Mathematical Calculations & Formulas

1. Contour Center Calculation (Centroid)

cx = M10 / M00, cy = M01 / M00

Where M10, M01, M00 are image moments from cv2.moments().

2. Kalman Filter Prediction Step

X' = A * X + W

Where A is the state transition matrix and W is process noise.

3. Kalman Filter Correction Step

X_new = X' + K * (Z - H * X')

Where K is the Kalman gain, Z is the measurement, and H is the measurement matrix.

4. Edge Detection using Canny

G = sqrt(Gx^2 + Gy^2)

Where Gx and Gy are intensity gradients in x and y directions.

5. Hough Transform for Line Detection

rho = x * cos(theta) + y * sin(theta)

Where rho is the distance from origin and theta is the angle of the line.

6. Optical Flow (Lucas-Kanade Algorithm)

[u] = M^-1 * [-sum(Ix * It)]

[v] [-sum(Iy * It)]

Where Ix, Iy are intensity gradients, It is the time change in intensity.

7. Contact Detection

y + h >= surface_y

Where y + h is the bottom of the object and surface_y is the detected surface level.

8. Contact Length Calculation

Contact Length = xmax - xmin

Where xmax and xmin are the left and right edges of the contact region.

9. Deformation Calculation (Aspect Ratio)

Aspect Ratio = Width / Height = w / h

OR

Deformation = Minor Axis / Major Axis

Where Major Axis is the longest ellipse dimension and Minor Axis is the shortest.