

## Motivation

- Measuring the teeth length of excavators is a manual process that involves stopping mining operations, which means losses in revenue.
- Automatic measurement could help find abnormal behaviours in teeth wear easier and faster.
- There is little work published on computer vision used in excavators, specially in monitoring teeth length.

## Data Acquisition

Data acquisition consisted in obtaining images from the arm of an excavator using a thermal camera of 320x256 pixels of resolution, as seen in fig. 1.



Figure 1: Installation of thermal camera in metal chassis in excavator

An object detection model was used to get the dimensions of the teeth from images, as in [2]. Model training consisted of these steps:

- Obtain images from videos, choose the images where multiple (more than 3) teeth are visible.
- 90/10 split of the dataset consisting of 700 labeled images.

## Video of datasets

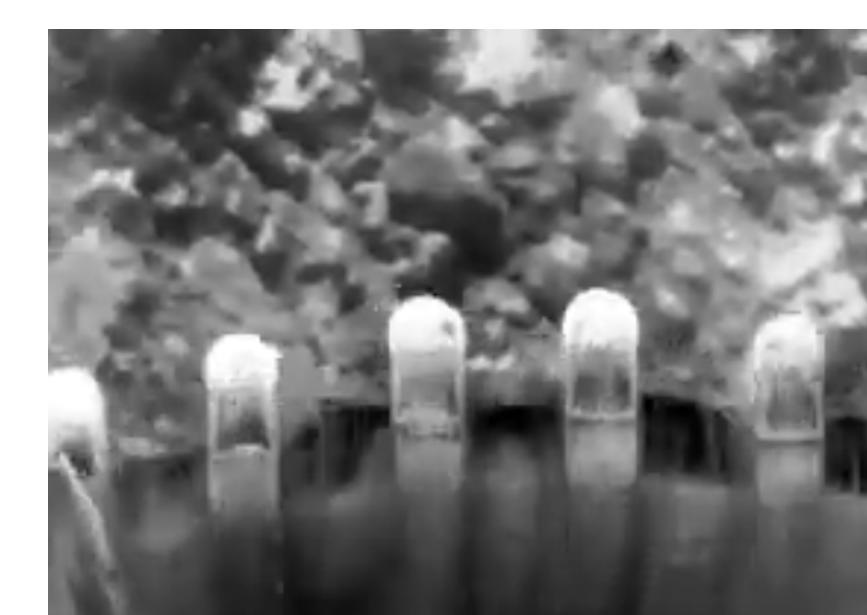


Figure 2: Camera view in the case of worn out teeth (left) and new teeth (right).

## Object Detection Results



Figure 3: Demo of the model.

The trained model was tested with images unrelated to the dataset used for training, using a tool [1] to calculate the mAP. The mAP was measured for 150 images, resulting in 87% mAP.

## Data Processing

Wide range of teeth length data is obtained, as shown in fig. 4. Holt's Exponential smoothing filter was applied to obtain a constant measurement.

## Measurements

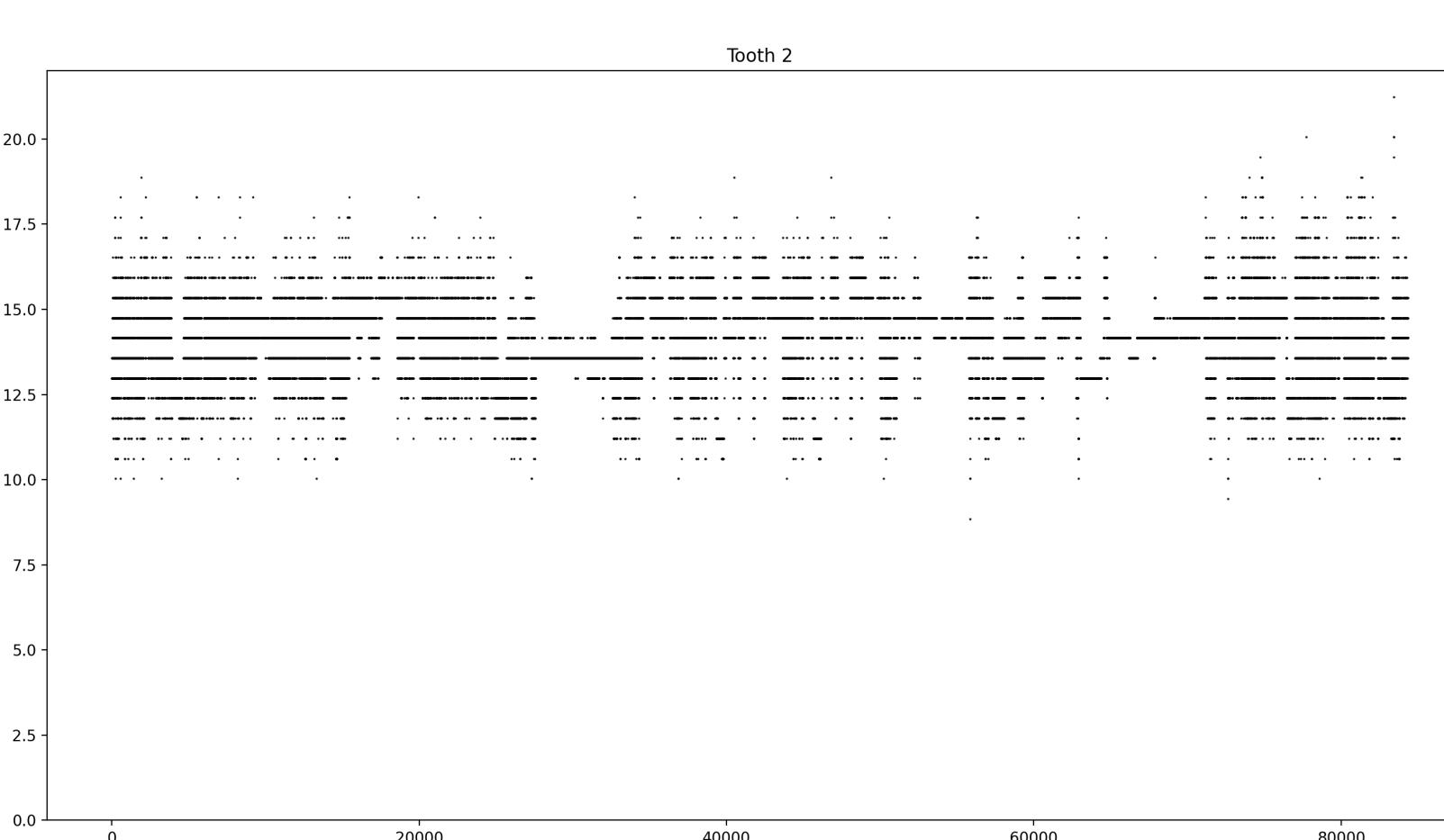


Figure 4: Spread plot of raw measured heights of the detection boxes for tooth 2 during an entire day.

A vast variance in the data obtained can be seen in fig. 4. For this reason we apply Holt's smoothing filter to the data obtained, as well as to be able to tell the downwards trend of the data.

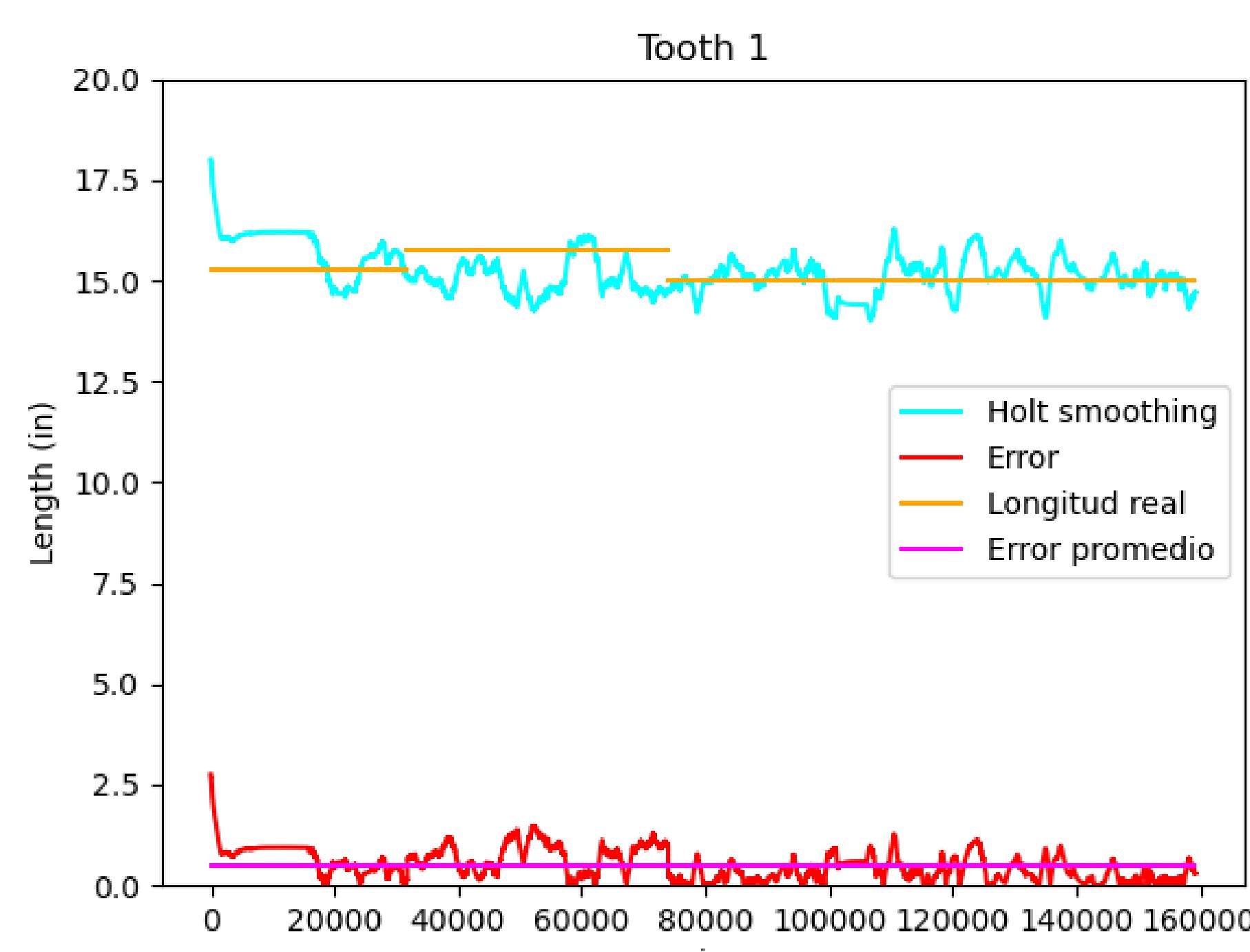


Figure 5: Measurements after applying Holt's Smoothing to raw data obtained from 2 days for tooth 2, against the real measurement given on the day, the average error is 0.5 inches.

According to the client, an error of  $\pm 2$  inches is acceptable, while an error within  $\pm 1$  inch is considered outstanding. The errors calculated for all teeth using Holt's filter are all within one inch of the real measurements counting both days.

## Conclusion & Future Work

- Using a tool [1] we measured the precision for our trained model, resulting in 87% mAP. The train/test split worked well, resulted in low overfitting.
- Holt's smoothing filter was easy to set up and it allowed for one continued feed, as well as to minimize up to  $\pm 1$  inches in error.
- 87% mAP in the object detection model was enough to achieve an accurate measurement, as shown in fig. 5.
- Further tests with different types of excavators and teeth would be necessary to verify if the method can be applicable to the general problem.
- Kalman filter approaches could also be applicable to this problem.

## References

- [1] Rafael Padilla, Wesley L. Passos, Thadeu L. B. Dias, Sergio L. Netto, and Eduardo A. B. da Silva. A comparative analysis of object detection metrics with a companion open-source toolkit. *Electronics*, 10(3), 2021.
- [2] Hooman Shariati, Anuar Yeraliyev, Burhan Terai, Shahram Tafazoli, and Mahdi Ramezani. Towards autonomous mining via intelligent excavators. In *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition Workshops*, pages 26–32, 2019.