Constellation Detection

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1. Introduction

The International Astronomical Union (IAU) defines a constellation not merely as a pattern or group of stars, but as a specific region of the sky bounded by officially recognized borders. These borders ensure that every point in the sky belongs to one, and only one, constellation. Within these defined regions, constellations are often recognized by groupings of prominent stars that form distinct patterns or figures. In total, there are 88 officially recognized constellations, each with its own unique history, mythology, and significance.

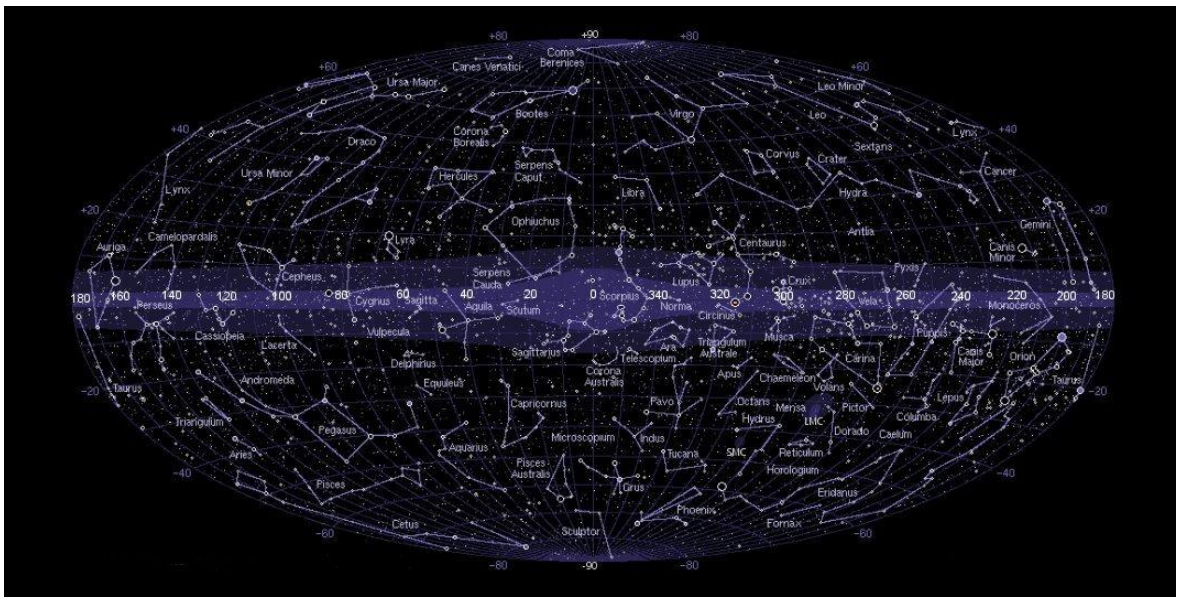


Figure 1. IAU 88 constellations

With modern smartphones providing accurate altitude, latitude, date, and time information, numerous apps have been developed to identify stars and the 88 constellations in the sky. However, without these specific spatial and temporal data, discerning constellations from a starry expanse or a digital image remains a challenge, even for seasoned stargazers. Our goal is to recognize the constellation from an image without any location and date/time information. It will give tremendous help to anyone who is fascinated in the starry night, astronomers, star gazers and photographers alike.

2. Challenges

By merely examining images, numerous challenges can arise in accurately identifying the correct constellations. Several factors contributing to these complications include:

a. The presence of a brighter star outside the constellation's defined boundary, which can mislead the observer.

b. Obscuration of a pivotal star within a constellation due to atmospheric conditions or physical obstructions like trees.

c. Interference from extraneous light sources, such as city lights or passing aircraft.

d. The image may capture fragments of various constellations or encompass multiple entire constellations."

3. Methods

Our constellation detection algorithm comprised three critical steps:

3.1. Template Database Creation

Our primary templates were sourced from a constellation image gallery [1]. We will include most of the 88 constellations, especially the 30 most significant and conspicuous constellations in the night sky [2]. Different image processing techniques are applied, relying on a pre-existing set of altered constellation charts[3].

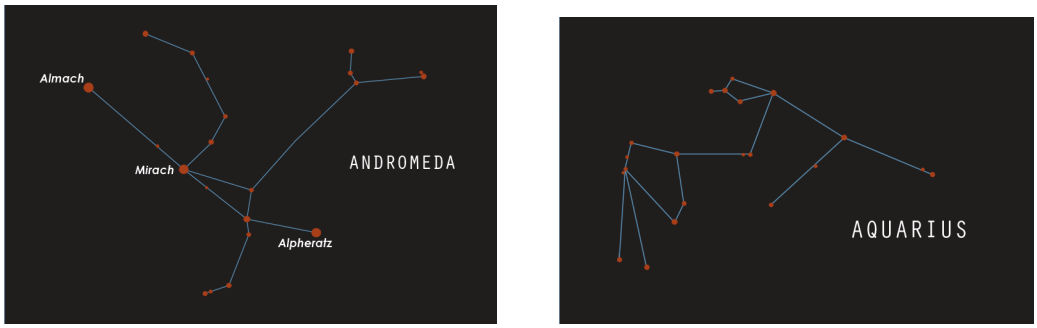


Figure 2. Example of constellations

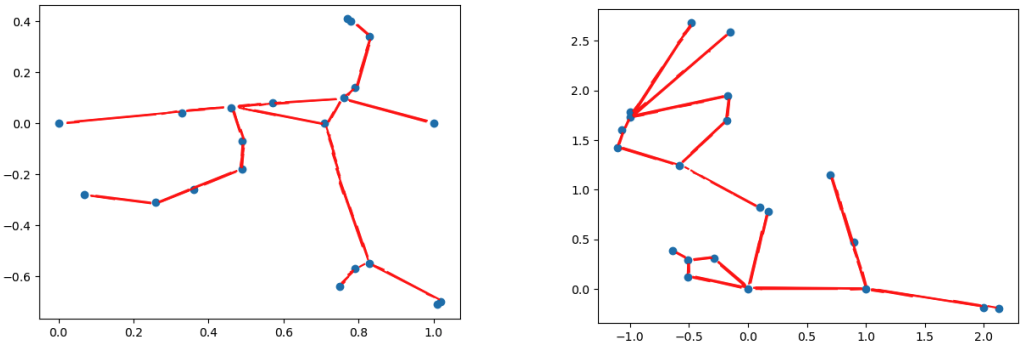
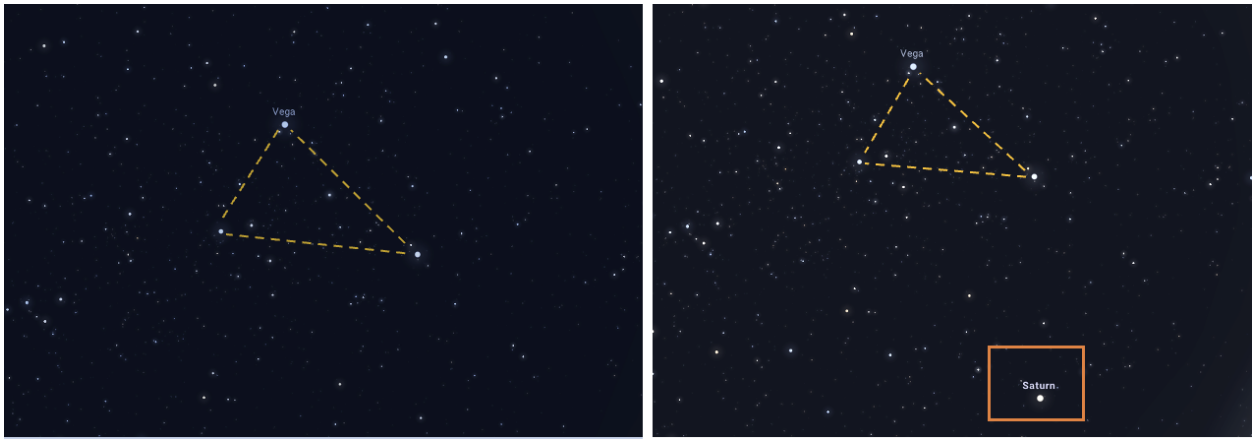


Figure 3. Example of possible way of constructing template based on the brightest star at (0,0) and the 2nd brightest star at (1, 0)

3.2. Processing of Test Images

Test images were acquired from a night sky observation application [4]. Images under different challenge conditions as described in part 2 are also incorporated in our database system. These templates were then refined using various image processing techniques (grayscale, threshold, median filter, FFT filter) to produce the template database vital for our detection algorithm.

- https://stellarium-web.org/



(a) Without brighter star(Saturn) **(b) With the brighter star(Saturn)**

Figure 4. Summer triangle from stellarium app

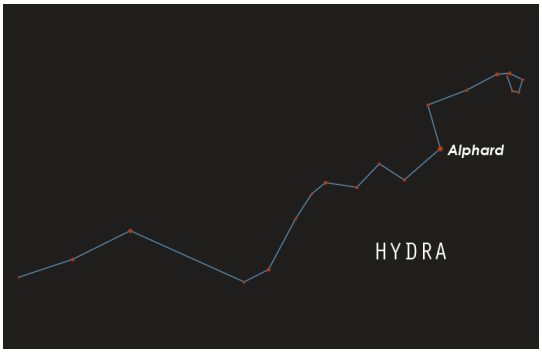
- Images from iPhone

Figure 5. Summer triangle by iPhone
(We can include star images with a streetlight or under different weather conditions)

3.3. Development of the Detection Algorithm

a. The Principal Component Analysis (PCA) method are chosen to be applied to the normalized template and test images to extract the main features. Most of the 88 constellations are linear, but some of them contains

nonlinear features, like HYDRA. We would like to see what will happen if we project the data to a high dimensional space.



b. Compare the similarity of a constellation in the template to the test image, compare the coordinates in the template to the coordinates in the test image or calculate distance of a star in template to the nearest coordinate in the test image.

4. Machine Learning Model

There are multiple published papers using machine learning models to detect constellations. To assess the performance of our forthcoming detection algorithm, we have selected two kinds of deep learning models [5] for comparison. In the training and test image datasets, we identify stars with the top k brightness levels and extract their corresponding coordinates and areas. The input of CNN is the whole image of the night sky, while the MLP model utilizes both coordinates and areas.

a. CNN

The Convolutional Neural Network (CNN) is a standard model for image recognition that leverages linear algebra in its operations. To account for variations in the sizes of the original images, resizing and normalizing are essential. These preprocessings can involve utilizing the extracted star coordinates and areas to generate the necessary images with the same size.

- VGGnet
- ResNet
- GoogLeNet

b. MLP

Multilayer perceptron is a supervised learning model using the back propagation method during training. The major applications of MLP are pattern classification, recognition, prediction and approximation.

The researchers also used PointNet for constellation recognition[5]. But according to the related papers[6], this model is suitable for 3-d object classification and segmentation. Though constellations are 3-d constructions in theory, they are so far from us that they

can be treated as the 2-D patterns in the night sky images. So we will not consider this model in our project.

5. References

[1] The night sky – 88 constellations
http://astronomyonline.org/Observation/Constellations.asp?Cate=Obse%20rvation&SubCate=MP07&SubCate2=MP0801
[2] List of constellations by their area
https://en.wikipedia.org/wiki/IAU_designated_constellations_by_area
[3] Jiang, M., etc. "A Novel Star Pattern Recognition Algorithm For Star Sensor" Proceedings of the Sixth International Conference on Machine Learning and Cybernetics, 19-22 August 2007
[4] Stellarium, an online planetarium, Matthew Gates, Barry Gerdes. https://stellarium-web.org/
[5]Nadamoto, S., Mori, N. & Okada, M. Constellation identification method using point set data. *Artif Life Robotics* 28, 361–366 (2023). https://doi.org/10.1007/s10015-023-00860-4
[6] https://doi.org/10.48550/arXiv.1612.00593