AprilCal: Assisted and Repeatable Camera Calibration

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Why do we need a new calibrator?
Repeatability
Calibration Target Design
Evaluation Metrics
Feedback
Expert Calibration Knowledge
Repeatability
Why do we need a new calibrator?

- Calibration is a fundamental prerequisite
- Accuracy is crucial
- Not all users are calibration experts

Real human study calibration images (OpenCV + ‘web instructions’)
Common Calibrator Issues

- **Repeatability**: Lacking for many users
- **Calibration targets**: Hard to get any constraints in distorted corners
- **Evaluation metrics**: Training error reflects only seen data, parameter uncertainties very unintuitive
- **Little feedback**: User has to guess when the calibration is done
- **Experiment design**: User must understand which images are ‘good’
AprilCal
AprilCal

- Interactive, suggestion-based calibrator
- Realtime marker detection with fiducial markers (AprilTags)
- Intuitive worst-case error metric for generating suggestions and automatic completion
Two Biggest Takeaways

1. Suggestion-based calibration improves repeatability

2. New evaluation metric summarizes calibration uncertainty intuitively, can be used as stopping criterion
   • Suggestions not required to use this metric
How can we generate suggestions?
Generating Suggestions

- Live, adaptive suggestions (not choreography)
- Concepts:
  - **Candidate poses**: database of candidate target positions spread over working area
Generating Suggestions

■ Live, adaptive suggestions (not choreography)

■ Concepts:
  ■ **Candidate poses**: database of candidate target positions spread over working area
  ■ **Frame scorer**: algorithm to rank a candidate pose. Two scorers (Intrinsics variance and Max Expected Reprojection Error)

■ Method:
  ■ For each candidate pose
    ■ Copy the calibration state
    ■ Observe target using mean model
    ■ Update model estimate
    ■ Evaluate frame score
    ■ Return pose with best score
Max Expected Reprojection Error (Max ERE)

- Worst-case expected error across the image, computed empirically via sampling

- Algorithm:
  - Marginalize-out observations
  - For N trials:
    - Sample calibration parameters from distribution
    - Observe a set of control points
    - Update Local ERE for each control point
  - Compute Max ERE
Max ERE Animation

Reference:
- Mean

Samples:
- Focal length
- Focal center
- Distortion
Max ERE Animation

Reference:
- Mean

Samples:
- Focal length
- Focal center
- Distortion

Metrics:
- Local ERE
- Max ERE
Images are shown in grayscale and mirrored for display purposes.

Align live detections with similarly-colored outlines.
Evaluation Preview

- 16-participant user study vs. OpenCV
- **Best** OpenCV MaxRE worse than **worst** AprilCal MaxRE
- Very accurate, very repeatable
Thanks!

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Software online:
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See me for a demo!
Error Distribution

(a) OpenCV (Radial, 3 dist. terms)  (b) AprilCal (Radial, 3 dist. terms)