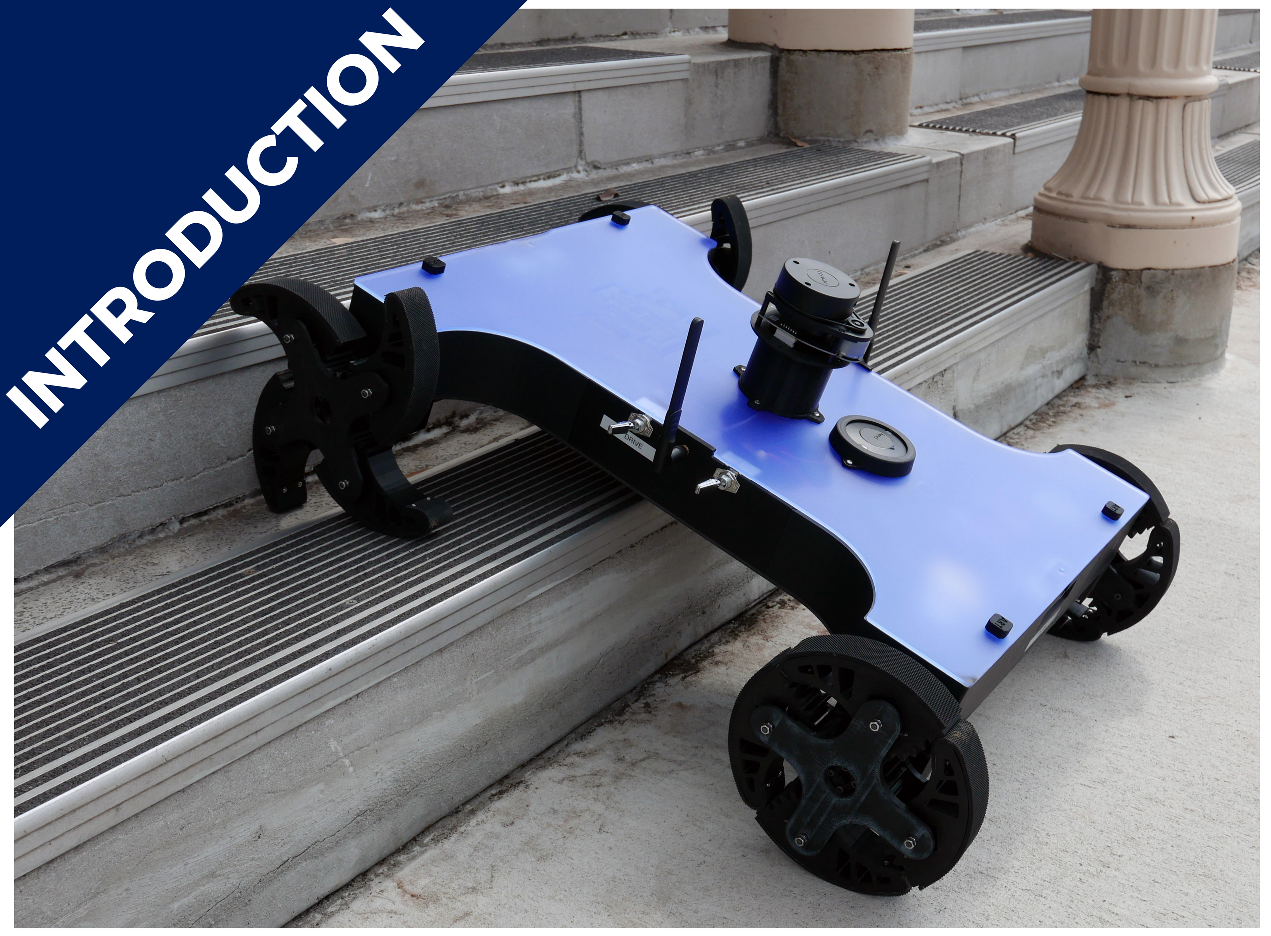


a-WaLTR: Adaptive Wheel-and-Leg Transformable Robot

a-WaLTR *is a new ground mobile platform developed for* ***stair climbing*** *and versatile multi-terrain locomotion. It is equipped with passive transformable wheels that can dynamically adapt to different terrain conditions.*

INTRODUCTION

Robots capable of traversing flights of stairs play an important role in both indoor and outdoor applications. We present a vision-based ascending stair detection algorithm using RGB-Depth (RGB-D) data based on an interpretable model.

TWO DATASETS

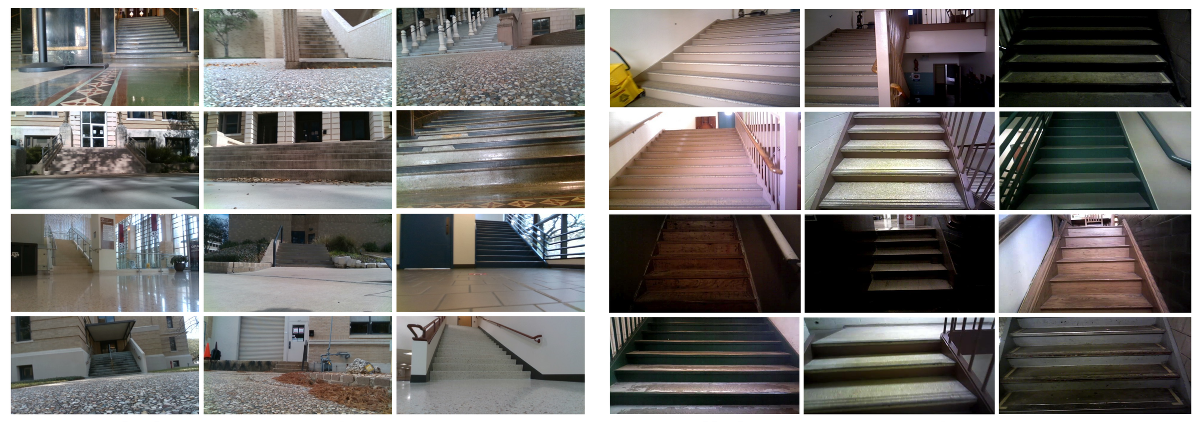


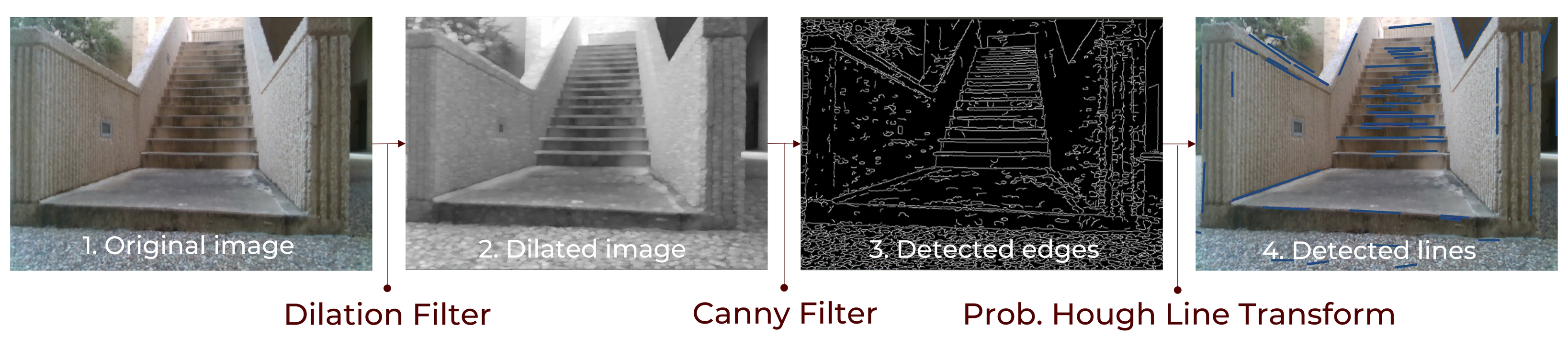
Figure. *Two datasets: (a) Texas A&M University (TAMU) dataset from a low viewpoint with diverse distances and angles; and (b) an existing public dataset (the Munoz dataset) mostly taken from a frontal angle at a higher viewpoint (about human height).*

Vision-based Ascending Staircase Detection with **Interpretable Classification Model** for Stair Climbing Robots

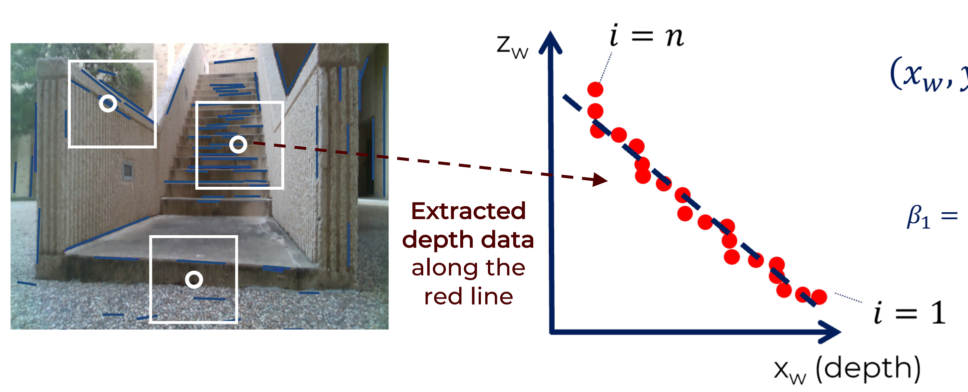
ALGORITHM

STAIR DETECTION ALGORITHM

1. RGB image preprocessing



2. Defining regions of interests (ROIs)



$$(x_w, y_w, z_w) = \left(d,\ \frac{n_{col}-p_{col}}{F}d,\ -\frac{n_{row}-p_{row}}{F}d\right)$$

$$\boldsymbol{\beta} = \sum_{i=1}^{n}[z_w^i - (a + \boldsymbol{m}x_w^i)]^2$$

$$\beta_1 = \sum_{i=1}^{n/2}[z_w^i - (a_1 + m_1 x_w^i)]^2;\quad \beta_2 = \sum_{i=n/2+1}^{n}[z_w^i - (a + m x_w^i)]^2$$

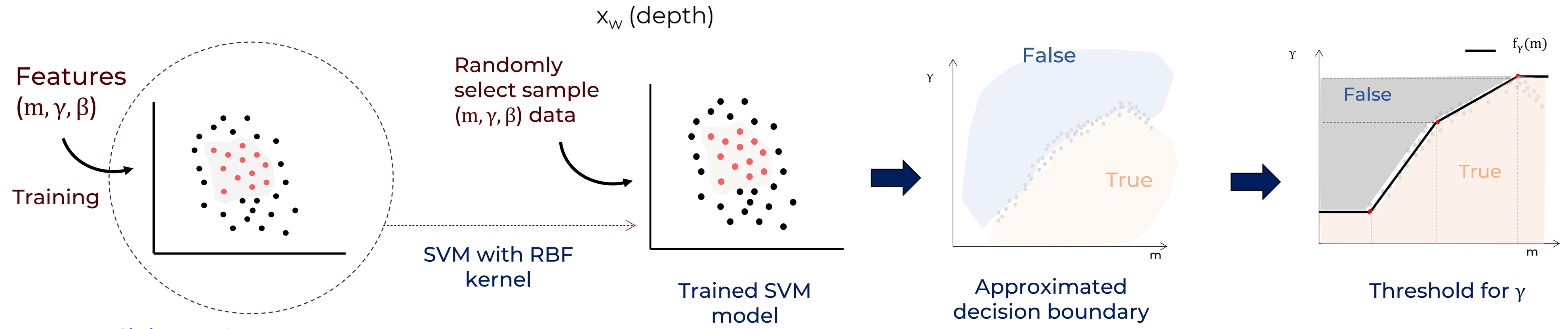
$$\boldsymbol{\gamma} = |m_1 - m_2|$$

d : depth, n_{col} : column index, p_{col} : optical center of columns, n_{row} : row index, p_{row} : optical center of rows, F : focal length

Three input features for Support Vector Machine (**SVM**):

1. **m**: Estimated gradient
2. **β**: Deviation cost
3. **γ** : Continuity factor

3. Building the interpretable model

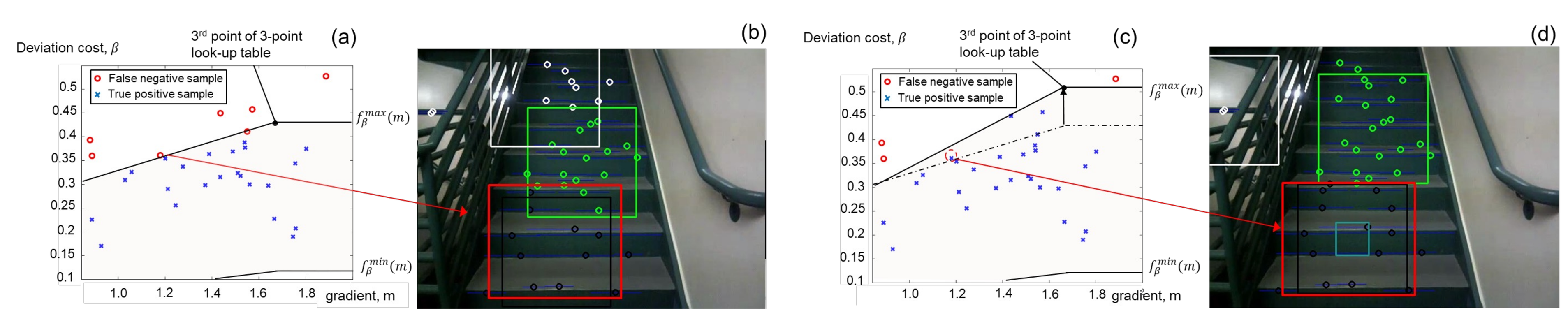


→ Condition 1 for true class : $\gamma < f_\gamma(m)$

→ Condition 2 for true class : $f_\beta^{min}(m) < \beta < f_\beta^{max}(m)$ (Same procedure described above for β)

→ Condition 3 for true class : $m^{min} < m < m^{max}$ *m^{min}: minimum value of m in true class, m^{max}: maximum value of m in true class*

4. Boundary shifting



EVALUATION

PERFORMANCE ON STAIR DETECTION

Table 1.	Trained and tested w/ TAMU dataset		
Algorithm	Sensitivity	Specificity	Accuracy
1) YOLOv3	65%	94%	77%
2) SVM-Munoz	47%	85%	62%
3) Interpretable model	85%	94%	89%

Table 2.	Trained w/ TAMU dataset & Tested w/ Munoz dataset		
Algorithm	Sensitivity	Specificity	Accuracy
1) YOLOv3	60%	92%	74%
2) SVM-Munoz	91%	60%	79%
3) Interpretable model	80%	90%	84%

**The result from "Decision boundary shifting" without retraining.*

Table 3.	Trained and tested w/ Munoz dataset		
Algorithm	Sensitivity	Specificity	Accuracy
1) YOLOv3	60%	92%	74%
2) SVM-Munoz	95%	93%	94%
3) Interpretable model*	90%	96%	93%

Table 1-3. *Stair detection performance of the presented algorithm in comparisons with two other existing algorithms.*

- The interpretable model outperformed the other two methods when trained by the TAMU dataset and tested using the TAMU and Munoz test data (**Table 1** and **Table 2**)
- Performance of the TAMU-trained interpretable model after efficient boundary shifting was comparable with the SVM-based method trained and tested using the Munoz dataset (**Table 3**)

ALGORITHM IMPLEMENTATION IN a-WaLTR

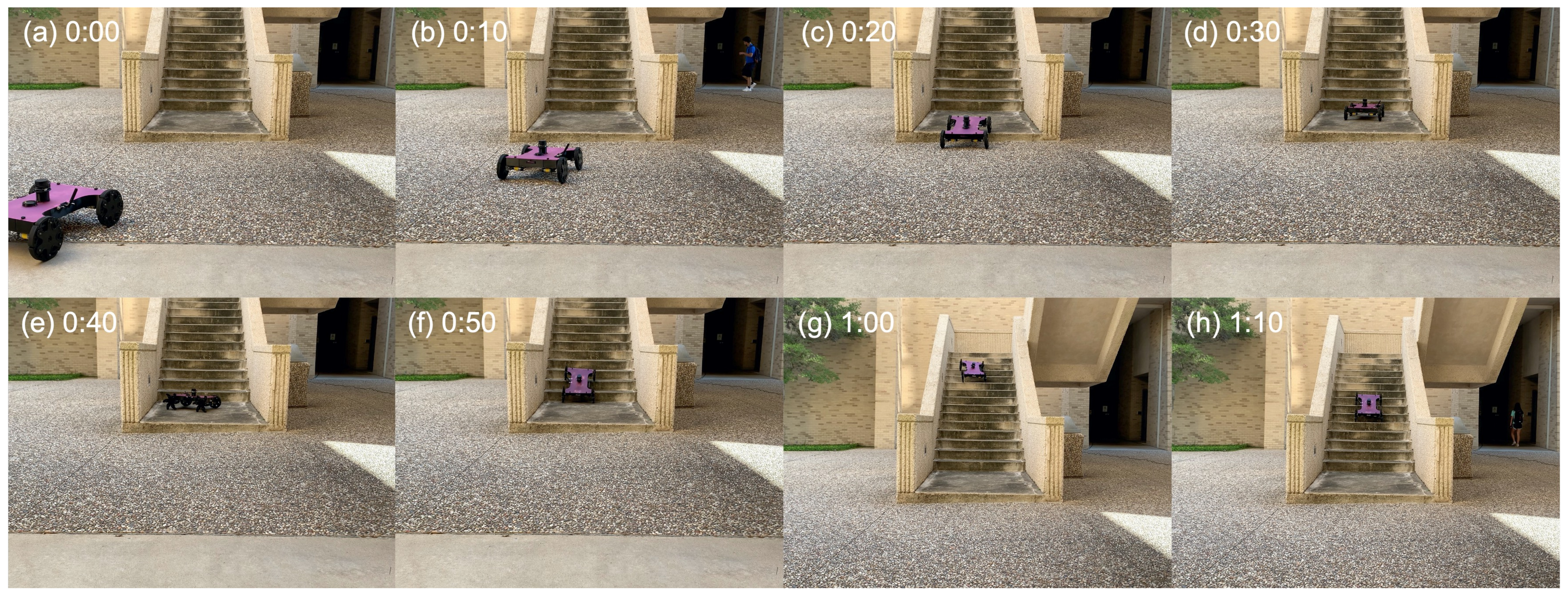


Figure. *Implementation of the integrated algorithms for stair detection followed by autonomous climbing*

CONCLUSION

DISCUSSION AND FUTURE WORK

- The interpretable model is well suitable for **embedded, deployable applications** considering its high efficiency and easy to adjust decision boundaries.
- Some limitations were observed in the RGB image preprocessing; **depth data** may be considered during this early stage for improving accurate ROI selections.
- Future work may include **online learning** strategies for stair detection.

AUTHORS

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