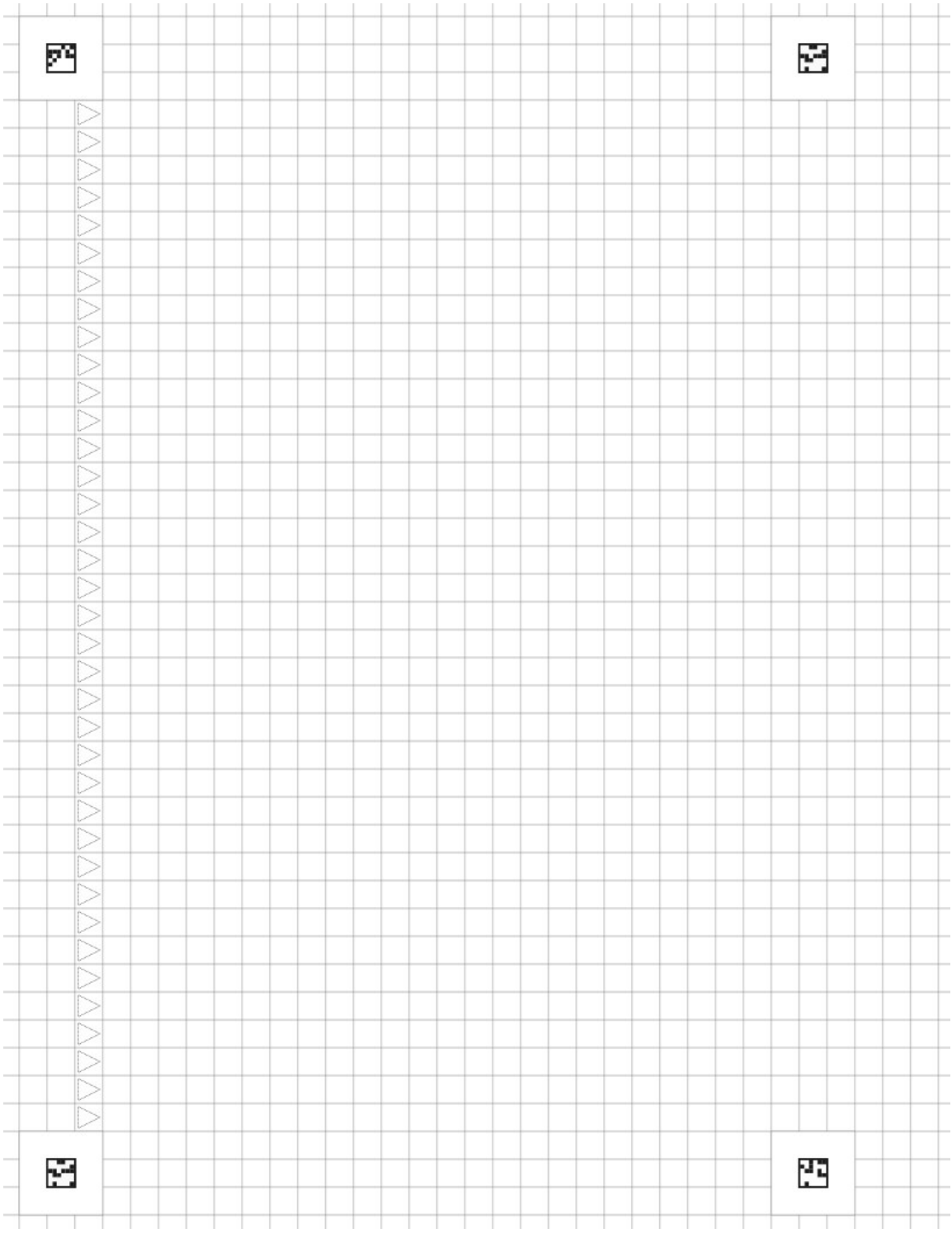
# A2 Image Normalization

Each image that is taken with the camera phone will need to be normalized.

In [4]:
```
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns
```

## Page Zero Display



# Page One Display

Calibration Page One Display

## Other Page Variants

Now that the calibration cubes have been assessed, we turn our attention to another form of

noise.

- Dot Matrix
- Lined
- Blank
- Hex

## Thoughts

It is not lost on me that there is an infinite amount of paper types that one could imagine in order to convey ideas. Personally, the type for which I am the most nostalgic is dot matrix. An example below:

Dot Matrix Page One

## Describing the Calibration Features

*Quick Calibration Squares:* `6 x 6` square in every corner. Each cell in the square is `0.975mm+/- 0.500mm` wide. There are 4 distinct styles:

- Top Left and Bottom Right QC square are the same per page (Page 0: Rear; Page 1; Front)
  - see:
    - Page Zero and One Bottom Right
    - Page Zero and One Top Left
- The Top Right and Bottom Left of each page is the same
  - see:
    - Page Zero Top Right and Bottom Left
    - Page One Top Right and Bottom Left

*QC Square Envelope:* Each QC square has an evelope around it (as seen in any appended images of the sqaures). The envelope is `0.75in`.

*Left Margin Arrows* Each page has directional triangles in a straight line along the Left Margin of the drawing area. There are `37` of them pointing with the tips towards the drawing area. The ratio of the triangle is such that the left edge, which is perpendicular to the column direction is `0.75in - 2mm` and the two other edges, which are congruent, are also `0.75in - 2mm`. The triangles are centered within each cell within each column and row.

Left Margin

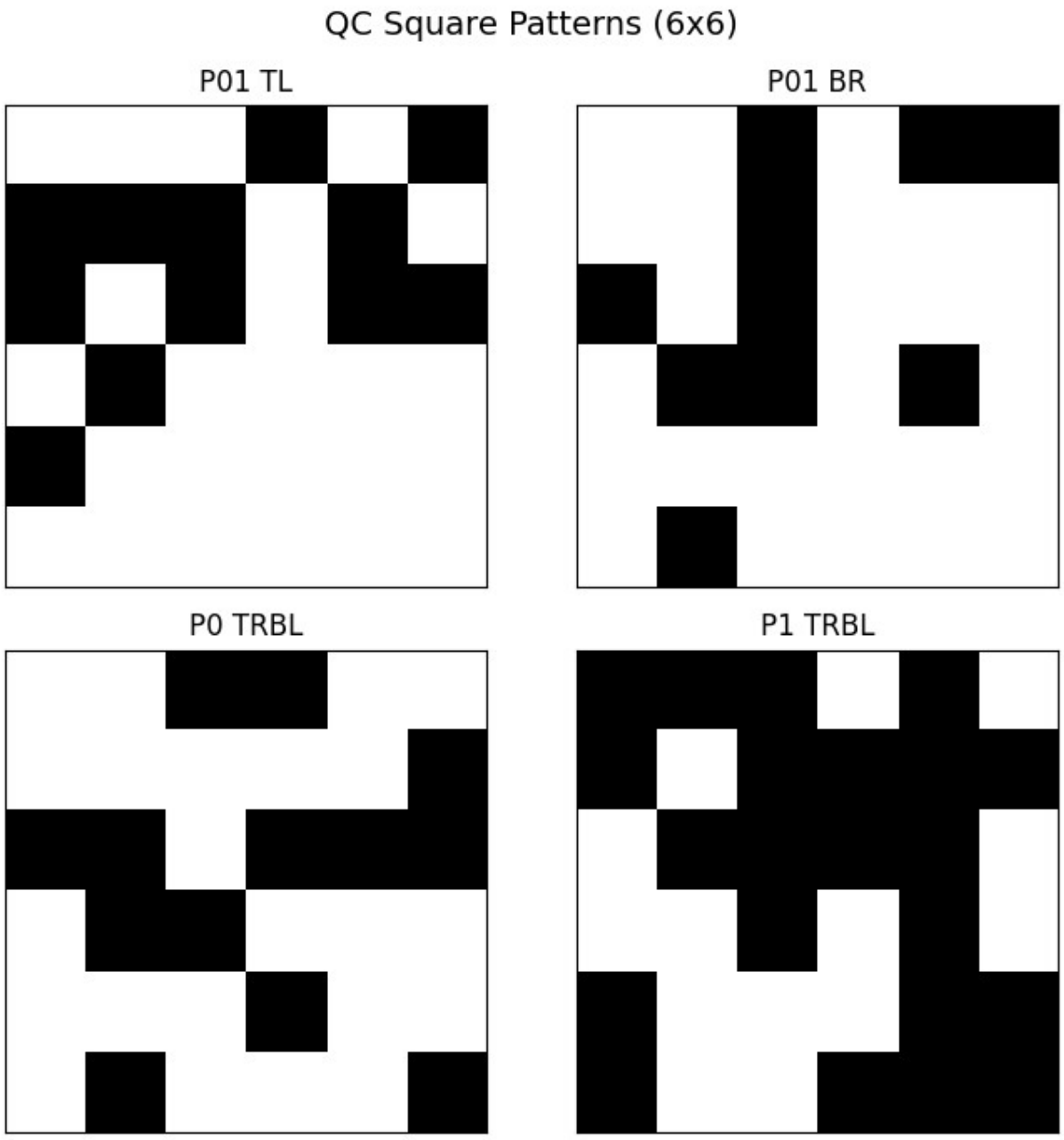
# Matrix Representations of QC Squares

In [5]:

```
# 0: black
# 1: white

n = [ # Empty Matrix
    [0, 0, 0, 0, 0, 0], # Row 0
    [0, 0, 0, 0, 0, 0], # Row 1
    [0, 0, 0, 0, 0, 0], # Row 2
    [0, 0, 0, 0, 0, 0], # Row 3
    [0, 0, 0, 0, 0, 0], # Row 4
    [0, 0, 0, 0, 0, 0]  # Row 5
]


# Page 0 and 1, Top Left
p01_tl = [
    [1, 1, 1, 0, 1, 0], # Row 0
    [0, 0, 0, 1, 0, 1], # Row 1
    [0, 1, 0, 1, 0, 0], # Row 2
    [1, 0, 1, 1, 1, 1], # Row 3
    [0, 1, 1, 1, 1, 1], # Row 4
    [1, 1, 1, 1, 1, 1] # Row 5
]

# Page 0 and 1, Bottom Right
p01_br = [
    [1, 1, 0, 1, 0, 0], # Row 0
    [1, 1, 0, 1, 1, 1], # Row 1
    [0, 1, 0, 1, 1, 1], # Row 2
    [1, 0, 0, 1, 0, 1], # Row 3
    [1, 1, 1, 1, 1, 1], # Row 4
    [1, 0, 1, 1, 1, 1]  # Row 5
]

# Page 0, Top Right and Bottom Left
p0_trbl = [
    [1, 1, 0, 0, 1, 1], # Row 0
    [1, 1, 1, 1, 1, 0], # Row 1
    [0, 0, 1, 0, 0, 0], # Row 2
    [1, 0, 0, 1, 1, 1], # Row 3
    [1, 1, 1, 0, 1, 1], # Row 4
    [1, 0, 1, 1, 1, 0]  # Row 5
]

# Page 1, Top Right and Bottom Left

p1_trbl = [
    [0, 0, 0, 1, 0, 1], # Row 0
    [0, 1, 0, 0, 0, 0], # Row 1
    [1, 0, 0, 0, 0, 1], # Row 2
    [1, 1, 0, 1, 0, 1], # Row 3
    [0, 1, 1, 1, 0, 0], # Row 4
    [0, 1, 1, 0, 0, 0] # Row 5
]
```

## Visual Representation

In [6]:
```
import matplotlib.pyplot as plt

# Show graph of what the QC squares look like

qc_patterns = {
    'p01_tl': np.array(p01_tl),
    'p01_br': np.array(p01_br),
    'p0_trbl': np.array(p0_trbl),
    'p1_trbl': np.array(p1_trbl)
}

fig, axes = plt.subplots(2, 2, figsize=(7, 7))
for ax, (name, pattern) in zip(axes.flatten(), qc_patterns.items()):
    ax.imshow(pattern, cmap='gray', vmin=0, vmax=1, interpolation='nearest')
    ax.set_title(name.replace('_', ' ').upper())
    ax.set_xticks([])
    ax.set_yticks([])
    ax.grid(False)

plt.suptitle('QC Square Patterns (6x6)', fontsize=14)
plt.tight_layout()
plt.show()
```




# Thought

I do not approve of the imperial system, but then I didn't make the paper. In future work, I would prefer a metric version of the medium. This is something that I think would take no longer than 30 minutes to design.

# Normalization Script

# Test Image

**Degenerate points**

points that do not form a valid geometric shape; they are collinear, overlapping, or not distinct enough to define a proper quadrilateral for transformations.

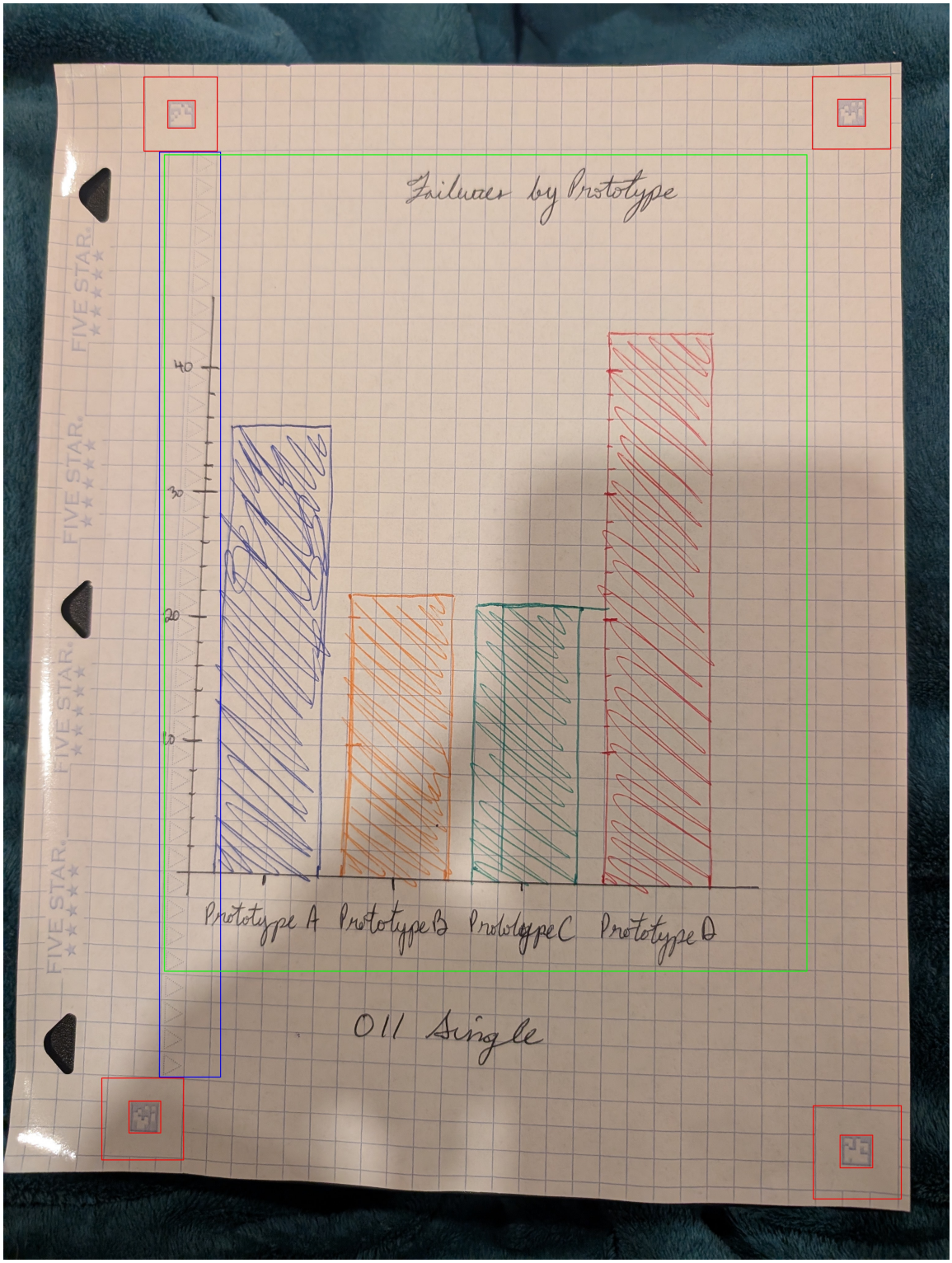
011 Single

## Identifying Page Features

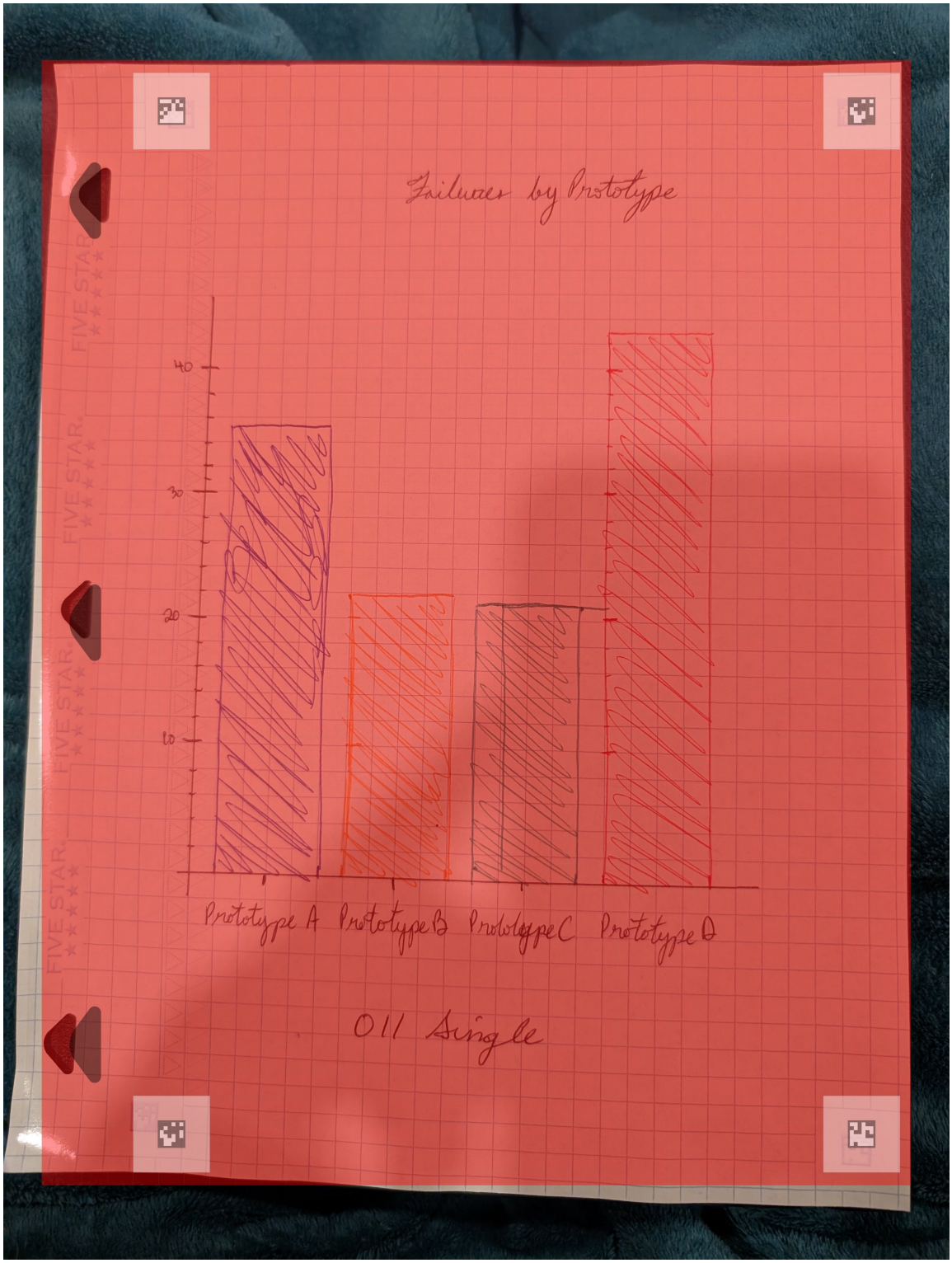
**Red:** QC squares

**Blue:** Triangles

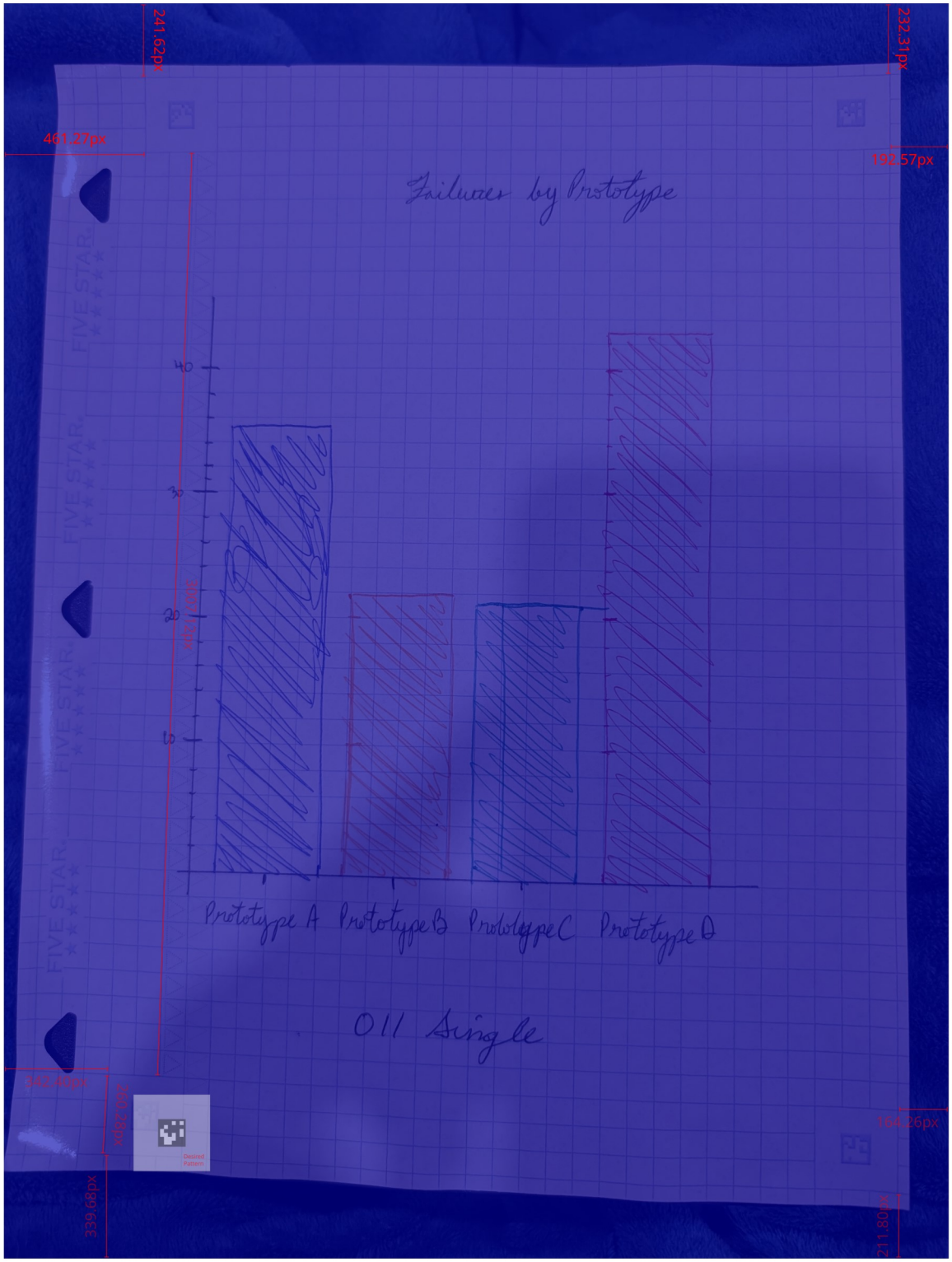
**Green:** Chart Area




Desired Features




Page Dimensions




In [7]:
```
## Test Image
import PIL
import os
import cv2
import numpy as np
```

In [8]:
```
def detect_qc_square(image, corner='auto', search_region_size=0.2, min_square_area=
    """
    Detect QC square in the image.
```

```
    Parameters:
    -----------
    image : numpy.ndarray
        RGB image (H, W, 3) or BGR if from cv2.imread
    corner : str, optional
        Which corner to search: 'tl', 'tr', 'bl', 'br', or 'auto' (search all)
        Default: 'auto'
    search_region_size : float
        Fraction of image dimensions to search in corner (0.0-1.0)
        Default: 0.2 (top/bottom/left/right 20%)
    min_square_area : int
        Minimum area for detected square (in pixels)
        Default: 100

    Returns:
    --------
    dict or list of dicts
        If corner='auto': list of dicts, one per detected QC square
        Otherwise: single dict with keys:
            - 'bbox': (x, y, width, height) bounding box
            - 'corner': detected corner position ('tl', 'tr', 'bl', 'br')
            - 'pattern': extracted 6x6 pattern (numpy array)
            - 'pattern_match': matched pattern name (if successful)
            - 'confidence': match confidence (0-1)
    """
    # Convert BGR to RGB if needed (cv2 loads as BGR)
    if len(image.shape) == 3:
        # Check if it's likely BGR by comparing first/last channels
        # Or just convert if from cv2.imread
        if image.dtype == np.uint8:
            rgb_image = cv2.cvtColor(image, cv2.COLOR_BGR2RGB)
        else:
            rgb_image = image.copy()
    else:
        raise ValueError("Image must be RGB/BGR (3 channels)")

    h, w = rgb_image.shape[:2]

    # Define search regions for each corner
    search_regions = {
        'tl': (0, 0, int(w * search_region_size), int(h * search_region_size)),
        'tr': (int(w * (1 - search_region_size)), 0, w, int(h * search_region_size)
        'bl': (0, int(h * (1 - search_region_size)), int(w * search_region_size), h
        'br': (int(w * (1 - search_region_size)), int(h * (1 - search_region_size))
    }

    # Convert to grayscale for detection
    gray = cv2.cvtColor(rgb_image, cv2.COLOR_RGB2GRAY)

    def detect_in_region(region_bbox, corner_name):
        """Detect QC square in a specific region."""
        rx, ry, rw, rh = region_bbox
        region_gray = gray[ry:rh, rx:rw]

        if region_gray.size == 0:
```

```
            return None

        # Enhance contrast for better detection
        clahe = cv2.createCLAHE(clipLimit=2.0, tileGridSize=(8,8))
        region_enhanced = clahe.apply(region_gray)

        # Adaptive threshold to find edges/boundaries
        binary = cv2.adaptiveThreshold(region_enhanced, 255,
                                       cv2.ADAPTIVE_THRESH_GAUSSIAN_C,
                                       cv2.THRESH_BINARY_INV, 11, 2)

        # Find contours
        contours, _ = cv2.findContours(binary, cv2.RETR_EXTERNAL,
                                       cv2.CHAIN_APPROX_SIMPLE)

        # Filter for square-like contours
        square_candidates = []
        region_area = region_gray.shape[0] * region_gray.shape[1]
        min_area_pixels = max(min_square_area, region_area * 0.01)  # At least 1% o

        for contour in contours:
            area = cv2.contourArea(contour)
            if area < min_area_pixels:
                continue

            # Approximate polygon
            peri = cv2.arcLength(contour, True)
            approx = cv2.approxPolyDP(contour, 0.02 * peri, True)

            # Check if roughly square (4 corners)
            if len(approx) >= 4:
                # Get bounding rect
                x_rect, y_rect, w_rect, h_rect = cv2.boundingRect(contour)

                # Check aspect ratio (should be roughly square)
                aspect_ratio = float(w_rect) / h_rect if h_rect > 0 else 0
                if 0.7 < aspect_ratio < 1.3:  # Allow some tolerance
                    # Check solidity (filled vs outline)
                    solidity = area / (w_rect * h_rect) if (w_rect * h_rect) > 0 el

                    square_candidates.append({
                        'contour': contour,
                        'area': area,
                        'bbox_local': (x_rect, y_rect, w_rect, h_rect),
                        'solidity': solidity,
                        'aspect_ratio': aspect_ratio
                    })

        if not square_candidates:
            return None

        # Sort by area (largest first) and prefer more square-like shapes
        square_candidates.sort(key=lambda x: x['area'] * x['solidity'], reverse=Tru
        best_candidate = square_candidates[0]

        # Convert local coordinates to global image coordinates
```

```
        x_local, y_local, w_local, h_local = best_candidate['bbox_local']
        bbox_global = (rx + x_local, ry + y_local, w_local, h_local)

        # Extract pattern from this region
        try:
            pattern = extract_pattern_from_rgb(rgb_image, bbox_global, envelope_mar

            # Match pattern against known patterns
            pattern_match, confidence = match_pattern(pattern, {
                'p01_tl': np.array(p01_tl),
                'p01_br': np.array(p01_br),
                'p0_trbl': np.array(p0_trbl),
                'p1_trbl': np.array(p1_trbl)
            })

            return {
                'bbox': bbox_global,
                'corner': corner_name,
                'pattern': pattern,
                'pattern_match': pattern_match,
                'confidence': confidence,
                'area': best_candidate['area'],
                'solidity': best_candidate['solidity']
            }
        except Exception as e:
            print(f"Error extracting pattern for {corner_name}: {e}")
            return {
                'bbox': bbox_global,
                'corner': corner_name,
                'pattern': None,
                'pattern_match': None,
                'confidence': 0.0,
                'error': str(e)
            }

    # Search in specified corner(s)
    if corner == 'auto':
        results = []
        for corner_name, region_bbox in search_regions.items():
            result = detect_in_region(region_bbox, corner_name)
            if result:
                results.append(result)
        return results
    else:
        if corner not in search_regions:
            raise ValueError(f"Corner must be one of: {list(search_regions.keys())}
        return detect_in_region(search_regions[corner], corner)

def match_pattern(extracted_pattern, known_patterns):
    """
    Match extracted 6x6 pattern against known patterns.

    Parameters:
    -----------
    extracted_pattern : numpy.ndarray
        6x6 binary pattern
```

```
    known_patterns : dict
        Dictionary of pattern_name -> pattern_array

    Returns:
    --------
    tuple: (best_match_name, confidence_score)
    """
    if extracted_pattern is None:
        return None, 0.0

    best_match = None
    best_score = 0.0

    for name, ref_pattern in known_patterns.items():
        # Calculate similarity (simple matching)
        matches = np.sum(extracted_pattern == ref_pattern)
        similarity = matches / 36.0  # 36 cells total (6x6)

        if similarity > best_score:
            best_score = similarity
            best_match = name

    return best_match, best_score
```

In [9]:

```
def extract_pattern_from_rgb(rgb_image, bbox, envelope_margin=0.1):
    """
    Extract 6x6 binary pattern from RGB image.

    envelope_margin: percentage of bbox to use as margin for envelope
    """
    x, y, w, h = bbox

    # Crop region
    qc_region_rgb = rgb_image[y:y+h, x:x+w]

    # Account for the 0.75in envelope - extract inner square
    margin = int(min(w, h) * envelope_margin)
    inner_region_rgb = qc_region_rgb[margin:h-margin, margin:w-margin]

    # Convert to grayscale
    inner_gray = cv2.cvtColor(inner_region_rgb, cv2.COLOR_RGB2GRAY)

    # Get dimensions
    grid_h, grid_w = inner_gray.shape

    # Divide into 6x6 cells
    cell_h = grid_h // 6
    cell_w = grid_w // 6

    # Extract binary pattern
    pattern_6x6 = np.zeros((6, 6), dtype=int)

    for i in range(6):
        for j in range(6):
            # Sample cell center region (avoid edges between cells)
            y_start = i * cell_h + cell_h // 4
```

```
            y_end = (i + 1) * cell_h - cell_h // 4
            x_start = j * cell_w + cell_w // 4
            x_end = (j + 1) * cell_w - cell_w // 4

            if y_end > y_start and x_end > x_start:
                cell_region = inner_gray[y_start:y_end, x_start:x_end]

                # Threshold: mean value determines if cell is black or white
                # Black cells (filled) have low pixel values
                # White cells (empty) have high pixel values
                mean_value = np.mean(cell_region)

                # Adaptive threshold based on local image statistics
                # If mean is below 128 (or use Otsu's method), it's black (filled)
                if mean_value < 128:
                    pattern_6x6[i, j] = 0  # black/filled
                else:
                    pattern_6x6[i, j] = 1  # white/empty

    return pattern_6x6
```

## Test

In [10]:
```
# Load image
image_path = 'hand_drawn_notes/bc_011_single-000.jpg'
image = cv2.imread(image_path)  # Returns BGR

# Detect all QC squares automatically
results = detect_qc_square(image, corner='auto', min_square_area=25)

# Process results
for result in results:
    print(f"Found QC square in {result['corner']} corner")
    print(f"  Bounding box: {result['bbox']}")
    if result['pattern_match']:
        print(f"  Matched pattern: {result['pattern_match']}")
        print(f"  Confidence: {result['confidence']:.2%}")
```

```
Found QC square in tr corner
  Bounding box: (2457, 266, 615, 550)
  Matched pattern: p01_br
  Confidence: 72.22%
Found QC square in bl corner
  Bounding box: (20, 3264, 594, 639)
  Matched pattern: p01_tl
  Confidence: 72.22%
Found QC square in br corner
  Bounding box: (2457, 3264, 615, 685)
  Matched pattern: p01_br
  Confidence: 66.67%
```

## Visualisation

In [11]:
```
import matplotlib.pyplot as plt
import matplotlib.patches as patches
```

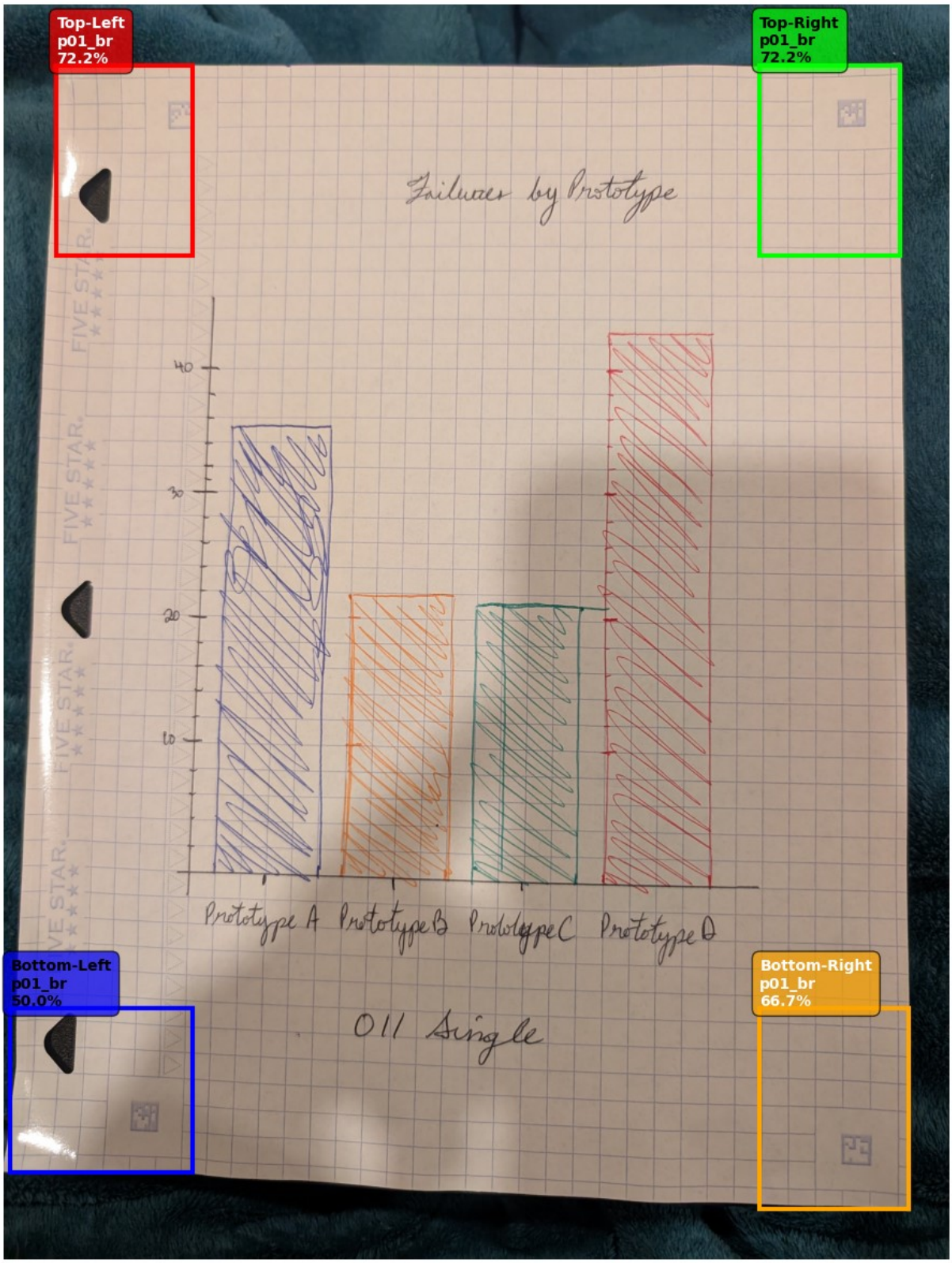
```python
def visualize_qc_squares(image, results, show_labels=True, figsize=(15, 12)):
    """
    Visualize detected QC squares on the original image.

    Parameters:
    -----------
    image : numpy.ndarray
        Original RGB image
    results : list of dicts
        List of detection results from detect_qc_square()
    show_labels : bool
        Whether to show labels with corner and pattern info
    figsize : tuple
        Figure size for matplotlib

    Returns:
    --------
    matplotlib.figure.Figure
        The figure object (can be saved or displayed)
    """
    # Create a copy of the image to draw on
    if len(image.shape) == 3:
        display_image = image.copy()
    else:
        display_image = cv2.cvtColor(image, cv2.COLOR_GRAY2RGB)

    # Define colors for each corner
    corner_colors = {
        'tl': (255, 0, 0),      # Red for top-left
        'tr': (0, 255, 0),      # Green for top-right
        'bl': (0, 0, 255),      # Blue for bottom-left
        'br': (255, 165, 0),    # Orange for bottom-right
    }

    corner_names = {
        'tl': 'Top-Left',
        'tr': 'Top-Right',
        'bl': 'Bottom-Left',
        'br': 'Bottom-Right'
    }

    # Create figure
    fig, ax = plt.subplots(1, 1, figsize=figsize)
    ax.imshow(display_image)
    ax.axis('off')

    # Draw bounding boxes for each detected QC square
    for result in results:
        if result is None:
            continue

        corner = result.get('corner', 'unknown')
        bbox = result.get('bbox', None)

        if bbox is None:
```

```
            continue

        x, y, w, h = bbox
        color = corner_colors.get(corner, (255, 255, 255))  # Default to white

        # Draw bounding box rectangle
        rect = patches.Rectangle(
            (x, y), w, h,
            linewidth=3,
            edgecolor=[c/255.0 for c in color],
            facecolor='none'
        )
        ax.add_patch(rect)

        # Add label if requested
        if show_labels:
            label_text = corner_names.get(corner, corner.upper())

            # Add pattern match info if available
            if result.get('pattern_match'):
                pattern_name = result['pattern_match']
                confidence = result.get('confidence', 0)
                label_text += f'\n{pattern_name}\n{confidence:.1%}'

            # Position label at top-left of bounding box
            # Adjust if too close to image edge
            label_x = x
            label_y = y - 10 if y > 30 else y + h + 10

            ax.text(
                label_x, label_y,
                label_text,
                fontsize=10,
                bbox=dict(
                    boxstyle='round,pad=0.5',
                    facecolor=[c/255.0 for c in color],
                    edgecolor='black',
                    alpha=0.7
                ),
                color='white' if corner in ['tl', 'br'] else 'black',
                weight='bold'
            )

    plt.tight_layout()
    return fig
```

In [12]:

```
# Load image and detect QC squares
image_path = 'hand_drawn_notes/bc_011_single-004.jpg'
image = cv2.imread(image_path)
rgb_image = cv2.cvtColor(image, cv2.COLOR_BGR2RGB)

# Detect all QC squares
results = detect_qc_square(rgb_image, corner='auto')

# Visualize using matplotlib
fig = visualize_qc_squares(rgb_image, results, show_labels=True)
```

```
plt.show()

# Or save the figure
# fig.savefig('output_files/qc_detections.png', dpi=150, bbox_inches='tight')
```




## Cropping

In [13]:

```python
def get_page_corners_from_qc(results, allow_diagonal_fallback=True):
    """
    Extract page corner coordinates from detected QC squares.

    Parameters:
    -----------
    results : list of dicts
        List of detection results from detect_qc_square()
        Should contain 4 results (one for each corner)
    allow_diagonal_fallback : bool
        When True (default) the function will synthesize the missing corners
        if only a TL/BR or TR/BL diagonal pair is detected.

    Returns:
    --------
    tuple
        (corner dictionary, fallback reason string or None). The dictionary has
        keys 'tl', 'tr', 'bl', 'br'. Returns (None, None) if the required
        corners cannot be computed.
    """
    corners = {}

    for result in results:
        if result is None:
            continue
        corner = result.get('corner')
        bbox = result.get('bbox')

        if corner and bbox:
            x, y, w, h = bbox

            # Use the outer corner of the bounding box (closest to image edge)
            # This represents the corner of the QC square envelope
            if corner == 'tl':
                corners['tl'] = (x, y)
            elif corner == 'tr':
                corners['tr'] = (x + w, y)
            elif corner == 'bl':
                corners['bl'] = (x, y + h)
            elif corner == 'br':
                corners['br'] = (x + w, y + h)

    required_corners = ['tl', 'tr', 'bl', 'br']
    if all(corner in corners for corner in required_corners):
        return corners, None

    def _synthesize_from_tl_br(tl, br):
        return {
            'tl': tl,
            'tr': (br[0], tl[1]),
            'br': br,
            'bl': (tl[0], br[1])
        }

    def _synthesize_from_tr_bl(tr, bl):
        return {
```

```
            'tl': (bl[0], tr[1]),
            'tr': tr,
            'br': (tr[0], bl[1]),
            'bl': bl
        }

    if allow_diagonal_fallback:
        if 'tl' in corners and 'br' in corners:
            synthesized = _synthesize_from_tl_br(corners['tl'], corners['br'])
            print("Partial corners detected: using TL/BR diagonal to estimate the m
            return synthesized, 'diagonal_tl_br'
        if 'tr' in corners and 'bl' in corners:
            synthesized = _synthesize_from_tr_bl(corners['tr'], corners['bl'])
            print("Partial corners detected: using TR/BL diagonal to estimate the m
            return synthesized, 'diagonal_tr_bl'

    missing = [c for c in required_corners if c not in corners]
    print(f"Warning: Missing corners: {missing}")
    return None, None


def crop_image_using_qc_corners(image, results, output_size=None, margin=0, allow_d
    """
    Crop and rectify the image using detected QC square corners.

    Parameters:
    -----------
    image : numpy.ndarray
        Original RGB image
    results : list of dicts
        List of detection results from detect_qc_square()
    output_size : tuple, optional
        Desired output size (width, height). If None, calculates from corners.
    margin : int or float
        Margin to add around the page (in pixels or as fraction of page size)
        Default: 0
    allow_diagonal_fallback : bool
        When True (default) synthesizes the missing corners when a TL/BR or
        TR/BL diagonal pair is available so the page can still be rectified.

    Returns:
    --------
    numpy.ndarray
        Cropped and rectified image
    dict
        Metadata including transformation matrix and corner coordinates
    """
    # Get corner coordinates
    corners, fallback_reason = get_page_corners_from_qc(results, allow_diagonal_fal
    if corners is None:
        raise ValueError("Could not extract all 4 corner points from QC squares")

    # Source points
    src_points = np.array([
        corners['tl'],  # Top-left
        corners['tr'],  # Top-right
```

```
        corners['br'],  # Bottom-right
        corners['bl']   # Bottom-left
    ], dtype=np.float32)

    # Calculate destination points
    if output_size is None:
        # Calculate output size based on the width and height of the page
        width_top = np.linalg.norm(src_points[1] - src_points[0])
        width_bottom = np.linalg.norm(src_points[2] - src_points[3])
        height_left = np.linalg.norm(src_points[3] - src_points[0])
        height_right = np.linalg.norm(src_points[2] - src_points[1])

        # Use average dimensions
        output_width = int(max(width_top, width_bottom))
        output_height = int(max(height_left, height_right))
    else:
        output_width, output_height = output_size

    # Apply margin
    if isinstance(margin, float):
        margin_x = int(output_width * margin)
        margin_y = int(output_height * margin)
    else:
        margin_x = margin_y = margin

    output_width += 2 * margin_x
    output_height += 2 * margin_y

    # Destination points
    dst_points = np.array([
        [margin_x, margin_y],                           # Top-left
        [output_width - margin_x, margin_y],            # Top-right
        [output_width - margin_x, output_height - margin_y],  # Bottom-right
        [margin_x, output_height - margin_y]            # Bottom-left
    ], dtype=np.float32)

    # Get perspective transformation matrix
    M = cv2.getPerspectiveTransform(src_points, dst_points)

    # Apply perspective transformation
    cropped = cv2.warpPerspective(
        image, M,
        (output_width, output_height),
        flags=cv2.INTER_LINEAR,
        borderMode=cv2.BORDER_CONSTANT,
        borderValue=(255, 255, 255)  # White background for areas outside page
    )

    metadata = {
        'transformation_matrix': M,
        'source_corners': corners,
        'output_size': (output_width, output_height),
        'margin': (margin_x, margin_y),
        'corner_source': fallback_reason or 'detected'
    }
```

```
    return cropped, metadata

# Alternative: Use center of QC squares instead of corners
def get_page_corners_from_qc_centers(results):
    """
    Extract page corners using the center of each QC square.
    This is useful if you want the page boundary to be at the center of the QC squa
    """
    corners = {}

    for result in results:
        if result is None:
            continue
        corner = result.get('corner')
        bbox = result.get('bbox')

        if corner and bbox:
            x, y, w, h = bbox
            # Use center of bounding box
            center_x = x + w / 2
            center_y = y + h / 2
            corners[corner] = (center_x, center_y)

    required_corners = ['tl', 'tr', 'bl', 'br']
    if all(corner in corners for corner in required_corners):
        return corners
    else:
        missing = [c for c in required_corners if c not in corners]
        print(f"Warning: Missing corners: {missing}")
        return None

# Visualization function to show the crop region
def visualize_crop_region(image, results, show_corners=True):
    """
    Visualize the crop region defined by QC squares.
    """
    corners, _ = get_page_corners_from_qc(results)
    if corners is None:
        print("Cannot visualize: missing corners")
        return None

    # Create a copy to draw on
    display_image = image.copy()

    # Draw lines connecting corners
    corner_order = ['tl', 'tr', 'br', 'bl', 'tl']  # Close the polygon
    points = [corners[corner] for corner in corner_order]
    points = np.array(points, dtype=np.int32)

    # Draw polygon outline
    cv2.polylines(display_image, [points], isClosed=True,
                  color=(0, 255, 0), thickness=3)

    # Draw corner points
    if show_corners:
        for corner_name, (x, y) in corners.items():
```

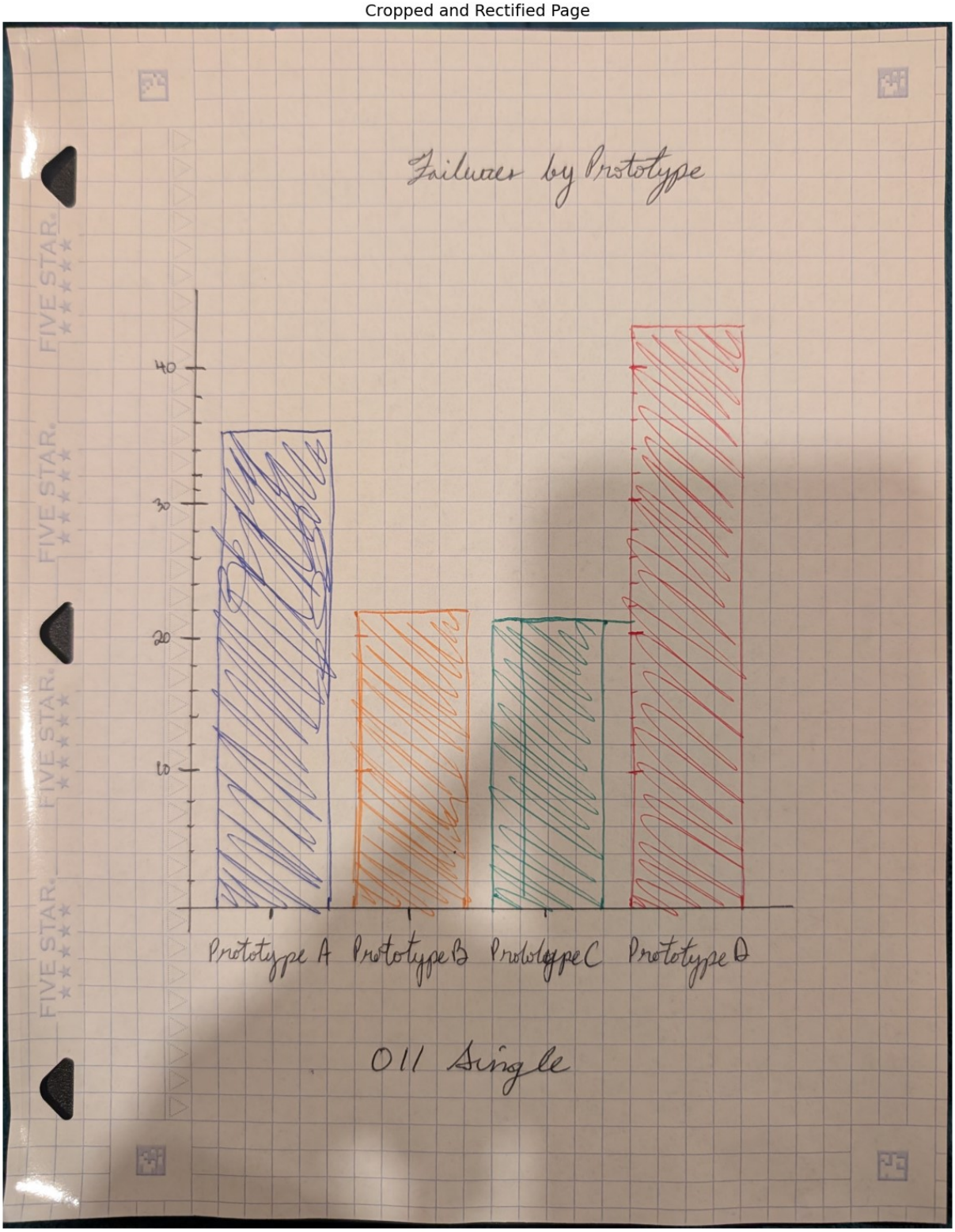
```
            cv2.circle(display_image, (int(x), int(y)), 10, (255, 0, 0), -1)
            cv2.putText(display_image, corner_name.upper(),
                        (int(x) + 15, int(y)),
                        cv2.FONT_HERSHEY_SIMPLEX, 0.7, (255, 0, 0), 2)

    return display_image
```

## Test

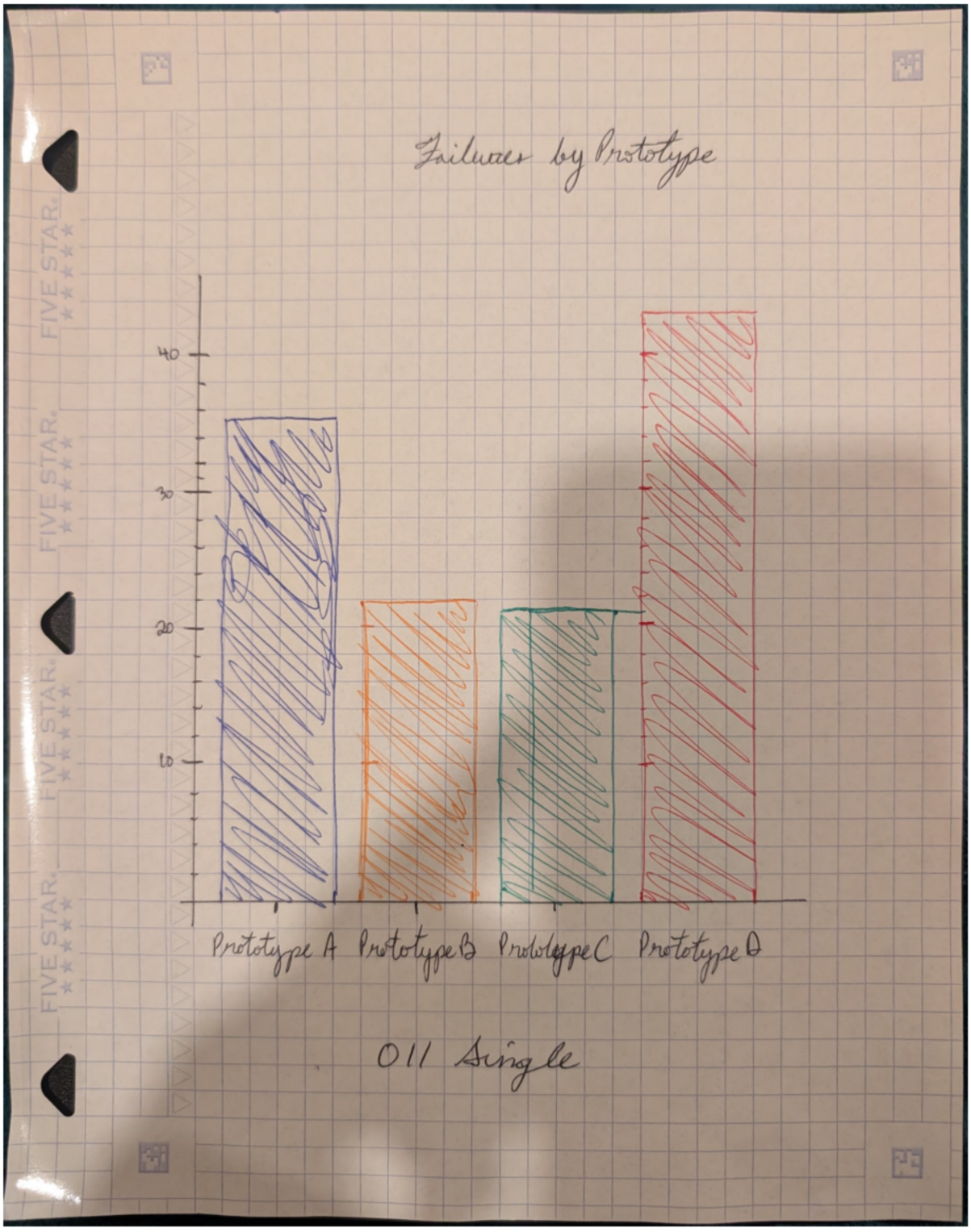
In [14]:
```
def visualize_cropped_result(cropped_image, title="Cropped and Rectified Page", fig
    """
    Visualize the cropped/rectified image result.

    Parameters:
    -----------
    cropped_image : numpy.ndarray
        The cropped image result
    title : str
        Title for the plot
    figsize : tuple
        Figure size for matplotlib
    """
    fig, ax = plt.subplots(1, 1, figsize=figsize)
    ax.imshow(cropped_image)
    ax.set_title(title, fontsize=14)
    ax.axis('off')
    plt.tight_layout()
    return fig
```

In [15]:
```
# Load and detect
image_path = 'hand_drawn_notes/bc_011_single-004.jpg'
image = cv2.imread(image_path)
rgb_image = cv2.cvtColor(image, cv2.COLOR_BGR2RGB)
results = detect_qc_square(rgb_image, corner='auto')

# Crop the image
cropped_image, metadata = crop_image_using_qc_corners(
    rgb_image, results, margin=20
)

# Show the cropped result
fig = visualize_cropped_result(cropped_image)
plt.figure(figsize=(12, 15))
plt.imshow(cropped_image)
plt.title('Cropped Result')
plt.axis('off')
plt.show()

fig.savefig('output_files/bc_011_single_cropped.png', dpi=150, bbox_inches='tight')
```

Cropped and Rectified Page



Cropped Result




# Rotated Photo

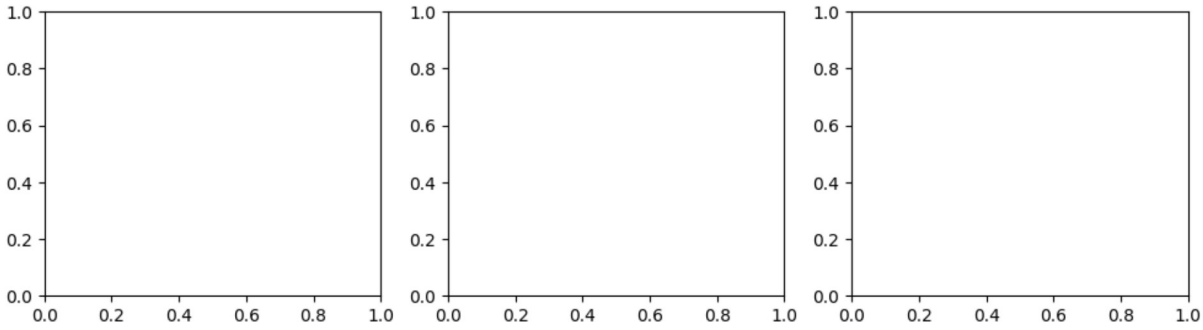
In [16]:
```
NotImplementedError
```

Out[16]:
```
NotImplementedError
```

## Gallery of Processed Images

In [21]:
```
# Gallery of Processed Images

import matplotlib.pyplot as plt
import matplotlib.patches as patches
# from normalize_image import detect_qc_square  # adjust import path
import cv2
import math

image_paths = [

...

]  # Selection
ncols = 3
nrows = math.ceil(len(image_paths) / ncols)
fig, axes = plt.subplots(nrows, ncols, figsize=(ncols * 4, nrows * 3))

for ax, path in zip(axes.flat, image_paths):
  image = cv2.cvtColor(cv2.imread(path), cv2.COLOR_BGR2RGB)
  results = detect_qc_square(image, corner='auto')
  ax.imshow(image)
  ax.axis('off')
  for result in results or []:
      x, y, w, h = result['bbox']
      color = {'tl':'red','tr':'green','bl':'blue','br':'orange'}.get(result['corne
      rect = patches.Rectangle((x, y), w, h, edgecolor=color, facecolor='none', lw=
      ax.add_patch(rect)
      ax.text(x, y - 5, f"{result['corner']} {result.get('confidence',0):.0%}", col
              bbox=dict(facecolor=color, alpha=0.6, pad=1), fontsize=8)

for ax in axes.flat[len(image_paths):]:
  ax.remove()
plt.tight_layout()
plt.savefig("output_files/qc_corner_gallery.png", dpi=150)
```

```
---------------------------------------------------------------------------
error                                     Traceback (most recent call last)
Cell In[21], line 19
     16 fig, axes = plt.subplots(nrows, ncols, figsize=(ncols * 4, nrows * 3))
     18 for ax, path in zip(axes.flat, image_paths):
---> 19   image = cv2.cvtColor(cv2.imread(path), cv2.COLOR_BGR2RGB)
     20   results = detect_qc_square(image, corner='auto')
     21   ax.imshow(image)

error: OpenCV(4.12.0) :-1: error: (-5:Bad argument) in function 'imread'
> Overload resolution failed:
>  - Expected 'filename' to be a str or path-like object
>  - Expected 'filename' to be a str or path-like object
>  - Expected 'filename' to be a str or path-like object
```




In [ ]: