



# Knot too Tight, Knot too Loose

**—**  
*The Knotorious Five*

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# Getting up to Speed

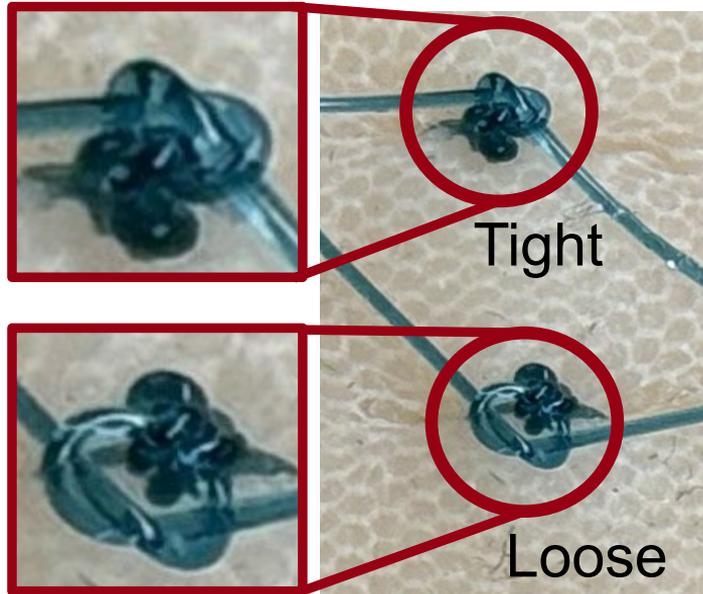


Figure 1: Comparison of tight and loose square knots.

- **Need:** System to train students on the correct tension needed for a secure suture knot
- **Current project state:** Machine learning model created on TensorFlow
  - Accuracy and precision  $\geq 80\%$  [1]
  - F1-Score  $\geq 0.8$

\*\* RoboFlow model does not integrate well with further development systems.

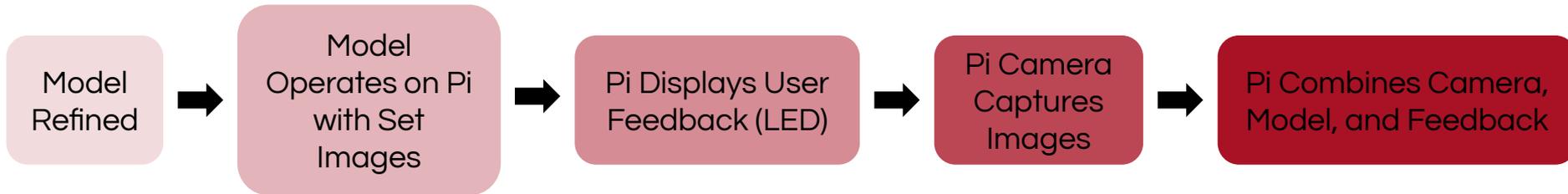
# Big Picture Tasks

## Model Refinement

- K-Fold Cross Validation
- Image Augmentation

## Creation of Physical Training Module

- Raspberry Pi Implementation
- Camera & Board Selection
- Add Accessories



# Model Refinement to Expand Limited Database



# Stratified K-Fold Cross Validation

## Pros:

- Efficient data usage
- Prevents overfitting
- Robust evaluation
- Maintains the same class distributions

## Cons:

- High computational cost

K = 5

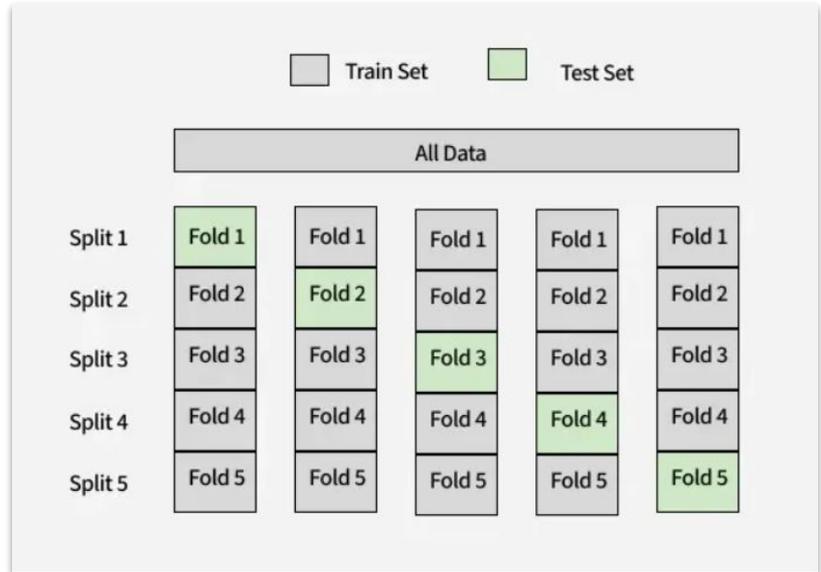


Figure 2: K-fold cross validation schematic [2].

# Image Augmentation

Preprocessed  
Images



Figure 3: Augmented images of a knot [3].

Flip

Rotation

Shear

Grayscale

Saturation

Hue

Horizontal

-15°

$\mp 10^\circ$  Horizontal,  
 $\mp 10^\circ$  Vertical

15% of images

-25%

-21°

Vertical

+15°

Augmented Images  
304 Images  $\rightarrow$  730 Images

+25%

+21°

# Model Testing within Jupyter Notebook

## Performance Testing:

*Goal:* Collect metrics on the augmented model's performance

### *Process:*

1. Run the model
2. Collect metrics:
  - F1 score
  - Accuracy
  - Recall/Sensitivity
  - Precision

## Stress Testing:

*Goal:* Evaluate the model's success classifying blurry, low light, and rotated images.

### *Process:*

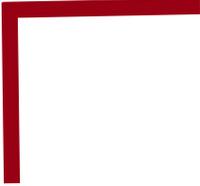
1. Run the model on a set of 10 images from each category
2. Record the models' prediction accuracy for each set

## Latency Testing:

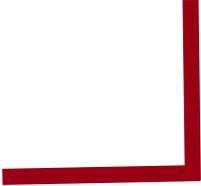
*Goal:* Measure the runtime from image input until model classification output

### *Process:*

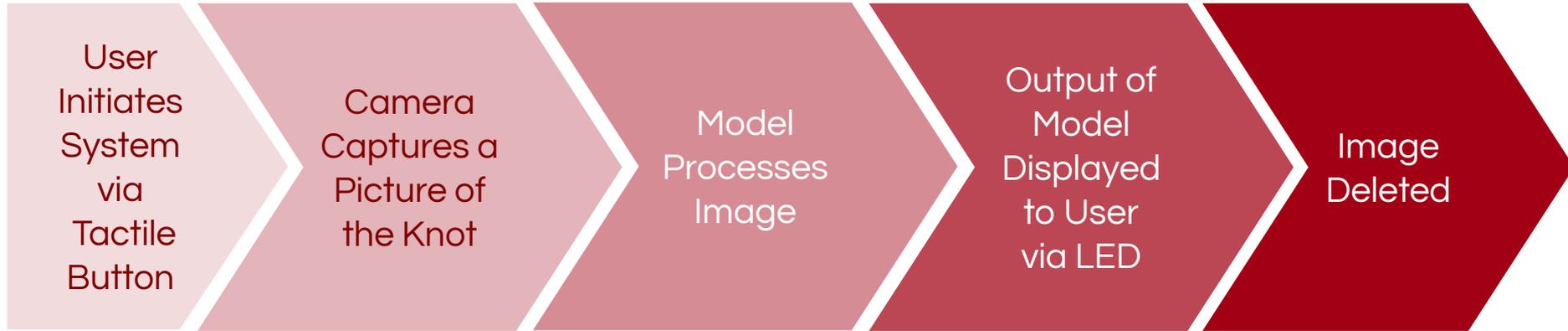
1. Run the model on a set of 10 images
2. Measure the code start time until code output using a stopwatch



# Raspberry Pi Implementation



# System Workflow: From Data Input to Results



Green for tight knot  
Red for loose knot

# Hardware

Micro SD card



Figure 4: SD card for storage (32G) [4].

USB-C Power Supply



Figure 5: 27W Power Supply [5].

Micro HDMI to HDMI cord



Figures 6 and 7 : Raspberry Pi board and HDMI cord to join Pi with monitor [6].

Raspberry Pi 5



Active Cooler



Figure 9: Fan for Raspberry Pi [8].

Camera

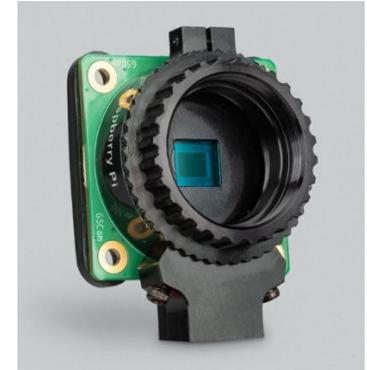


Figure 8: HQ camera [7].

# Raspberry Pi HQ Camera for Image Collection

## Features:

- Interchangeable lens
- Can capture fine details well
- Higher processing latency - in Raspberry Pi board
- Tensorflow fully supported
- 12.3 MP Sensor → high resolution



Figure 11: HQ camera [7].

# Raspberry Pi Module 5 Board for Model Hosting

## Features:

- Wifi
- Bluetooth 5.0
- 2 USB 3.0 ports
- 2 USB 2.0 ports
- Ethernet
- 4 Lane MIPI camera transceivers
- DC power via USB-C
- 40 pin header
- Power button
- Faster and greater computing capabilities compared to the Pi 4b

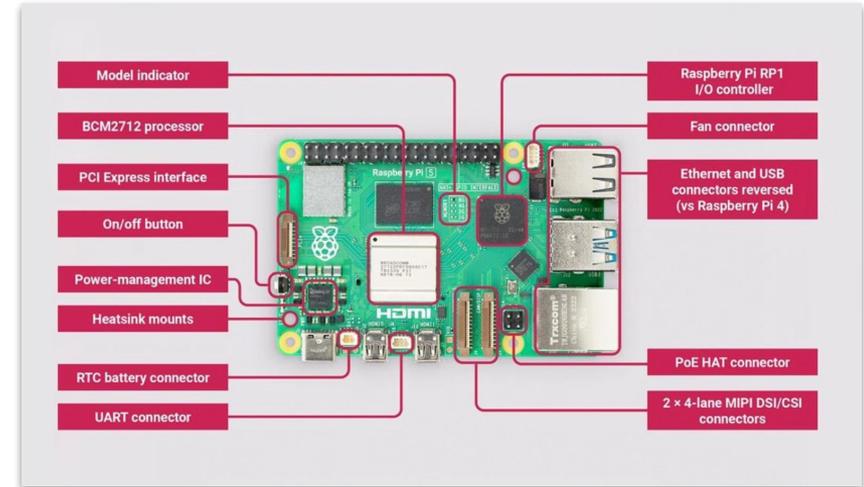


Figure 12: Raspberry Pi 5 Board [6].

# Component Verification Testing

## LED Testing

*Goal:* Verify that the LEDs activate at the correct times to accurately reflect the system's current state

*Process:*

1. Induce tight, loose, and processing model inputs
2. Identify LED reflects model's decision

## Button Testing

*Goal:* Confirm that pressing the button triggers the camera to capture an image

*Process:*

1. Click button 25 times
2. After each click, check that a picture is taken

## Camera Focus Testing

*Goal:* Explore camera focus behavior to ensure sharp images for ML accuracy

*Process:*

1. Establish focus ranges
2. Take an image at consistent distances
3. Evaluate sharpness using Laplacian filter

# Full System Testing

## Field Testing:

*Goal:* Validate the system fits and operates within the space constraints of the lab

### *Process:*

1. Place Pi system into the lab space
2. Confirm the system is securely mounted
3. Check camera FOV and lighting
4. Ensure appropriate power source

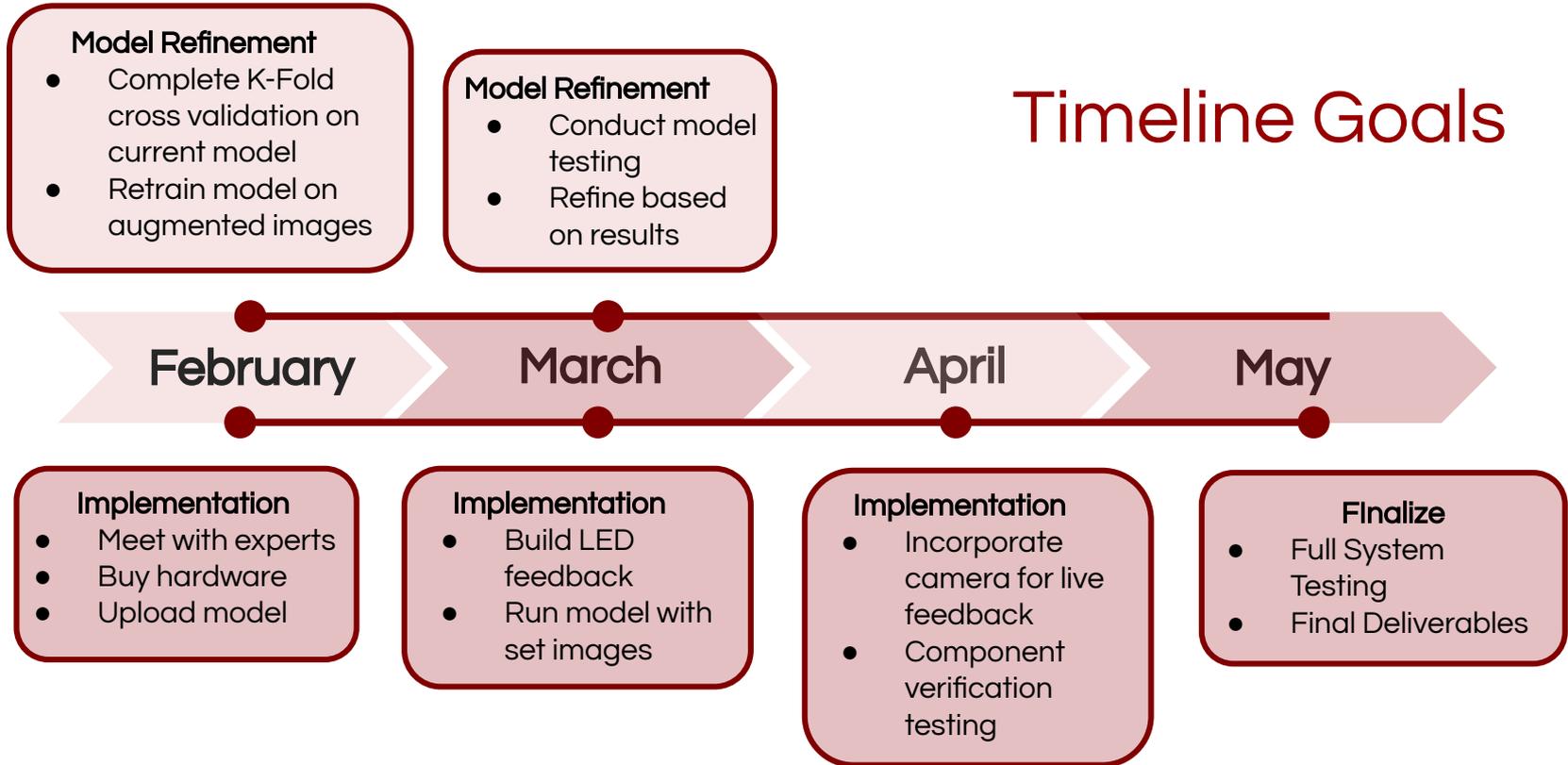
## Latency Testing:

*Goal:* Measure the latency of the system from button → ML output.

### *Process:*

1. Press the button on the fully assembled system and start timer
2. Wait for LED output to stop the timer
3. Obtain a running time under 3 seconds

# Timeline Goals



# Acknowledgements

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Dr. Wally Block



## Clients

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# Questions?

