



**Samueli**  
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# Situational Awareness and Gesture Control for Smart Lights

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# Overall Project Goals and Specific Aims

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**Create a smart light switch that responds to the environment**

**Situational awareness capabilities**

- Adaptive brightness
- Motion detection
- Set personalized profiles using BLE or gestures

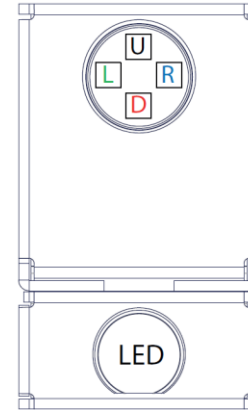
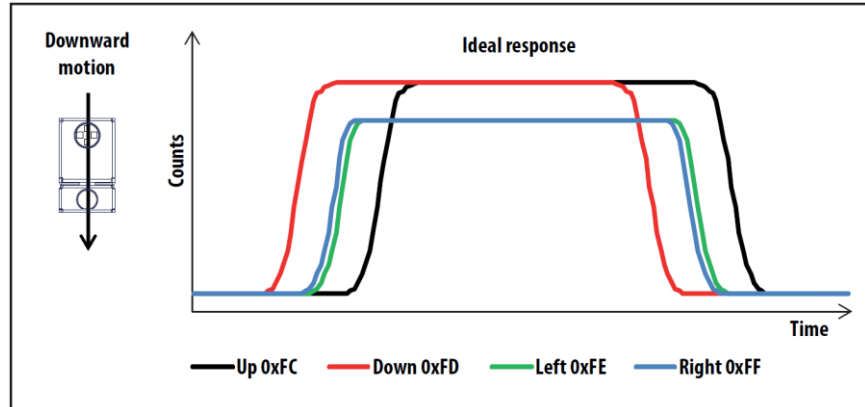
**Advanced gesture control for manual operation**

- Powered by neural networks
- Optimized for low power, resource constrained systems

# Technical Approach

## Arduino Nano 33 BLE Sense

- SoC with integrated Bluetooth
- On-board APDS-9960 sensor for gesture recognition and ambient light sensing
  - Modify drivers to intercept data in directional photodiode FIFO
  - Edge Impulse – embedded machine learning SaaS platform

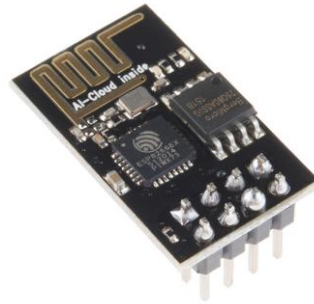


# Technical Approach

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## External components

- LIFX smart lights
- ESP8266 WiFi module communicates with lights on same LAN network using UDP
- HC-SR501 passive infrared (PIR) motion sensor



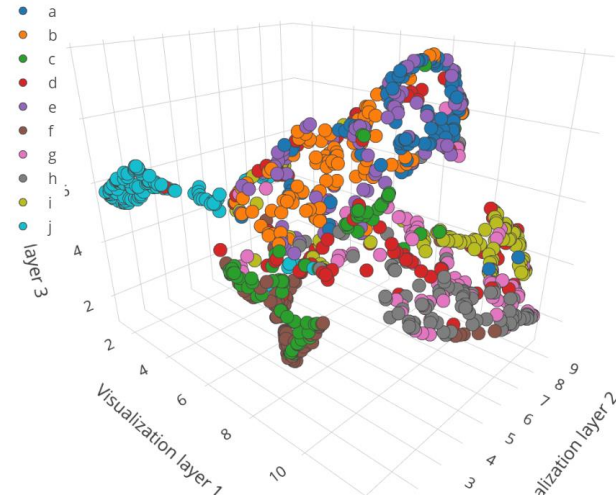
# Gesture Detection

## Overview

- Create model architecture for generic gesture detection with APDS-9960 sensor
- Train with 10 gestures for American Sign Language (ASL) letters A-J
- Purpose: understand sensor limitations

## Dataset collection

- ASL sign waved in front of sensor, left to right
- 1200 samples collected in four sittings
- Two scenarios: train/test data shuffled, train/test data split by collection time



# Gesture Detection

## Model

- Basic convolutional neural network (CNN)
- 1D convolutional layer helps identify spatial information
  - Filters: 16
  - Kernel size: 64
- Dense layers help find correlations and classify the signal
- Statistics
  - Inference time: 75 ms
  - Peak RAM usage: 4.8K
  - ROM usage: 257.4K

Layer (type)	Output Shape	Param #
reshape (Reshape)	(None, 48, 4)	0
conv1d (Conv1D)	(None, 48, 16)	4112
max_pooling1d (MaxPooling1D)	(None, 24, 16)	0
dropout (Dropout)	(None, 24, 16)	0
flatten (Flatten)	(None, 384)	0
dense (Dense)	(None, 384)	147840
dense_1 (Dense)	(None, 192)	73920
y_pred (Dense)	(None, 10)	1930
Total params: 227,802		
Trainable params: 227,802		
Non-trainable params: 0		

# Gesture Detection

## Results on 10-character ASL dataset

- Shuffled dataset
  - Training accuracy: 93.3% (loss 0.20)
  - Test accuracy: 88.9%
- Separated dataset
  - Training accuracy: 94.0% (loss 0.50)
  - Test accuracy: 71.0%
- Problems
  - Overfitting
  - Dataset too small
  - Gestures too similar

	A	B	C	D	E	F	G	H	I	J
A	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%
B	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%
C	0%	0%	87.5%	0%	0%	12.5%	0%	0%	0%	0%
D	0%	0%	0%	76.5%	11.8%	0%	0%	0%	11.8%	0%
E	0%	5.9%	0%	0%	94.1%	0%	0%	0%	0%	0%
F	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%
G	8%	0%	0%	0%	0%	0%	92%	0%	0%	0%
H	0%	0%	0%	0%	0%	0%	11.1%	88.9%	0%	0%
I	4.5%	0%	0%	0%	4.5%	0%	0%	0%	90.9%	0%
J	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%
F1 ...	0.93	0.97	0.93	0.87	0.89	0.95	0.92	0.94	0.91	1.00

Confusion matrix (shuffled dataset, training)

# Gesture Detection

## Results on 7-character ASL dataset

- Removed D, C, G (most problematic labels)
- Shuffled dataset
  - Training accuracy: 94.2% (loss 0.35)
  - Test accuracy: 97.4%
- Separated dataset
  - Training accuracy: 100.0% (loss 0.00)
  - Test accuracy: 88.6%
- Potential improvements
  - Additional training data
  - More distinct gestures (such as ASL numbers 1-10)



	A	B	E	F	H	I	J
A	100%	0%	0%	0%	0%	0%	0%
B	4.8%	90.5%	4.8%	0%	0%	0%	0%
E	4.3%	0%	95.7%	0%	0%	0%	0%
F	0%	0%	0%	95.7%	0%	4.3%	0%
H	0%	0%	0%	0%	93.8%	6.3%	0%
I	0%	11.8%	5.9%	0%	0%	82.4%	0%
J	0%	0%	0%	0%	0%	0%	100%
F1 SCO...	0.95	0.90	0.94	0.98	0.97	0.85	1.00

Confusion matrix (shuffled dataset, training)



# Smart Switch

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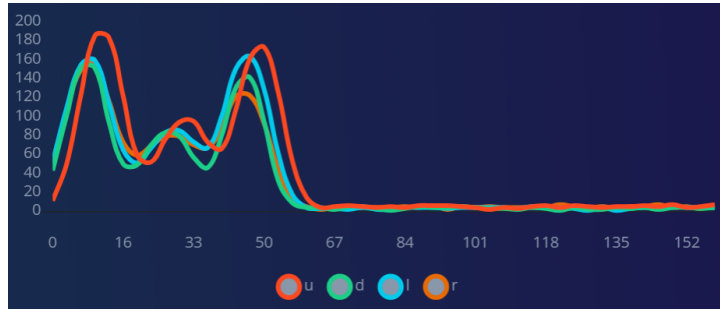
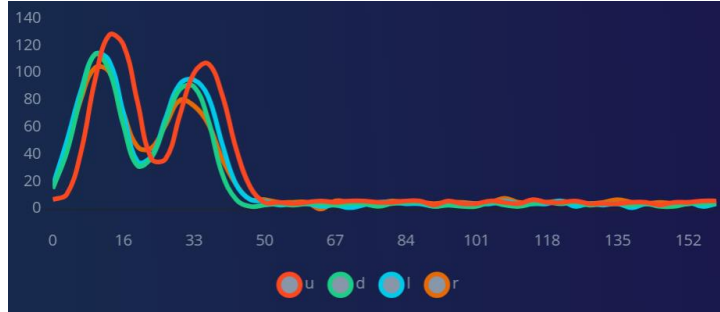
## Overview

- Gesture recognition for manual control
  - Turn lights on/off
  - Adjust brightness
  - Select custom lighting profiles
- Motion detection with timeout automatically turns lights on/off
- Ambient light sensor ensures lights only automatically turn on if it is dark enough
- Bluetooth control to select custom lighting profiles from a distance
- Light control packets broadcasted on local network using UDP

# Smart Switch

## Gesture control dataset

- 7 classes
  - Power: up/down
  - Brightness: left/right
  - Custom profiles
    - Up-1, up-2, up-3
- 50 samples each class
- 350 samples total



# Smart Switch

## Gesture control model

- Training accuracy: 98.2% (loss 0.10)
- Test accuracy: 97.1%
- Inference time: 55 ms
- Peak RAM usage: 4.3K
- ROM usage: 209.4K

	DOWN	LEFT	RIGHT	UP	UP-1	UP-2	UP-3
DOWN	100%	0%	0%	0%	0%	0%	0%
LEFT	0%	100%	0%	0%	0%	0%	0%
RIGHT	0%	0%	100%	0%	0%	0%	0%
UP	0%	0%	0%	100%	0%	0%	0%
UP-1	0%	0%	0%	0%	87.5%	12.5%	0%
UP-2	0%	0%	0%	0%	0%	100%	0%
UP-3	0%	0%	0%	0%	0%	0%	100%
F1 SCO...	1.00	1.00	1.00	1.00	0.93	0.95	1.00

Confusion matrix

# Demo

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# Future Work

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## **Gesture detection**

- Experiment with modifying model architecture
- Tweak directional photodiode gain, drive strength, and pulse settings
- Investigate optimal gesture distance
- Tune training hyperparameters

## **Smart switch**

- Tune environment parameters and timeouts
- Learn and adapt parameters according to user behavior