Problem definition

Climbing is a sport that is growing in popularity. Route difficulty ratings are often highly subjective, varying drastically in indoor settings between different gyms and even between setters within the same gym. This variability in grading leads to confusion amongst climbers when trying to do a new route, especially beginners who are not yet confident in their skills.

Bouldering routes in the US are typically graded using the V-scale, which uses V0 for the easiest climbs, and increases to V1, V2, V3 ….

For this project, I will develop a machine learning model that will identify holds and routes in an indoor climbing gym. Using the identified routes, it will classify the routes based on grade.

Data

I will use the dataset "Indoor Climbing Gym Hold and Route Segmentation" on Kaggle created by Göldner, Kisin, and Sláma. This dataset consists of around 2000 images, some of which are labeled. In the paper that originally used this dataset, they only used 30 images for training and test data to do route segmentation and achieved an accuracy of 81.74% [1], leading me to believe that the task I want to do can be done with a relatively small amount of data. I will supplement the data in the Kaggle dataset with approximately 15 images that I will take from local climbing gyms and label by hand. Due to the color contrast between the holds and the wall (holds are usually brightly colored and walls are usually neutral colors like white, grey, and black), this can be done relatively quickly in CVAT using the Segment Anything 2.0 interactor. Having tested this labeling method, I believe it will take no longer than 10 minutes to label each image.

To evaluate performance of the route segmentation, I will either calculate the percentage of routes that are complete or calculate the percentage of holds that are in the correct route.

To evaluate performance of the grade classification, I will weight each of the classifications on how close they are to the actual grade.

Approach

To segment the holds, I will use a mask R-CNN to identify the objects. Climbing holds are very distinct from the wall, so I believe that it will be possible to get a very high accuracy using this method.

To segment the routes, I will use a triplet model to find similarities between the colors of different holds. Routes are comprised of several holds (usually between 10-20) of the same color. In the route segmentation method described by Göldner, Kisin, and Sláma in "Indoor Climbing Hold and Route Segmentation", they used both a Siamese network and a triplet network to do route segmentation [1]. Their results showed a much higher accuracy using the triplet network than the Siamese network (81.74% vs. 66.95%), which is why I will try to implement the triplet network. I will use triplet loss, which uses both a positive and a negative example to learn which direction to move. The output of this step will be an image containing only a single route.

To classify the grade of the route, I will use a CNN using cross entropy loss. This neural network will use the images of routes from the first part of the project labeled with route difficulty as training data and attempt to predict the grades of other routes that have been segmented but not labeled with a grade.

Risks

The biggest challenge for this project is that the grade classification is highly dependent on the performance of the route segmentation. If the route segmentation does not work or is not accurate, it will be very difficult to move forward with grade classification. Additional challenges are with the quality of the data. There are different lighting conditions that appear in the data, as well as different angles and image qualities. Another challenge is that there is already variability in the grading of routes, so defining accuracy of the classification based on the labeled grade is not necessarily correct. However, this is part of the problem that I'm interested in looking into, so I think it will be very valuable to see how the prediction differs from the actual grade.

References

[1] Philipp Göldner, Kiryl Kisin, Tomáš Sláma, "Indoor Climbing Hold and Route Segmentation", Accessed: Nov. 08, 2024. [Online].