Bubble Digit Detection using OpenCV

# 1. Objective

This project demonstrates the use of computer vision (OpenCV) for automatic bubble digit recognition from scanned or photographed OMR-style answer sheets. The program detects filled bubbles in two columns (left and right), converts them into digit values, and calculates the final two-digit number as (Left × 10 + Right). The result is saved into a CSV file.

# 2. Detection Workflow

1. Image Acquisition – Input: scanned image or high-quality photo of the bubble sheet.
2. Preprocessing – Convert to grayscale, apply Gaussian blur, and thresholding using Otsu’s method.
3. Contour Detection – Extract contours and filter by bubble size (20–50 px).
4. Bubble Analysis – Calculate fill ratio. If ratio > 0.4, mark as filled bubble.
5. Digit Assignment – Sort bubbles top-to-bottom and map positions to digits (0–9).
6. Final Number – Left digit × 10 + Right digit.
7. Result Export – Save detected digits and final result into a CSV file.

# 3. When Detection Works

The algorithm successfully detects bubbles when:  
- The image is clear, properly scanned, or photographed without blur.  
- Bubble sizes are consistent (20–50 px).  
- Bubbles are properly filled (dark enough to exceed 40% fill ratio).  
- Columns are well-separated.

# 4. When Detection Fails

Detection may fail when:  
- Image is low resolution or blurred.  
- Bubbles are lightly shaded (fill ratio < 0.4).  
- Overfilled or irregular bubble shapes.  
- Skewed or rotated sheet.  
- Extra noise or marks around bubbles.

# 5. Image Quality Requirements

- Resolution: ≥ 300 DPI (scanned) or ≥ 1080p (photo).  
- Format: JPG or PNG.  
- Lighting: Even, no shadows.  
- Contrast: Dark pen/pencil on white background.  
- Alignment: Flat, not skewed.

# 6. Limitations

- Works only for two columns.  
- Sensitive to rotation and noise.  
- Requires bubbles of similar size.  
- Picks only the most filled bubble per column.

# 7. Possible Improvements

- Apply perspective correction for skewed sheets.  
- Use morphological operations to reduce noise.  
- Train ML/CNN models for robust detection.  
- Extend for multiple columns and answers.  
- Dynamic calibration instead of fixed size filter.

# 8. Frequently Asked Questions (FAQs)

* Q: Why is my bubble not detected?

A: It may be too lightly shaded, too small/large, or blurred.

* Q: What image quality is recommended?

A: Scanned at 300 DPI or photo at 1080p+ resolution.

* Q: Can this code detect multiple filled bubbles per column?

A: No, it selects the most filled bubble only.

* Q: What if the sheet is tilted?

A: Bubble order may misalign, leading to wrong detection.

# 9. Conclusion

This program provides a rule-based computer vision solution for detecting filled bubbles and mapping them to digits. It calculates a final number using (Left × 10 + Right). While effective for clean and well-scanned images, accuracy drops with noisy, tilted, or low-resolution inputs. Future work can improve robustness with ML techniques.