

Due Date: 23:59 on Tuesday, 28 October 2025

Generalized Hough Transform with Scale and Rotation

In this assignment, you will get familiar with Generalized Hough Transform (GHT) for object detection. You will first obtain edge points from an image using a suitable edge detection method. Then, you will implement the Generalized Hough Transform to detect a given template object within a target image, taking into account both scale and rotation variations.

Edge Detection and Hough Transform

Edge Detection:

We can define edges as sudden changes of brightness values in the image pixels. These sudden level of transition determines how the candidate pixel groups have potential to construct an edge. Generally several different edge detection methods are utilized to extract horizontal, vertical, and diagonal edge information by constructing an edge map of an image. Edge detection is a critical process as most of the shape information is intrinsically encoded in edges.

Hough Transform:

Hough Transform is a voting method which was developed to solve these issues:

1. Detection of a potential line object with respect to the given points
2. Determining the count of the potential line objects
3. Assigning the given points to the one of the potential line objects detected.

Hough Transform proposes to save votes for each potential line on which each edge point exists and search for the lines obtained.

The *Generalized Hough Transform (GHT)* generalizes this idea to arbitrary shapes that do not have explicit parametric equations.

Instead of parameterizing a specific shape, GHT uses an R-table that maps local edge gradient directions to displacement vectors relative to a reference point (usually the object's center). During detection, edge points in the target image vote for potential reference point locations under various scale and rotation configurations. Peaks in this voting space correspond to likely object detections.

Dataset

You will be provided with 2 datasets. For each dataset you will be provided with:

- 1 template image
- Several scene images containing one or more instances of the template at different scales and rotations.

Each dataset includes template instances scaled by $1\times$, $1.5\times$, $2\times$, or $3\times$, and rotated by multiples of 15° . You do not need to use all of the images in the dataset, but you must analyze examples from both datasets to answer the questions in "What should you write in the report?" section.

You may use ready-made edge detection functions (such as Canny, Sobel, or Laplacian) to obtain the edge map. However, you **must implement the Generalized Hough Transform algorithm yourself**.

Download Links: daisy_dataset & fish_dataset

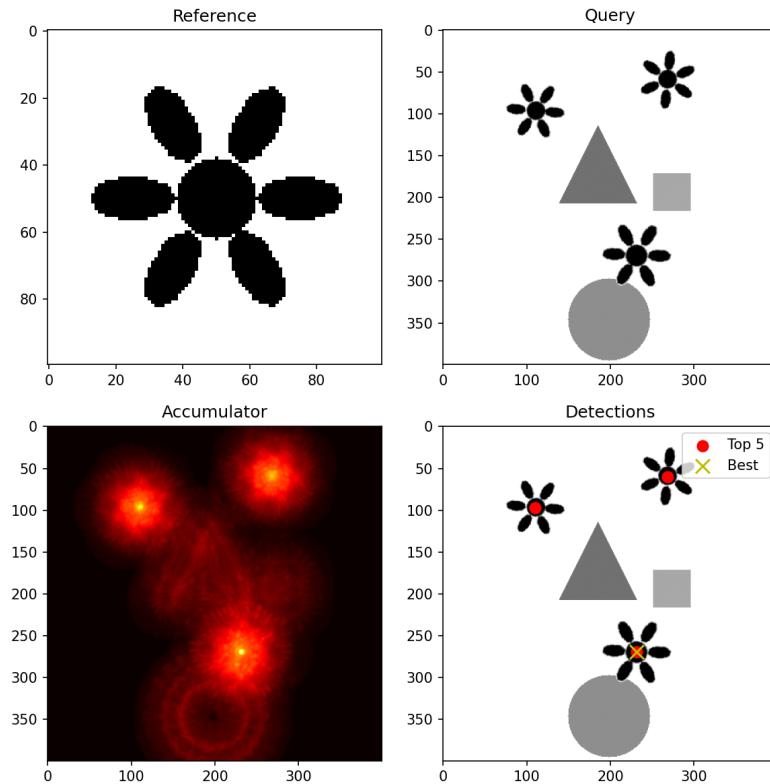


Figure 1: Example for daisy dataset and its annotations with GHT.

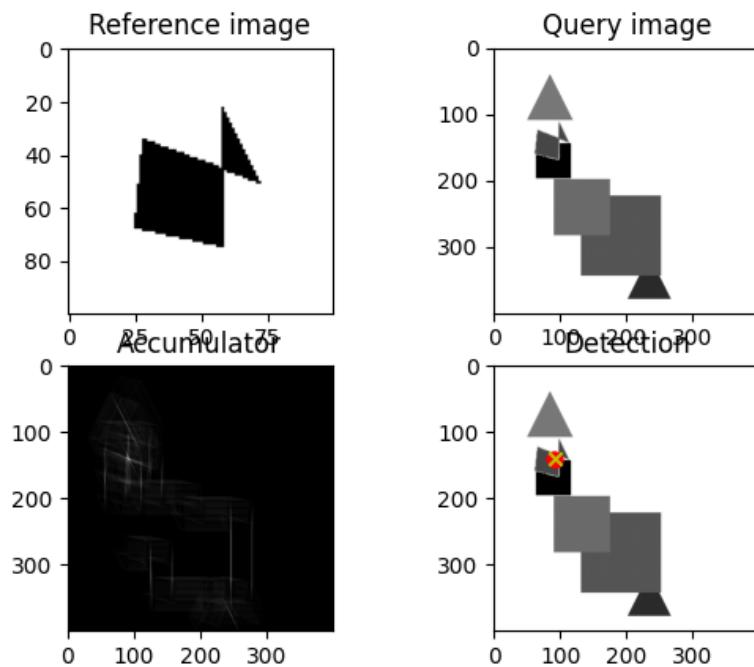


Figure 2: Example for fish dataset and its annotations with GHT.

Note: You do not need to follow the exact format of Figure 1 and Figure 2 as long as the necessary information is shown.

Implementation Details

Code Part

- Edge Detection

Use a suitable edge detection method to obtain an edge map of both the template and scene images. You may use OpenCV or similar libraries for this step.

- Generalized Hough Transform (GHT)

Implement the Generalized Hough Transform to detect the template within scene images under scale and rotation variations. The GHT search should only consider discrete scale and rotation values:

- **Scales:** 1.0, 1.5, 2.0 and 3.0

- **Rotations:** multiples of 15° (i.e., 0°, 15°, 30°, …, 345°)

You do not need to use continuous or random values. Your method should:

- Construct a representation of the template suitable for GHT.

- Perform a voting-based search in the parameter space (position, scale, rotation).

- Identify the location(s) with the highest vote values as detections.

- Detection Output

For each detected instance:

- Visualize detected template locations and centers on the scene image, i.e. draw the center point (e.g., with a red circle or cross).

- Optionally draw a bounding box or overlay to visualize the detection area.

- Print or return the center coordinates in the output (e.g., Detected center: (x, y)).

- Show accumulator maps to illustrate voting peaks.

- Code Quality

- Write clean, modular, and **well-commented** code.

- Avoid hard-coding parameters and repeated code blocks.

- Organize your code clearly within the notebook.

What should you write in the report?

Your notebook will serve as both your implementation and report. Include the following sections with short explanations and relevant visual results:

1. Title & meta

Notebook title, your name, student number, brief one-line description of what the notebook does, and OUT_PUT_DIR and DATASET_DIR variables that you will use in your code.

2. Introduction

Briefly describe what the Generalized Hough Transform does and what the assignment is about.

3. Edge Detection Results

Show edge maps for the template and 1-2 scene images. Talk about which detector you used and why.

4. GHT Implementation and Detections

Display at least 5 test results from each dataset (you may try more).

For each test image, show:

- The accumulator heatmap,

- The final detection overlay (center point, bounding markers or template overlay), and

- Short comments on whether the detected position matches visually.

5. Evaluation

Compare the two templates:

- Did one of them yield clearer peaks or more accurate detections?
- Which one was easier for your implementation to detect?
- Why do you think this happened?

Keep your explanations concise and focus on observations and reasoning rather than long theoretical descriptions.

6. Failure Cases

Show a few examples where your method fails or performs poorly, with *short* comments on possible causes.

7. Summary

Write a *short* paragraph about what you learned and how the algorithm could be improved.

What to Hand In

Your submission format will be:

- b<studentNumber>.ipynb (Jupyter notebook)

The notebook must include:

- Code cells for each step (edge detection, R-table, voting, visualization).
- Markdown explanations describing your approach and observations.
- Plots showing detected template regions and accumulator peaks.

No separate PDF report is required. Submit this as **b<studentNumber>.zip** to <https://submit.cs.hacettepe.edu.tr>.

Grading

The assignment will be graded out of 100:

- CODE: 0 (no implementation), 10 (a partial solution– only edge detection), 30 (a partially correct solution - edge detection and partially correct Generalized Hough Transform (without scale and rotation)), 50 (a correct solution) and REPORT: 50.

Academic Integrity

All work on assignments must be done individually unless stated otherwise. You are encouraged to discuss with your classmates about the given assignments, but these discussions should be carried out abstractly. That is, discussions related to a particular solution to a specific problem (either in actual code or in the pseudocode) will not be tolerated. In short, turning in someone else's work, in whole or in part, as your own will be considered a violation of academic integrity. Please note that the former condition also holds for the material found on the web as everything on the web has been written by someone else. You may not share or receive concrete solutions such as code, pseudocode, or detailed proof steps, nor may you copy, adapt, or refine text or code produced by LLM tools (e.g., ChatGPT, Gemini, Copilot) or any online source.

Good Video Resources For Theoretic Foundation of GHT

1. https://www.youtube.com/watch?v=XRBC_xkZREg
2. https://www.youtube.com/watch?v=_mGxmZW9Zw