

# TRAINED CLASSIFICATION OF SURFACES VIA IMU-DRIVEN TACTILE SENSATION



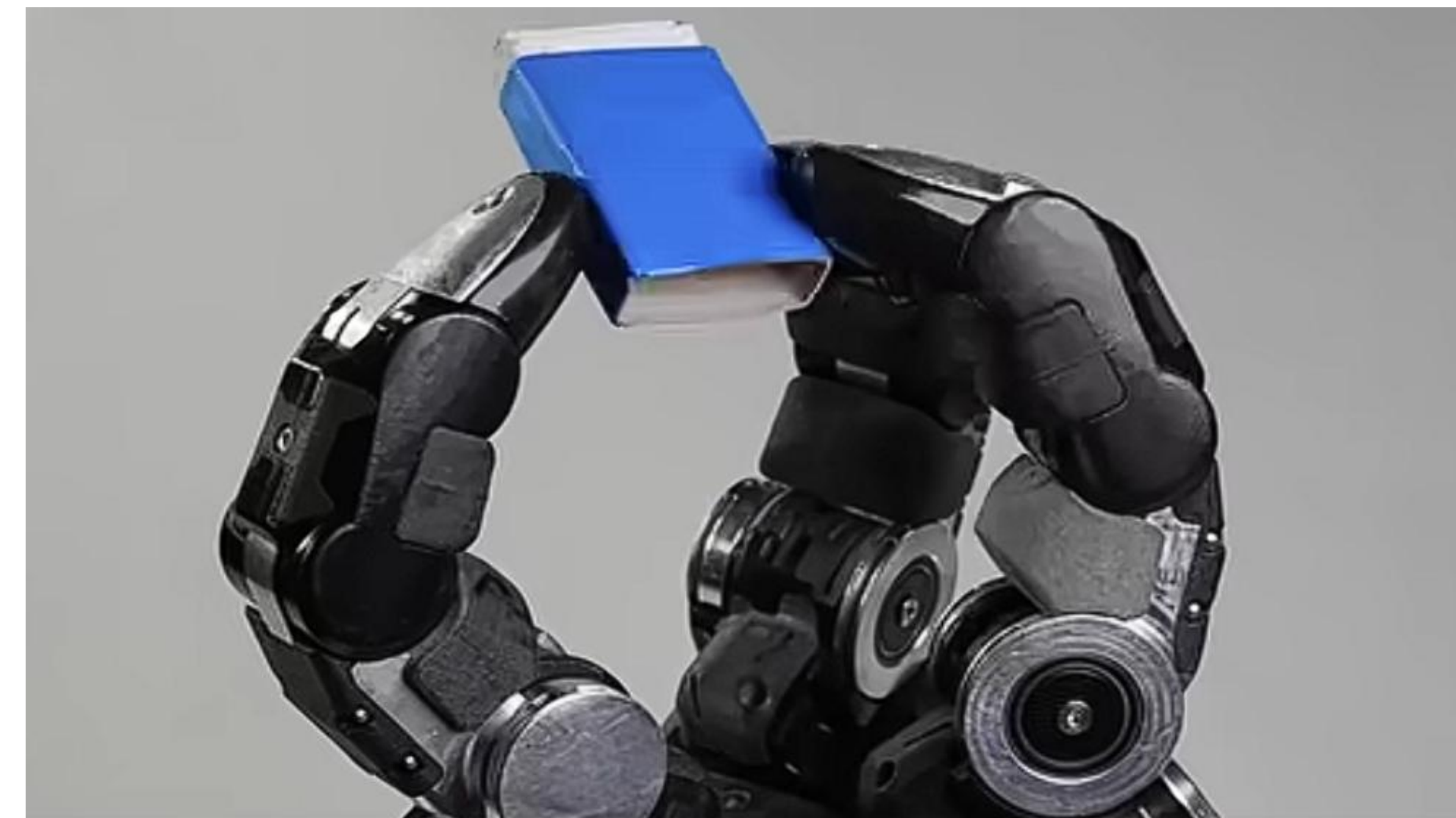
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## BACKGROUND, MOTIVATION, GOALS

Dexterity is a major challenge for modern robotics. Current robot hands can pick up a cup, but none of them can button a shirt. Some robotic systems rely on computer vision only, but viable robotic hands will most likely need tactile sensors to help them touch and understand the detailed geometries of the objects they interact with.

There is no current consensus on the ideal sensation approach.

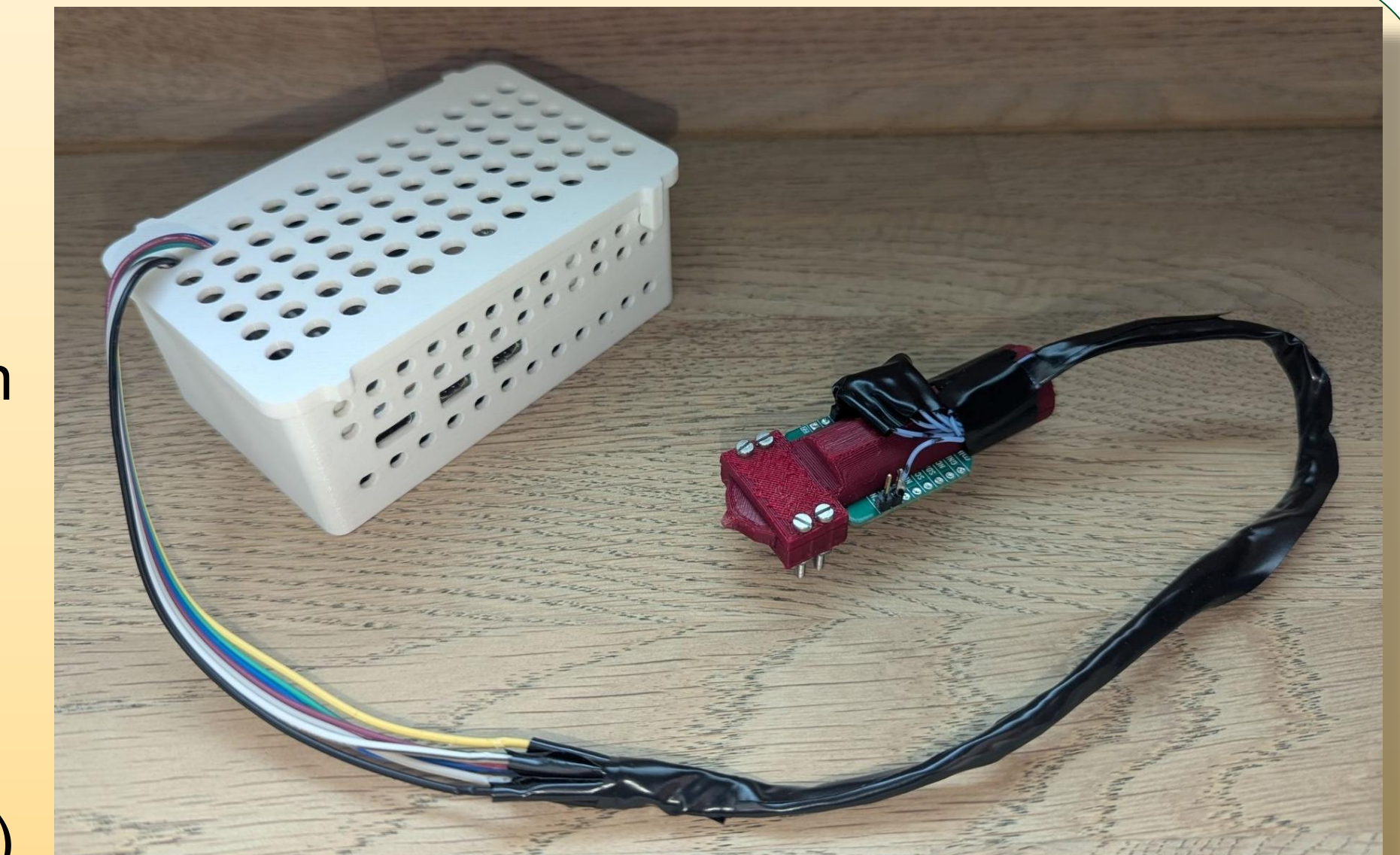
This project is to explore the usefulness of inertial measurement units (IMUs) (also known as accelerometers) to probe and correctly identify various surfaces.



The DEX-EE robotic hand by Shadow Robot uses many high-quality tactile optical sensors to understand object geometry.

## DATA COLLECTION

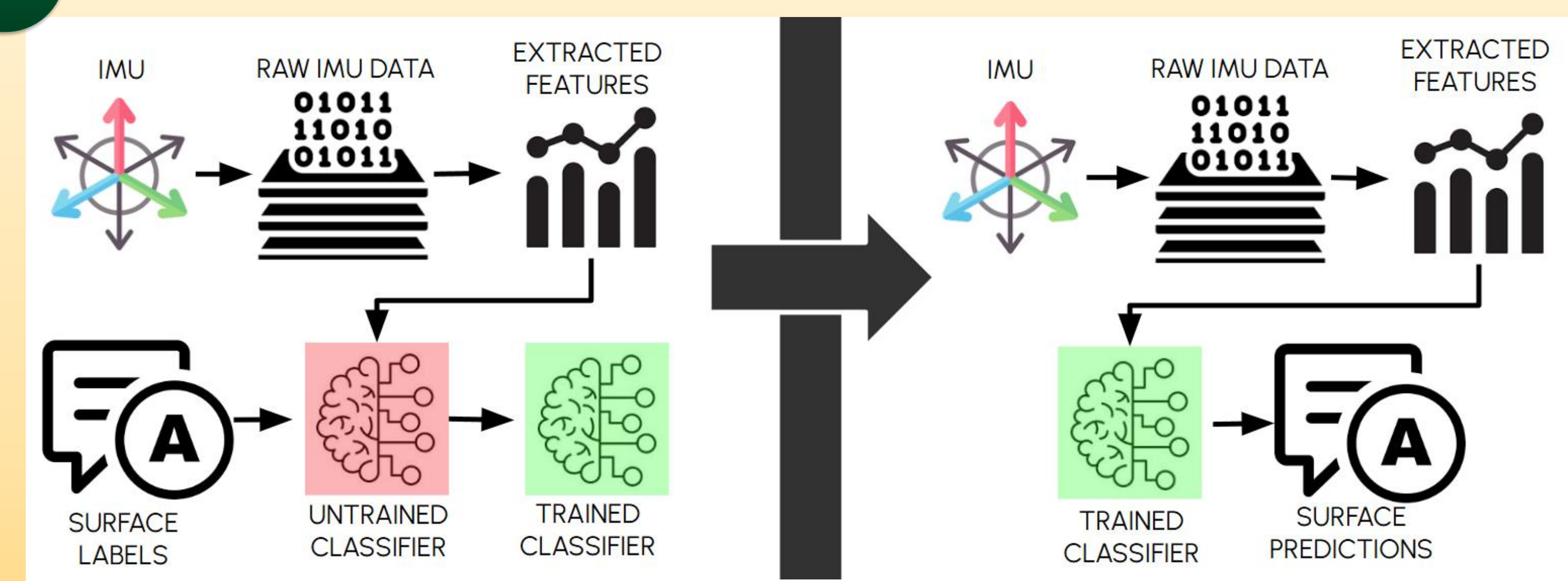
- An "ICM-42688-P" IMU is rigidly attached to a sharp sensing tip.
- The sharp tip allows the IMU to collect information about the small crevices of rougher surfaces.
- A Raspberry Pi 5 runs a program that communicates with the IMU and collects six channels of IMU data (Acceleration in three directions and rotational speed about 3 directions).
- The data is stored as csv files and can be downloaded to a PC.



The recording setup that consists of a Raspberry Pi 5 connected to an IMU enclosed in a chassis.

## CLASSIFICATION TRAINING PROCESS

- The IMU produces a signal as the sensor is dragged across a surface, recording implicit information about the roughness, hardness, and frictional qualities of the material.
- The data is processed to extract statistical features, selecting the most useful features to be used for training.
- A dataset of extracted features, manually labeled with surface types, is recorded and then used to train a variety of MATLAB classification models.
- New, unlabeled IMU data is then passed to one of these classifiers, which can now automatically predict the surface.



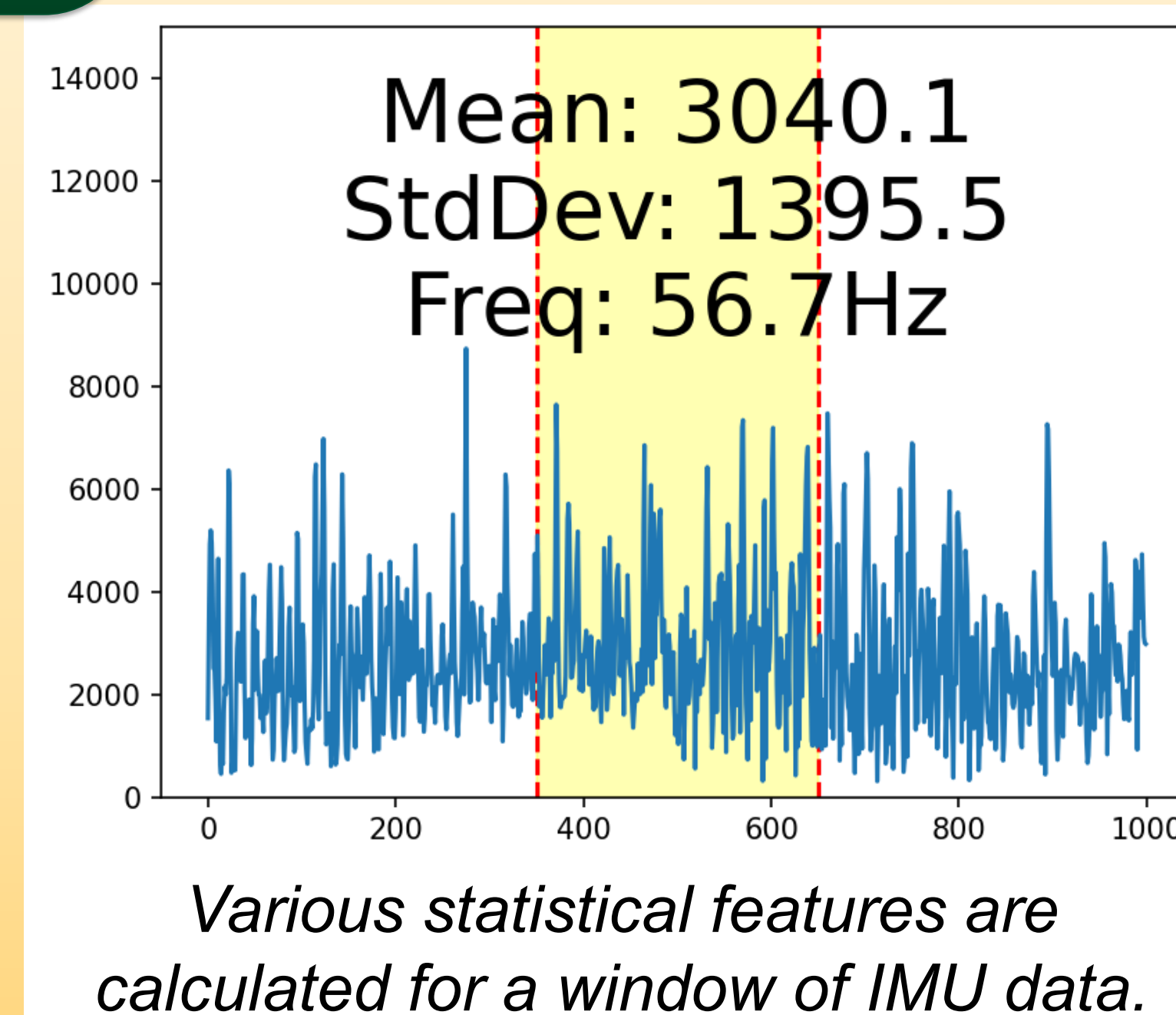
Data paired with labels can train a classifier (Left).  
A trained classifier paired with unlabeled data can produce a prediction (Right).

## CROSS-VALIDATION & TESTING SETS

- Classification models are prone to overfitting, a problem where trained models have learned by rote memorization rather than pattern comprehension. As a result, they cannot accurately make predictions on new data. To protect against this, cross validation and testing set separation are used.
- Cross-validation splits the training process into multiple sessions, evaluating the progress of each against its peers rather than against itself.
- Testing set separation moves a percentage of the dataset into a testing set (we use 20%). The testing set is used to evaluate the accuracy of the final classification model and provides a more unbiased insight into a model's performance.

## FEATURE EXTRACTION

- Before data can be fed to a classifier, quantitative features of the signal need to be extracted to allow for any predictive accuracy.
- The raw waveforms are first divided into small windows and then statistical features (mean, standard deviation, max frequency) are calculated for each one.



## RESULTS

Data was collected on 120-grit and 40-grit sandpaper. 7 models were trained. Cross-validation and testing set accuracies were recorded.

Model Type	Cross-validation	Testing Set
CubicSVM	92.3%	95.6%
WideNN	90.5%	93.7%
MediumNN	89.7%	93.4%
SVM Kernel	89.8%	93.4%
BaggedTrees	88.9%	92.3%
QuadraticSVM	91.7%	92.3%
MediumGaussianSVM	88.8%	91.9%

## DISCUSSION & FUTURE WORK

- Cross-validation accuracy correlates with how distinct the data of the different surfaces are from each other.
- A low cross-validation accuracy implies a dataset with unclassifiable data.
- Testing set accuracy correlates with how well the trained model performs on new data.
- Our results show that an IMU can distinguish between basic roughness properties of surfaces.
- Future work could involve experimenting with an increased amount of IMU sensors in varying configurations as this could lead to more latent surface characteristics being collected.