Knot too Tight, Knot too Loose

The Knotorious Five

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Getting up to Speed

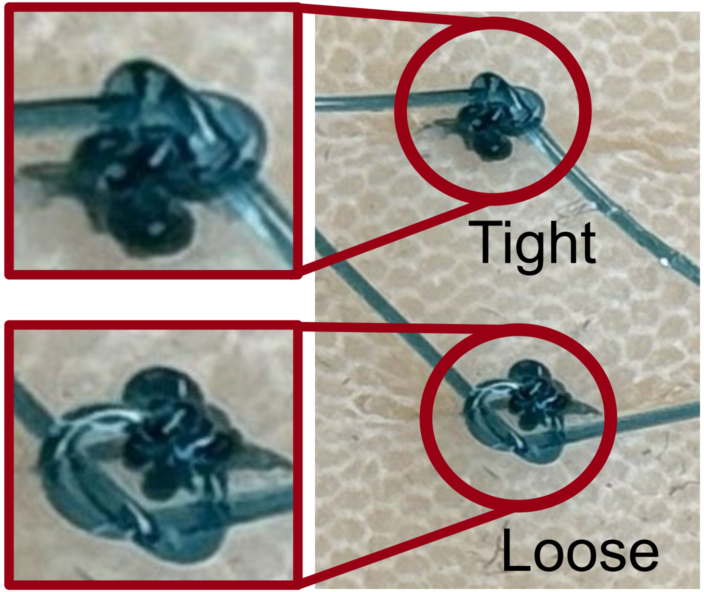


Figure 1: Comparison of tight and loose square knots.

- **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 ≥ 80% [1]
  - F1-Score ≥ 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 Refined → Model Operates on Pi with Set Images → Pi Displays User Feedback (LED) → Pi Camera Captures Images → Pi Combines Camera, Model, and Feedback

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

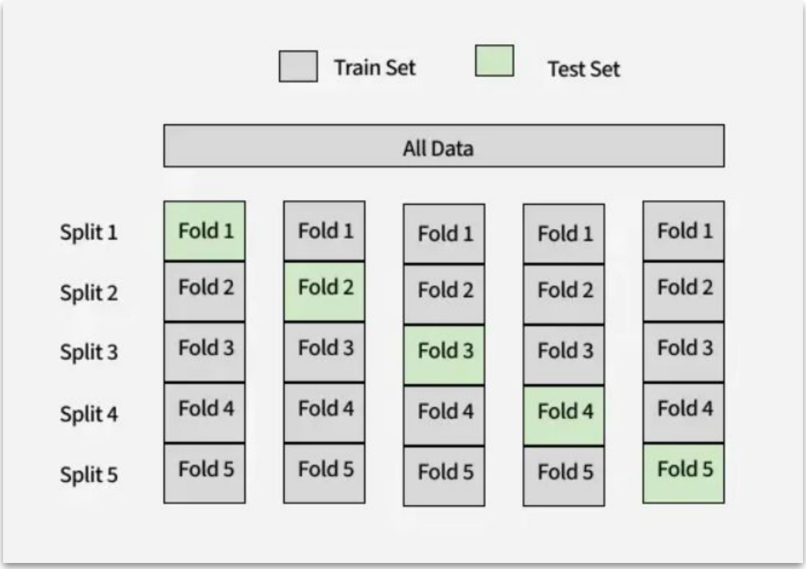


Figure 2: K-fold cross validation schematic [2].

Image Augmentation

Preprocessed Images

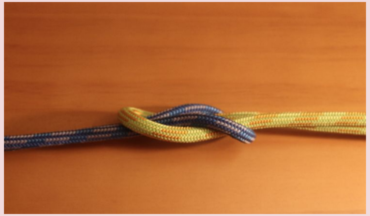
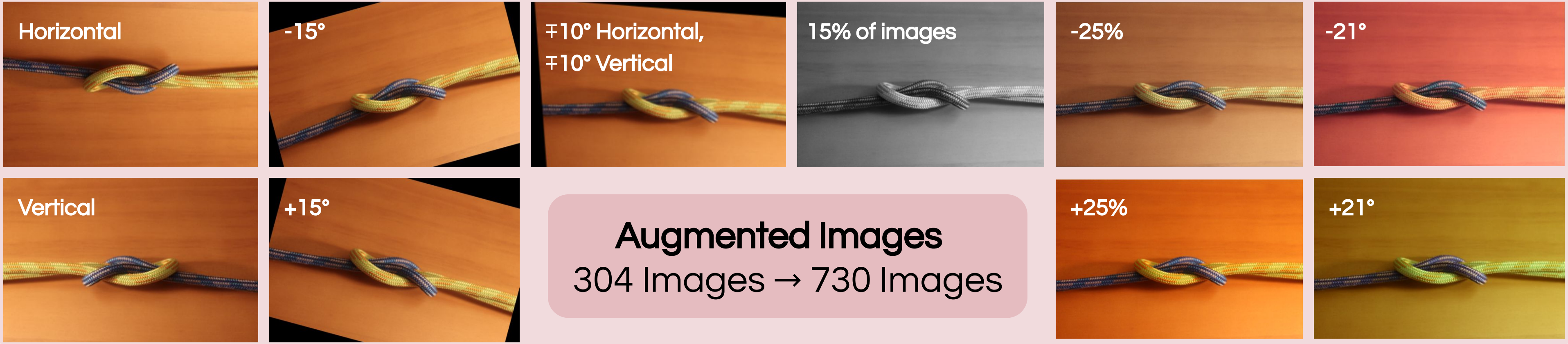


Figure 3: Augmented images of a knot [3].

Flip	Rotation	Shear	Grayscale	Saturation	Hue



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

1. User Initiates System via Tactile Button
2. Camera Captures a Picture of the Knot
3. Model Processes Image
4. Output of Model Displayed to User via LED
5. Image Deleted

Green for tight knot
Red for loose knot

Hardware

Micro SD card

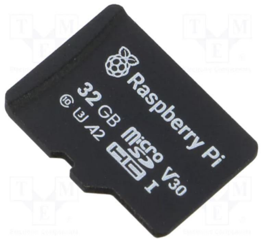
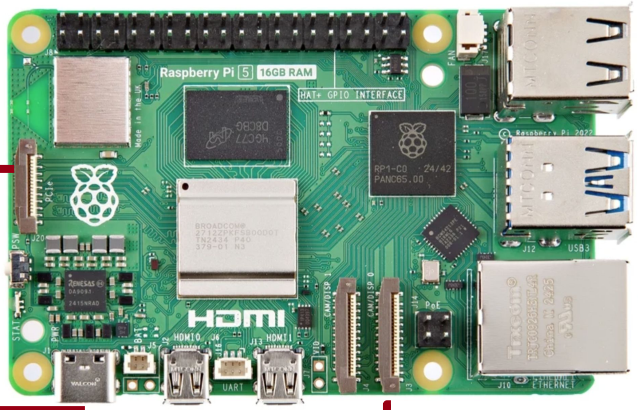


Figure 4: SD card for storage (32G) [4].

USB-C Power Supply

Figure 5: 27W Power Supply [5].

Raspberry Pi 5



Micro HDMI to HDMI cord

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

Active Cooler

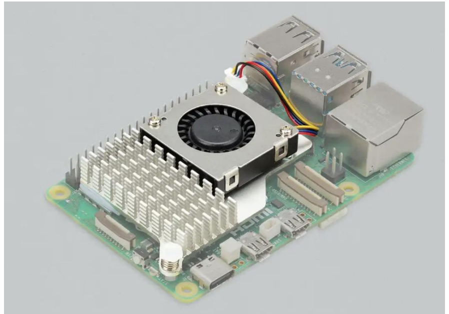


Figure 9: Fan for Raspberry Pi [8].

Camera

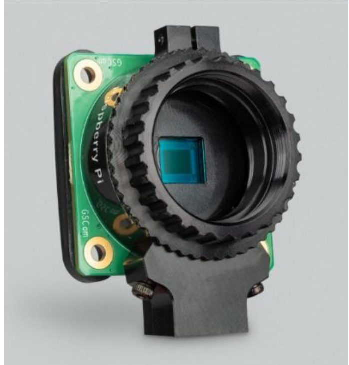


Figure 8: HQ camera [7].

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

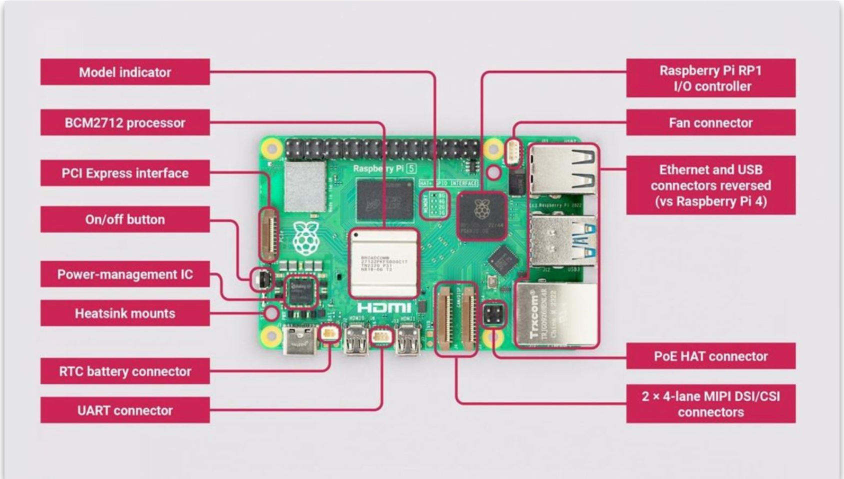


Figure 12: Raspberry Pi 5 Board [6].

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. Enable power system from location

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

Timeline Goals

February

Model Refinement
- Complete K-Fold cross validation on current model
- Retrain model on augmented images

Implementation
- Meet with experts
- Buy hardware
- Upload model

March

Model Refinement
- Conduct model testing
- Refine based on results

Implementation
- Build LED feedback
- Run model with set images

April

Implementation
- Incorporate camera for live feedback
- Component verification testing

May

FInalize
- Full System Testing
- Final Deliverables

Acknowledgements

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Questions?