Indonesian vs Polish Flag Recognition

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1 Methodology

1.1 Overall Strategy

The flag detection and classification system follows a sequential two-task approach:

1. **Task 1: Object Detection and Cropping** - Utilize YOLOv5 to detect and extract flag regions from input images
2. **Task 2: Flag Classification** - Apply HSV color analysis to distinguish between Indonesian and Polish flags

1.2 Task 1: Flag Detection Using YOLOv5

1.2.1 Model Selection and Loading

The system employs YOLOv5s (small variant) for computational efficiency while maintaining adequate detection accuracy. The model is loaded using the Ultralytics framework:

```
from ultralytics import YOLO
model = YOLO('yolov5s.pt')
```

Listing 1: YOLOv5 Model Loading

1.2.2 Coordinate Extraction

The bounding box coordinates are extracted from PyTorch tensors and converted to usable format:

```
x1, y1, x2, y2 = box.xyxy[0].cpu().numpy().astype(int)
cropped_flag = img[y1:y2, x1:x2]
```

Listing 2: Coordinate Processing

1.2.3 Flag Detection and Cropping

The detection process follows these steps:

Algorithm 1 Flag Detection Algorithm

```
Load input image $I$ using OpenCV
Apply YOLOv5 model: $R = \text{model}(I)$
Extract bounding boxes from results $R$
if bounding boxes detected then
    Select first detection with coordinates $(x_1, y_1, x_2, y_2)$
    Crop flag region: $F = I[y_1 : y_2, x_1 : x_2]$
    return $F$
else

    return original image $I$
end if
```

1.3 Task 2: HSV-Based Flag Classification

1.3.1 Color Space Conversion

The RGB color space is converted to HSV (Hue, Saturation, Value) for improved color detection robustness:

$$I_{HSV} = \text{cvtColor}(I_{BGR}, \text{COLOR\_BGR2HSV}) \tag{1}$$

HSV color space advantages:

- Separates color information (hue) from intensity
- More robust to lighting variations
- Intuitive color range definition

1.3.2 Red Color Range Definition

Red color detection requires two HSV ranges due to hue wraparound:

$$\text{Range 1:} \quad H \in [0, 10], S \in [50, 255], V \in [50, 255] \tag{2}$$

$$\text{Range 2:} \quad H \in [170, 180], S \in [50, 255], V \in [50, 255] \tag{3}$$

```
red_lower = np.array([0, 50, 50])
red_upper = np.array([10, 255, 255])
red_lower2 = np.array([170, 50, 50])
red_upper2 = np.array([180, 255, 255])
```

Listing 3: Red Color Range Definition

1.3.3 Mask Generation

Binary masks are created using the `cv2.inRange()` function:

$$M_{red}(x, y) = \begin{cases} 255 & \text{if } (H, S, V)_{(x,y)} \in \text{RedRange} \\ 0 & \text{otherwise} \end{cases} \tag{4}$$

The `cv2.inRange()` function performs element-wise comparison:

```
mask_red1 = cv2.inRange(hsv, red_lower, red_upper)
mask_red2 = cv2.inRange(hsv, red_lower2, red_upper2)
mask_red = cv2.bitwise_or(mask_red1, mask_red2)
```

Listing 4: Mask Creation Process

1.3.4 Spatial Color Analysis

The classification strategy leverages the spatial distribution of red pixels:

Algorithm 2 Flag Classification Algorithm

```
Compute flag height: $h = \text{flag\_image.shape}[0]$
Split red mask vertically: $M_{top} = M_{red}[0 : h/2, :]$, $M_{bottom} = M_{red}[h/2 : h, :]$
Count red pixels: $P_{top} = \text{countNonZero}(M_{top})$, $P_{bottom} = \text{countNonZero}(M_{bottom})$
if $P_{top} > P_{bottom}$ then
    return "Indonesian Flag"
else
    return "Polish Flag"
end if
```

2 Mathematical Foundation

2.1 HSV Color Space Transformation

The BGR to HSV conversion follows standard color space transformation equations. For a pixel with BGR values (B, G, R):

$$V = \max(R, G, B) \tag{5}$$

$$S = \begin{cases} 0 & \text{if } V = 0 \\ \frac{V - \min(R,G,B)}{V} \times 255 & \text{otherwise} \end{cases} \tag{6}$$

$$H = \text{calculated based on dominant color channel} \tag{7}$$

2.2 Pixel Classification Metrics

The classification decision is based on the ratio of red pixels in each half:

$$\text{Classification} = \begin{cases} \text{Indonesian} & \text{if } \frac{P_{top}}{P_{total}} > \frac{P_{bottom}}{P_{total}} \\ \text{Polish} & \text{otherwise} \end{cases} \tag{8}$$

where $P_{total} = P_{top} + P_{bottom}$.

3 Implementation Details

3.1 Key Parameters

- **HSV Red Range 1:** $[0, 50, 50]$ to $[10, 255, 255]$

- **HSV Red Range 2:** $[170, 50, 50]$ to $[180, 255, 255]$
- **Minimum Saturation:** 50 (filters out pale colors)
- **Minimum Value:** 50 (filters out dark colors)