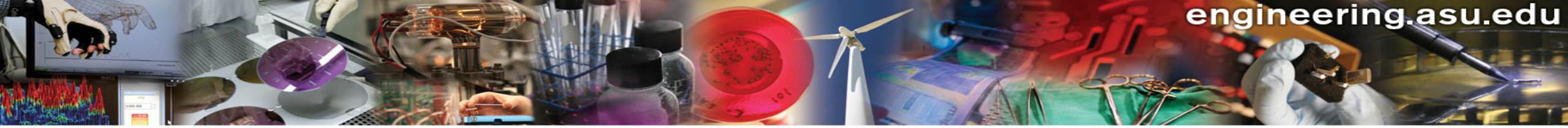

IRA A. FULTON SCHOOLS OF ENGINEERING

Leading engineering discovery and innovative education for global impact on quality of life.

Engaging First-Year Engineering Students with Deep Learning and IoT

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MATLAB EXPO 2023

MathWorks®

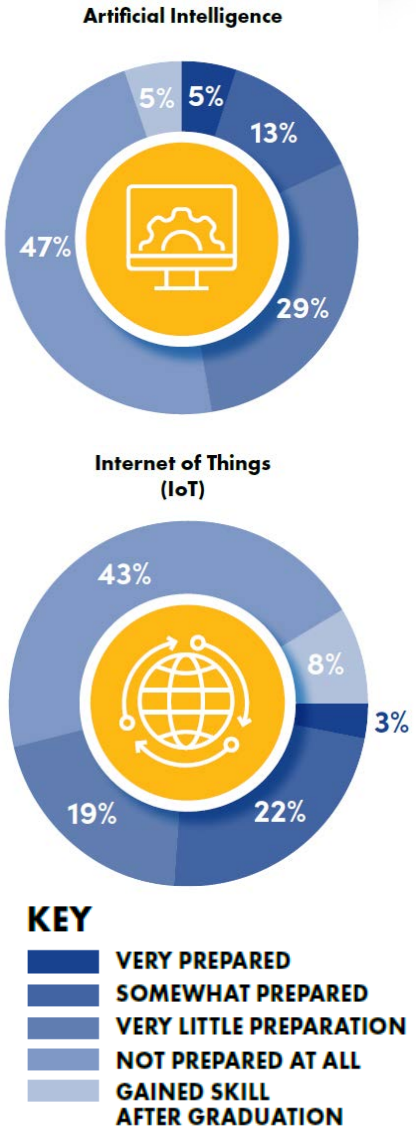
ASU Arizona State University

Outline

- Motivation
- Innovative approach
- Implementation
- Assessment and results
- Conclusion

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

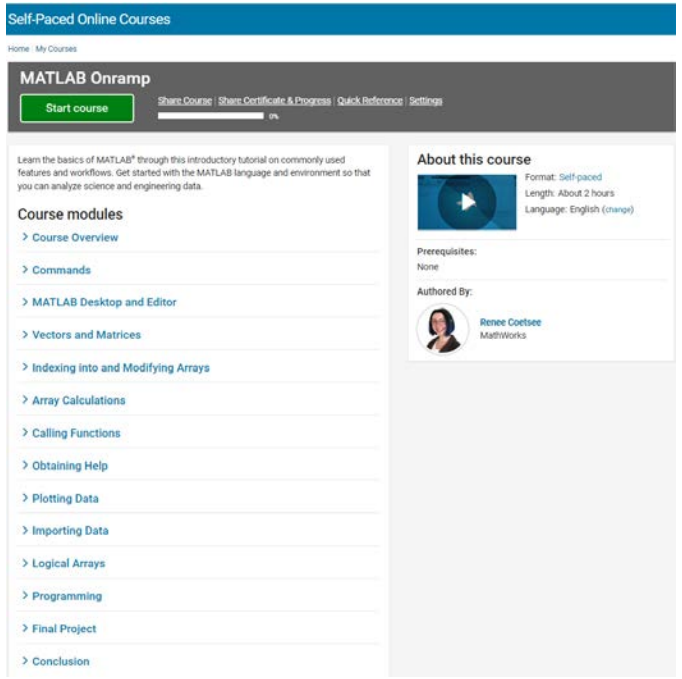
- There is a need to incorporate lessons into existing coursework to provide students with the most up-to-date training to help them keep pace with skills in demand beyond the classroom.
- Most existing work requires
  - Students of extensive programming background, and/or
  - Microcontroller hardware, 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.

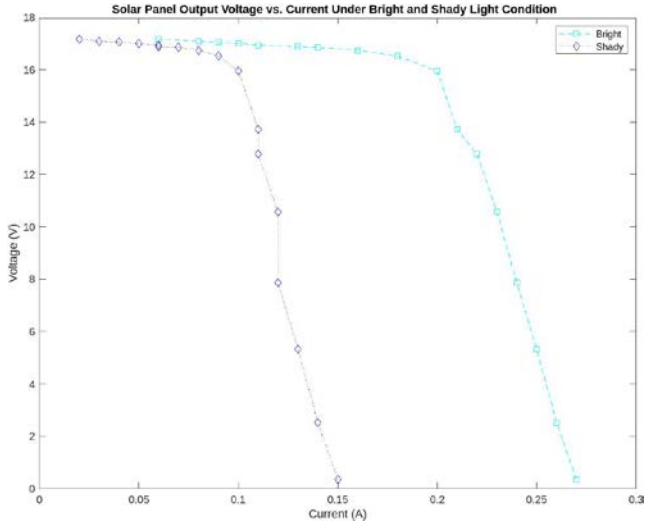
MATLAB Instruction in the "Introduction to Engineering" Course

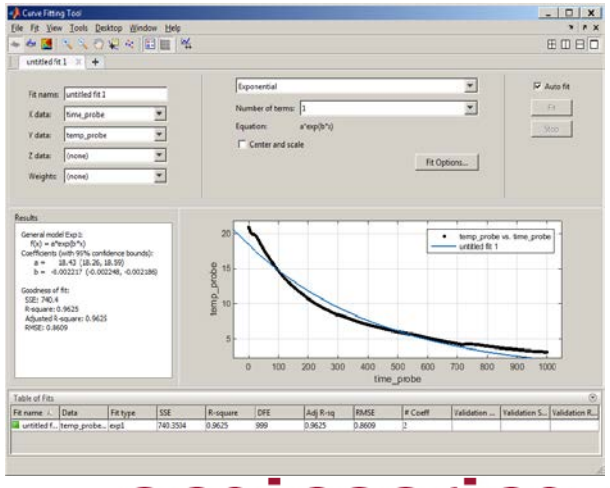
- Taught as a data analysis and visualization tool using three lecture periods.
  - Use Onramp tutorial as pre-lecture homework.



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

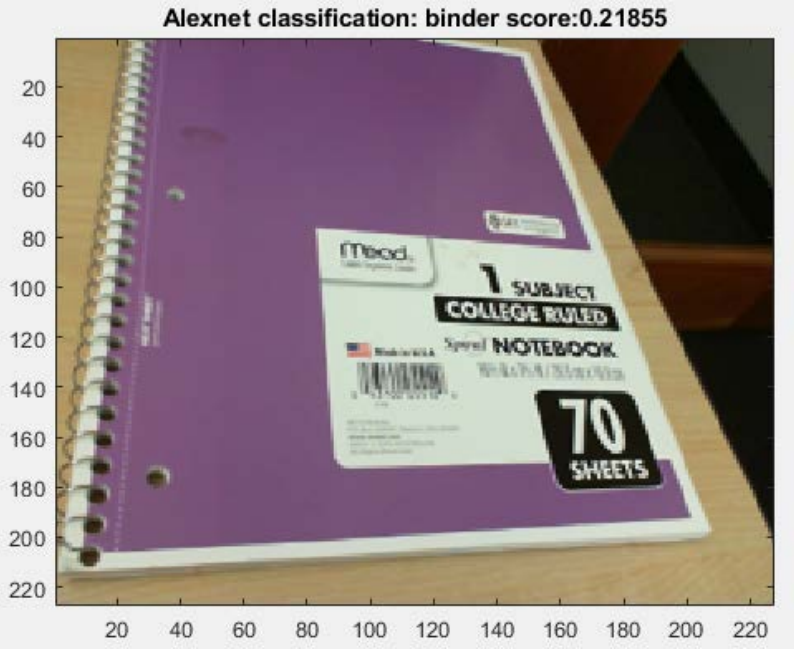
- A workshop developed by MathWorks on Hands-on Deep Learning & IoT is adapted and used in the 3rd MATLAB lecture.
- The workshop uses an image classification application to introduce deep learning and IoT.
- Students can perform the hands-on exercises in the module with very basic knowledge of MATLAB.
- 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

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

Loading the neural net named: Alexnet

```
2  nnet = alexnet; % Load the neural net
```

Capturing & classifying image data

Take a picture

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

Resize the picture

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

Classify the picture and obtain confidence score

```
5  [label,scores] = classify(nnet, picture);
```

Sorting scores in descending order

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

Show the picture with the label

```
7  image(picture);
8  title(['Alexnet classification: ',char(label),' score:', num2str(sorted_scores(1))]);
9  clear camera
10 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

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

Loading the neural net named: Alexnet

```
nnet = alexnet;
```

Capturing image data

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

Classifying image data

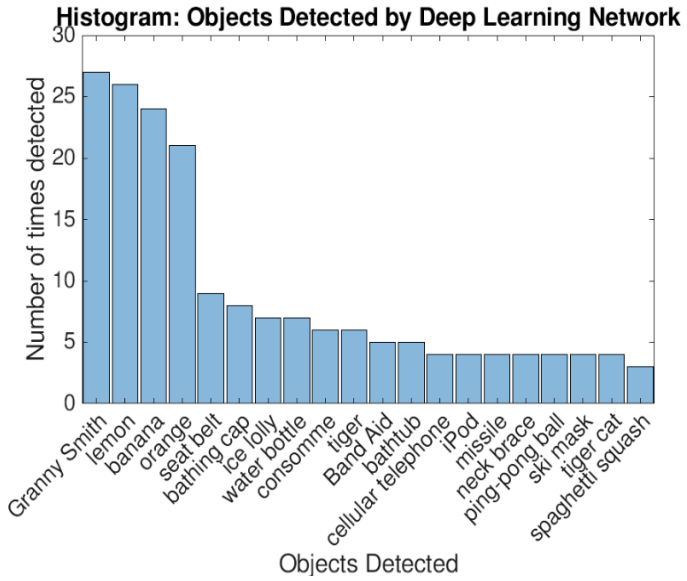
```
picture = imresize(picture,[227,227]); % Resize the picture
[label,scores] = classify(nnet, picture); % Classify the picture and obtain confidence score
[sorted_scores,indices]=sort(scores,'descend'); % Sorting scores in descending order
image(picture); % Show the picture
title(['Alexnet classification: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

Aggregating label data to open IoT platform

```
try
    thingSpeakWrite( 1318077 ,cellstr(label),'WriteKey',' ILR82KUA6QKDC0LV ')
catch
    pause(randi(5))
end
```

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

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

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

Visualizing data using a histogram

```
if (not(isempty(dataForLastHours)))
    labelsForLastHours = categorical(dataForLastHours.Label);
    numbins = min(numel(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:

	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

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.

	Overall (N=74)	Percentage of scores ≥ 4	Male (N=61)	Female (N=13)	White (N=38)	Non-White (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

- 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:
  - https://www.mathworks.com/company/newsletters/articles/introducing-deep-learning-and-iot-to-first-year-engineering-students-with-matlab.html
- ASEE conference paper:
  - C. Wang, “WIP: A Brief Introduction of Deep Learning and IoT to Freshman Engineering Students,” in Proc. 129st ASEE Annual Conference & Exposition, Minneapolis, Minnesota, June, 2022.
- Contact me at chao.wang.6@asu.edu if you have any questions.