

Testing Plan for **dvi3v** project

v3.9.2.208

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1 Introduction

1.1 Purpose

This document defines a comprehensive testing plan for the `dvi3v` system (jig + software) to validate functionality, identify edge cases, and establish quality baselines.

1.2 Scope

- Hardware jig validation

- Software object extraction accuracy
- Scale detection reliability
- Edge case handling
- Quality metrics establishment

1.3 Success Criteria

- 95% successful extraction for standard objects
- Scale accuracy within $\pm 2\%$ for A4 reference
- Graceful degradation for edge cases
- Clear error messages for failures

2 Test Categories

2.1 Category 1: Baseline Validation Tests

2.1.1 Purpose

Establish system works correctly under ideal conditions.

2.1.2 Test Objects

1. Simple Geometric Shapes

- Black circle (25mm, 50mm, 75mm diameter)
- Black square (25mm, 50mm, 75mm sides)
- Black rectangle (50mm $\times$ 100mm)
- Black triangle (equilateral, 80mm sides)

Why: Known dimensions for accuracy validation **Expected:** ± 1 mm accuracy, clean contours

2. Reference Standards

- Printed reference card with known dimensions
- Calibration target (checkerboard pattern)

Why: Establish baseline measurement accuracy **Expected:** Exact dimensional match

2.1.3 Validation Method

- Measure physical objects with calipers ($\pm 0.1\text{mm}$)
- Compare SVG dimensions with physical measurements
- Calculate error percentage
- Document scale detection method (A4 vs base-feet when implemented)

2.1.4 Success Metrics

- Dimensional error $< 2\%$ for all baseline objects
- Contour completeness 100% (no gaps)
- Consistent scale detection across multiple captures

2.2 Category 2: Material and Contrast Tests

2.2.1 Purpose

Test detection across different materials and contrast levels.

2.2.2 Test Objects by Material

1. Matte Materials

- Matte black paper cutout
- Matte colored paper (red, blue, green)
- Cardboard (brown)

Why: No reflections, ideal for detection **Expected:** Near-perfect extraction

2. Glossy Materials

- Glossy black paper
- Laminated card
- Photo print

Why: Reflections may confuse edge detection **Expected:** May need lighting adjustment or threshold tuning

3. Textured Materials

- Fabric swatch
- Textured cardboard

- Cork

Why: Texture may create noise in binary threshold **Expected:** May need morphological operation tuning

4. Transparent/Translucent

- Clear plastic shape
- Frosted plastic
- Colored acetate

Why: Edge case - minimal contrast **Expected:** Likely to fail, documents limitations

5. Metallic/Reflective

- Aluminum cutout
- Copper shape
- Chrome-plated object

Why: Specular reflections, extreme edge case **Expected:** High failure rate, documents limitations

2.2.3 Test Matrix

Material Type	Black	White	Red	Blue	Green	Yellow
Matte paper	✓	✓	✓	✓	✓	✓
Glossy paper	✓	-	✓	-	-	-
Textured	✓	-	-	-	-	-
Transparent	-	-	✓	✓	-	-
Metallic	-	✓	-	-	-	-

✓ = Required test, - = Optional

2.2.4 Validation Method

- Document threshold value needed for successful extraction
- Note any preprocessing required (lighting adjustment)
- Measure extraction quality score
- Photograph failure cases for documentation

2.3 Category 3: Shape Complexity Tests

2.3.1 Purpose

Validate handling of increasingly complex shapes.

2.3.2 Test Objects (Ordered by Complexity)

1. Level 1 - Convex Shapes (No Holes)

- Circle, square, triangle (already in baseline)
- Ellipse
- Pentagon, hexagon, octagon
- Smooth organic shape (leaf outline)

Expected: Perfect extraction

2. Level 2 - Concave Shapes

- Star shape (5-pointed)
- Crescent moon
- Hand silhouette
- Letter shapes (C, G, S)

Expected: Good extraction, may need contour simplification

3. Level 3 - Shapes with Holes

- Ring (donut shape)
- Letter O, B, P, A
- Picture frame shape
- Swiss cheese pattern (multiple holes)

Expected: Requires `--no-holes` flag testing **Critical:** Known issue to validate fix for

4. Level 4 - Thin Features

- Scissors (thin blades)
- Key (thin shaft)
- Fork/spoon (tines/handle)
- Wire frame object

Expected: Thin features may disappear with threshold **Test:** Threshold sensitivity

5. Level 5 - High Detail

- Gear (teeth)
- Snowflake pattern
- Lace doily
- Circuit board outline

Expected: Detail loss at coarse threshold **Test:** Auto-threshold feature

2.3.3 Complexity Metrics

- Perimeter-to-area ratio
- Number of concave vertices
- Number of holes
- Minimum feature width
- Contour point count in SVG

2.3.4 Validation Method

- Visual inspection of SVG overlay on original photo
- Measure detail preservation percentage
- Test different threshold values (manual and auto)
- Document optimal threshold range per complexity level

2.4 Category 4: Size Range Tests

2.4.1 Purpose

Establish minimum and maximum object size limits.

2.4.2 Test Objects

1. Minimum Size Tests

- 10mm × 10mm square
- 15mm × 15mm square
- 20mm × 20mm square
- 5mm diameter circle

- 10mm diameter circle

Why: Find lower detection limit **Expected:** Below certain size, lost in noise or margin

2. Maximum Size Tests

- 180mm × 250mm rectangle (nearly full A4)
- Object extending to paper edges
- Object larger than paper (partially off-frame)

Why: Test margin handling and cropping **Expected:** Margin settings become critical

3. Aspect Ratio Extremes

- 200mm × 10mm strip (20:1 ratio)
- 10mm × 200mm strip (1:20 ratio)
- Very elongated ellipse

Why: Test bounding box calculation **Expected:** Should handle well but may challenge auto-cropping

2.4.3 Validation Method

- Binary search for minimum detectable size
- Test with different margin settings (0mm, 2mm, 5mm)
- Document size limits in documentation
- Verify no clipping at maximum sizes

2.5 Category 5: Positioning Tests

2.5.1 Purpose

Validate center-priority detection algorithm.

2.5.2 Test Scenarios

1. Center Position (Baseline)

- Object exactly centered on A4

Expected: Always selected correctly

2. Off-Center Positions

- 25mm from center (4 directions: N, S, E, W)
- 50mm from center
- 75mm from center
- Near edge of A4 (10mm margin)

Expected: Should still detect if within reasonable distance

3. Multiple Objects Test

- Two identical objects: one centered, one at edge
- Three objects: small centered, large at edges
- Multiple small objects scattered

Expected: Center object selected **Validation:** Confirms center-priority algorithm

4. Rotated Placement

- Object rotated 45°, 90°, 180°

Why: Ensure rotation doesn't affect detection **Expected:** No impact on detection

2.5.3 Validation Method

- Photograph grid positions (3×3 grid on A4)
- Test each grid position
- Document detection success rate vs. distance from center
- Create heat map of detection reliability

2.6 Category 6: Lighting Condition Tests

2.6.1 Purpose

Establish lighting requirements and robustness.

2.6.2 Test Conditions

1. Uniform Lighting (Baseline)

- Diffuse overhead light
- Shadowless, even illumination

Expected: Ideal conditions, 100% success

2. Directional Lighting

- Single light source from left
- Single light source from above
- Creates shadow on one side

Expected: Shadow may be detected as part of object **Test:** Shadow impact on dimensions

3. High Contrast Lighting

- Direct sunlight
- Very bright studio lights

Expected: May cause overexposure or harsh shadows **Test:** Threshold adjustment needed

4. Low Light

- Dim indoor lighting
- Evening/twilight conditions

Expected: Reduced contrast, may need exposure adjustment **Test:** Camera exposure compensation needed

5. Mixed Color Temperature

- Daylight + incandescent
- Fluorescent + LED

Expected: Color cast may affect colored object detection **Test:** Impact on threshold for colored objects

2.6.3 Measurement

- Use light meter if available
- Document lux levels
- Photograph test setup showing lighting
- Record camera exposure settings (ISO, shutter, aperture if DSLR)

2.6.4 Validation Method

- Test same object under different lighting
- Compare threshold values required
- Measure dimensional accuracy variance
- Document acceptable lighting ranges

2.7 Category 7: A4 Reference Detection Tests

2.7.1 Purpose

Validate scale detection reliability.

2.7.2 Test Scenarios

1. Optimal A4 Placement

- A4 fully visible, flat, parallel to camera

Expected: 100% detection, accurate scale

2. Partial A4 Obscuration

- Object covering corner of A4
- Object covering 25% of A4
- Object covering 50% of A4

Expected: Detection fails above certain threshold **Test:** Find maximum acceptable obscuration

3. A4 Variations

- White A4 (standard)
- Colored A4 (blue, as in WhatTheCameraSees.jpeg)

- Grid-printed A4
- Textured A4

Expected: Color shouldn't matter if high contrast with base **Test:** Validate `--paper-color` option

4. Non-A4 Papers

- A3 paper (297mm × 420mm)
- A5 paper (148mm × 210mm)
- Letter paper (216mm × 279mm)

Expected: Requires `--paper-format` option **Test:** Validate other ISO formats

5. No Reference Paper

- Object alone on base (no A4)
- Using `--reference-mm` manual override

Expected: Falls back to estimation or manual scale **Test:** Accuracy with manual reference

2.7.3 Validation Method

- Measure A4 detection success rate
- Compare scale accuracy: A4 detected vs. estimated
- Test all supported paper formats
- Document when manual override is necessary

2.8 Category 8: Edge Cases and Failure Modes

2.8.1 Purpose

Document system limitations and error handling.

2.8.2 Edge Cases to Test

1. Extremely Low Contrast

- Gray object on gray background
- White object on white paper

Expected: Detection fails **Validation:** Error message is clear

2. Object Color Same as Base Feet

- Red object on red base feet

Expected: May confuse detection **Test:** Base-feet detection impact

3. Highly Irregular Shapes

- Crumpled paper ball (3D object)
- Tangled string/wire
- Natural twig/branch

Expected: 2D projection may not match expectations **Validation:** Document as out-of-scope for 3D objects

4. Transparent Objects with Opaque Features

- Clear ruler with black markings
- Transparent protractor

Expected: Only opaque parts detected **Test:** Partial extraction behavior

5. Motion Blur

- Intentionally defocused image
- Camera shake simulation

Expected: Fuzzy edges degrade quality **Test:** Quality metric correlation

6. Multiple Overlapping Objects

- Two objects touching
- One object partially behind another

Expected: Detected as single merged object **Validation:** Document requirement for object separation

2.8.3 Validation Method

- Photograph each edge case
- Document error messages or failure modes
- Categorize: "Works with adjustment", "Acceptable degradation", "Documented limitation"
- Update documentation with limitations

2.9 Category 9: Software Option Tests

2.9.1 Purpose

Validate all command-line options work correctly.

2.9.2 Options to Test Systematically

1. Color Options (**-c, --color**)

- All named colors (black, red, blue, etc.)
- Hex colors (#FF0000, #00FF00, etc.)
- Invalid colors (error handling)

2. Margin Options (**-m, --margin-mm**)

- 0mm (no margin)
- 2mm (default)
- 5mm, 10mm (large margins)
- Negative value (error handling)

3. Threshold Options (**-t, --threshold**)

- Range sweep: 20%, 30%, 40%, 50%, 60%, 70%, 80%
- Optimal value per object type
- Auto-threshold (**-a**) validation

4. Auto-Threshold (**-a, --auto-threshold**)

- Different TRIES values (3, 5, 7, 10)
- Compare auto vs manual results
- Performance impact measurement

5. No-Holes Flag (**--no-holes**)

- Objects with holes (ring, letters O/B/P/A)
- Objects without holes (should be identical)
- Known bug validation (if still present)

6. Paper Format (**-p, --paper-format**)

- A4, A3, A5, Letter
- Invalid format (error handling)

7. Debug Mode (-d, --debug)

- Verify all debug images generated
- Check debug directory structure
- Validate debug image content

2.9.3 Validation Method

- Create test matrix: Object $\times$ Option $\times$ Value
- Automated testing where possible (script-driven)
- Document which options affect which object types
- Create "best practices" guide from results

2.10 Category 10: Real-World Object Tests

2.10.1 Purpose

Validate practical usefulness with actual use-case objects.

2.10.2 Common Use-Case Objects

1. Office/Craft Supplies

- Scissors (thin metal)
- Paperclip (wire)
- Pen/pencil
- Stapler
- USB drive
- Key

Why: Common small objects **Expected:** Mixed results due to reflectivity and thin features

2. Electronic Components

- Arduino board
- Raspberry Pi
- PCB (circuit board)
- Component footprints

Why: Technical documentation use case **Expected:** Good for rectangular boards, challenging for components

3. Natural Objects

- Leaf (various species)
- Flower petal
- Feather
- Rock/pebble cross-section

Why: Organic shapes, educational use **Expected:** Good for flat objects, poor for 3D

4. Fashion/Textiles

- Button
- Zipper pull
- Fabric swatch
- Pattern template

Why: Design/craft use case **Expected:** Flat items good, 3D items poor

5. Maker/Prototyping

- 3D printed part
- Laser-cut template
- Gasket/washer
- Mechanical part

Why: Reverse engineering, documentation **Expected:** Excellent for flat parts

2.10.3 Validation Method

- Prioritize objects from actual user requests/use cases
- Create gallery of successes and failures
- Document workarounds for common object types
- Build "object type → settings" recommendation table

3 Test Execution Plan

3.1 Phase 1: Baseline

- Category 1: Baseline validation
- Category 4: Size range (partial - standard sizes)
- Establish measurement procedures
- Create test templates and documentation forms

Deliverable: Baseline accuracy report, measurement protocols

3.2 Phase 2: Systematic Coverage

- Category 2: Materials
- Category 3: Shape complexity
- Category 5: Positioning
- Build test object library

Deliverable: Material compatibility matrix, shape complexity limits

3.3 Phase 3: Environmental

- Category 6: Lighting conditions
- Category 7: A4 reference detection
- Document environmental requirements

Deliverable: Setup guide, lighting requirements

3.4 Phase 4: Edge Cases

- Category 8: Failure modes
- Category 9: Software options (systematic)
- Document all limitations

Deliverable: Known limitations document, troubleshooting guide

3.5 Phase 5: Real-World Validation

- Category 10: Practical objects
- Integration testing
- User acceptance scenarios

Deliverable: Use case gallery, best practices guide

3.6 Phase 6: Regression (Ongoing)

- Maintain test suite
- Test with each software version
- Add tests for bug fixes

Deliverable: Automated test suite

4 Test Documentation Requirements

4.1 For Each Test

Record:

- Test ID and category
- Object description and photo
- Physical measurements (caliper readings)
- Camera settings used
- Lighting conditions
- Command line used
- SVG output
- Dimensional comparison (actual vs SVG)
- Error percentage
- Notes on quality/issues

4.2 Test Result Database

Structure:

```
test_results/
├─ baseline/
│   ├─ circle_50mm/
│   │   ├─ photo.jpg
│   │   ├─ output.svg
│   │   └─ Measurements.org
│   │   └─ Notes.org
│   └─ square_100mm/
│   └─ ...
├─ materials/
├─ complexity/
└─ ...
```

4.3 Success/Failure Criteria Matrix

Category	Success Rate	Max Error	Notes
Baseline geometric	> 95%	< 2%	Fundamental
Matte materials	> 90%	< 3%	Common case
Glossy materials	> 70%	< 5%	May need tuning
Complex shapes	> 80%	< 4%	Level dependent
Size range (20-180mm)	> 90%	< 3%	Normal range
A4 detection	> 95%	< 1%	Critical

5 Test Equipment and Materials

5.1 Required Equipment

- Google Pixel 9a (or equivalent smartphone) - primary camera
- Digital calipers ($\pm 0.1\text{mm}$ precision)
- Light meter (optional but recommended)
- Color reference card (X-Rite ColorChecker or similar)
- Ruler/straightedge (300mm, metric)

5.2 Test Materials to Acquire

- Black matte paper (A4 sheets)
- Colored matte paper (red, blue, green, yellow)
- Glossy photo paper
- Cardboard samples
- Transparent acetate sheets
- Aluminum sheet (thin, cuttable)
- Various A4 colored papers for reference tests
- A3, A5, Letter size papers

5.3 Test Object Creation

Precision-cut geometric shapes (laser cut or die cut), 3D printed test shapes, and printed patterns on cardstock. The 3D printed shapes are the primary dimensional standard in current use; the material below documents how they are made, measured, and why, folded in from a former standalone note.

5.3.1 Directory Structure

`TestInstrumentation/GeometricShapes/` holds one subdirectory per test object, each named for its known dimensions (`Circle50mm/`, `Square25mm/`, `Rectangle50x100mm/`, `Triangle80mm/`, etc.). The reference calibration target lives separately, in `TestInstrumentation/ReferenceCard/` — see [ReferenceCard.org](#).

Each geometric shape directory holds:

1. `ObjectName.scad` — OpenSCAD source with precise dimensions
2. `ObjectName.stl` — exported STL for 3D printing (optional, can be regenerated from the `.scad`)
3. `ObjectName.3mf` — PrusaSlicer project with the actual manufacturing settings used
4. `PhysicalMeasurements.org` — caliper measurements after printing
5. `Notes.org` — observations about the printed object

Org-mode files (points 4-5) were chosen for structured tables and checkboxes, L^AT_EX/PDF export if a report is needed, and plain-text, version-control-friendly storage — consistent with the rest of the project. `.3mf` files (point 3) capture the complete manufacturing context (slicer settings, print orientation, material, infill, perimeters, supports) in one place,

alongside the `.scad` source, so a print can be reproduced exactly, what actually worked (vs. what was merely recommended) is on record, and settings are easy to compare if a print fails.

5.3.2 Actual Manufacturing Settings

All geometric test shapes were printed with these settings (recorded in each object's own `.3mf`):

Material Black PLA (matte finish)

Printer Prusa XL with 0.6mm HF nozzle

Tool used Tool 1 / Extruder 1 (second extruder)

Layer height 0.2mm

Infill 100% (solid objects)

Speed 30mm/s (perimeters, infill, external perimeters); 40mm/s first layer

Nozzle temperature 230°C (PLA)

Bed temperature 60°C

30mm/s was chosen deliberately over the printer's 200mm/s capability, trading print time for dimensional accuracy. These are test instrumentation settings, distinct from the hardware/jig components (see ManufacturingConfig.org), which use PETG on tool 0.

Black matte PLA specifically, rather than the jig's PETG: PLA shrinks less than PETG (~0.3% vs ~0.7%, mattering for dimensional accuracy), a matte surface minimizes reflections in photographs, black gives high contrast against white A4 paper, PLA prints at lower temperature with less warping, and it is lower cost for consumable, deliberately-replaceable test objects.

5.3.3 Post-Processing and Measurement

After printing:

1. Remove carefully from the bed; let cool completely (30+ minutes)
2. Remove any brim/raft carefully
3. Measure with calipers (± 0.1 mm precision)
4. Record actual dimensions in PhysicalMeasurements.org
5. Compare to the `.scad` source's nominal dimensions
6. Accept if within ± 0.2 mm tolerance

The known dimensions — from both the `.scad` source and the physical caliper measurements — are what `dvi3v`'s extracted SVG dimensions are validated against.

6 Quality Metrics

6.1 Dimensional Accuracy

$\text{Error}_{\%} = |\text{SVG_dimension} - \text{Actual_dimension}| / \text{Actual_dimension} \times 100$

6.2 Contour Completeness

- Visual inspection: complete/incomplete
- Point count comparison (complex shapes)

6.3 Detection Reliability

$\text{Reliability} = \text{Successful_detections} / \text{Total_attempts} \times 100$

6.4 Processing Time

- Measure end-to-end time per object
- Identify performance bottlenecks

6.5 Quality Score

Composite metric (0-100):

- Dimensional accuracy: 40 points
- Contour completeness: 30 points
- Edge smoothness: 20 points
- Hole preservation: 10 points

7 Automated Testing Strategy

7.1 Script-Based Testing

Create test harness:

```
#!/bin/bash
# test_runner.sh

for test in test_cases/*.jpg; do
    name=$(basename "$test" .jpg)
```

```
dvi3v "$test" "results/${name}.svg"  
# Validate output  
# Record metrics  
done
```

7.2 Validation Scripts

- SVG dimension extractor
- Comparison with ground truth
- Automated report generation

7.3 Regression Testing

- Maintain known-good test set
- Run on each version release
- Flag dimensional changes $> 0.5\%$

8 Expected Outcomes

8.1 Documentation Deliverables

1. Test Results Database
2. Material Compatibility Matrix
3. Shape Complexity Limits Guide
4. Lighting Requirements Specification
5. Best Practices Guide
6. Troubleshooting Decision Tree
7. Known Limitations Document

8.2 Software Improvements

Based on testing, prioritize:

- Auto-threshold refinement
- Better error messages for edge cases
- See FutureResearch.org for tracked, not-yet-implemented features (base-feet detection, multi-object detection, perspective correction, etc.)

8.3 Hardware Improvements

If needed:

- Lighting recommendations (LED ring?)
- Background color optimization
- Camera position fine-tuning

9 Risk Assessment

9.1 High Risk Items

- Glossy/reflective objects may have low success rate
- Very small objects (<15mm) may be unreliable

9.2 Mitigation Strategies

- Document workarounds for problematic materials
- Establish minimum size guidelines upfront

10 Conclusion

This comprehensive testing plan provides systematic validation of the `dvi3v` system across multiple dimensions: object types, materials, sizes, lighting conditions, and software options.

Working through the phases establishes quality baselines, documents limitations, and guides development priorities.

The structured approach ensures reproducibility and builds a knowledge base for users and developers.