Robust Methods for Accurate 3D Measurement in Multiview Systems

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Imagination in progress

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3D Inspection

Problem
- ✓ 100% Inspection of 3D shapes in Automotive Part Manufacturing Lines

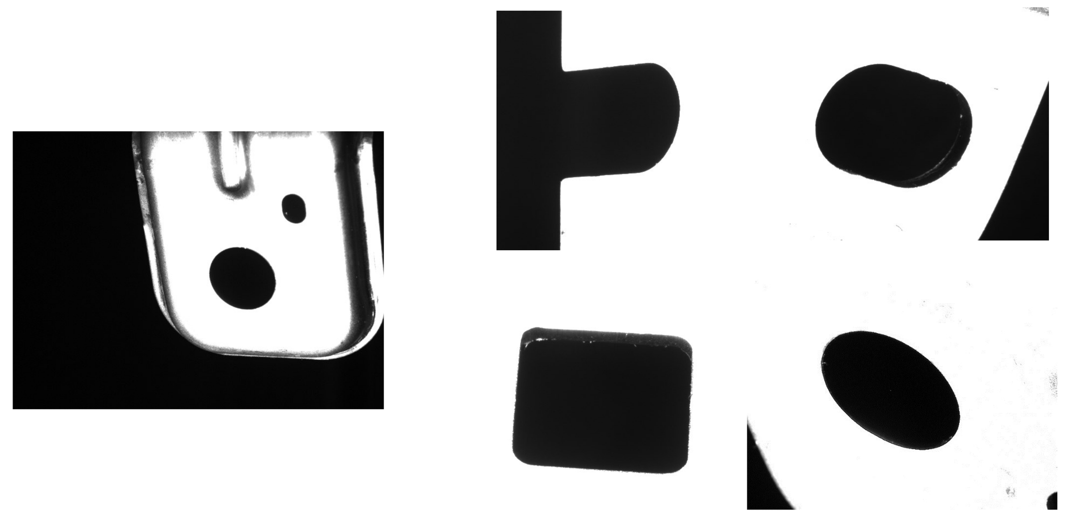
Current State
- ✓ Sector Relies on Mechanical CMM Devices
- ✓ 100% inspection is not done due to its high cost
- ✓ Only up to 0.1 % sampling is done [1]

What We Propose
- ✓ Accurate CAD fitting for %100 Inspection of Parts
- ✓ Invariant from Primitive Parametrization

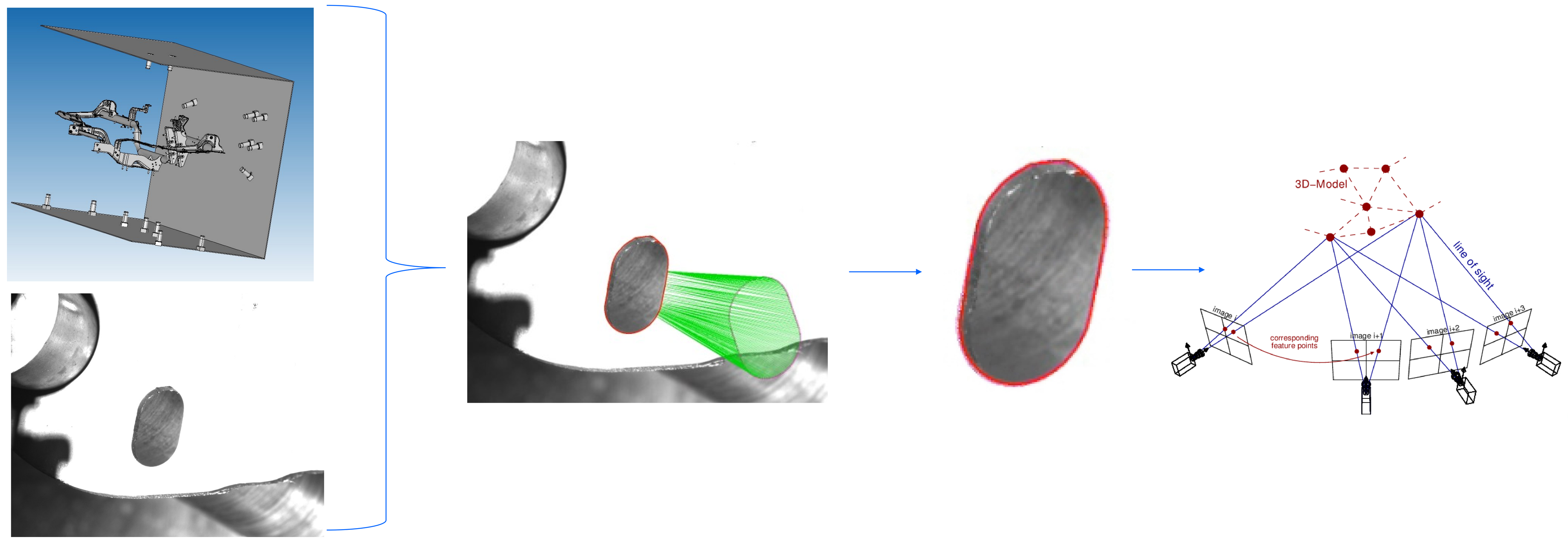
What Else is Done?
- ✓ Fitting of Primitives Using Geometric Active Shape Models [2]
- ✓ Calibrated / uncalibrated bundle adjustment, SLAM and SFM [3]
- ✓ Multiview Calibration and Triangulation
- ✓ Primitive Based Fitting of 3D Holes [4]

What Is Not There?
- ✓ A Generic, Multiview, Primitive Invariant Fitting
- ✓ Accurate Measurement in Multiview Systems
- ✓ A Full 3D Inspection System with 100 % Inspection Capability

Multiview Setup
- ✓ 1280 x 960, 30fps Monochrome Cameras
- ✓ 25 mm Lenses
- ✓ 3 Cameras per Measurement Point
- ✓ White LED Illumination



Our Approach



Inputs: CAD Model and Image | Subpixel Edges & Initial Pose | Projective Optimization | 3D Triangulation

Multiview Calibration
- ✓ Circular Control Points
- ✓ Zhang Like Minimization [5]
- ✓ Estimation of Extrinsics from Iterative Calibration

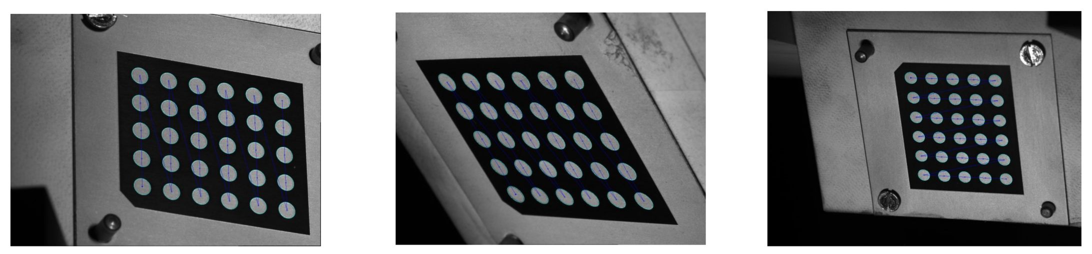


Figure 3. Calibration Targets from 3 Cameras

Subpixel Edge Extraction
- ✓ Third Order Edge Filter [6]
- ✓ Polynomial Refinement
- ✓ Further Processing and Linking [7]
- ✓ At least 1/20th of a pixel accuracy

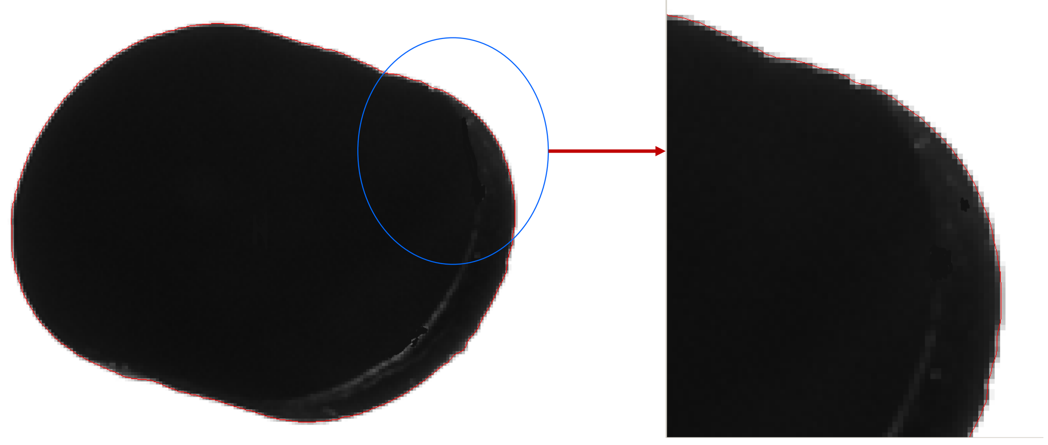


Figure 5. Demonstration of subpixel accuracy

Accurate Projective Primitive Fitting

$$E(\theta)=\sum_{i=1}^{N}\sum_{j=1}^{K} w_j^i \| S_j^i(\theta) - Q^i(T(X_j,\theta)) \|$$

- ✓ Minimize the distance of the projection of 3D transformed points to the closest 2D edge points
- ✓ Levenberg Mardquardt Minimization
- ✓ KD-Tree for Closest Point Computation
- ✓ Projective LM-ICP
- ✓ Parameter Estimate: Quaternion + Translation
- ✓ Scale is fixed
- ✓ Weights can be computed in a robust manner e.g. Huber, Tukey

Advantages
- ✓ Only depends on CAD Model: Free of parametrization
- ✓ Efficient (Convergence in ~150 ms)
- ✓ Robust to Surface Noise and Defects
- ✓ Easy to incorporate other regularizers or robust methods

- [1] *Valtteri Tuominen* , Cost Modeling of Inspection Strategies in Automotive Quality Control
- [2] *Filippo Bergamasco, Luca Cosmo, Andrea Albarelli and Andrea Torsello* A Robust Multi-Camera 3D Ellipse Fitting for Contactless Measurements
- *[3] Hartley, R.~I. and Zisserman,* A. Multiple View Geometry in Computer Vision
- [4] *Malassiotis, Sotiris and Strintzis, MichaelG.Stereo vision system for precision dimensional inspection of 3D holes*
- [5] *Z. Zhang* A flexible new technique for camera calibration
- [6] *Tamrakar, A., and B. B. Kimia*, No Grouping Left Behind: From Edges to Curve Fragments
- [7] *Carsten Steger*, SUBPIXEL-PRECISE EXTRACTION OF LINES AND EDGES

Results

Visual

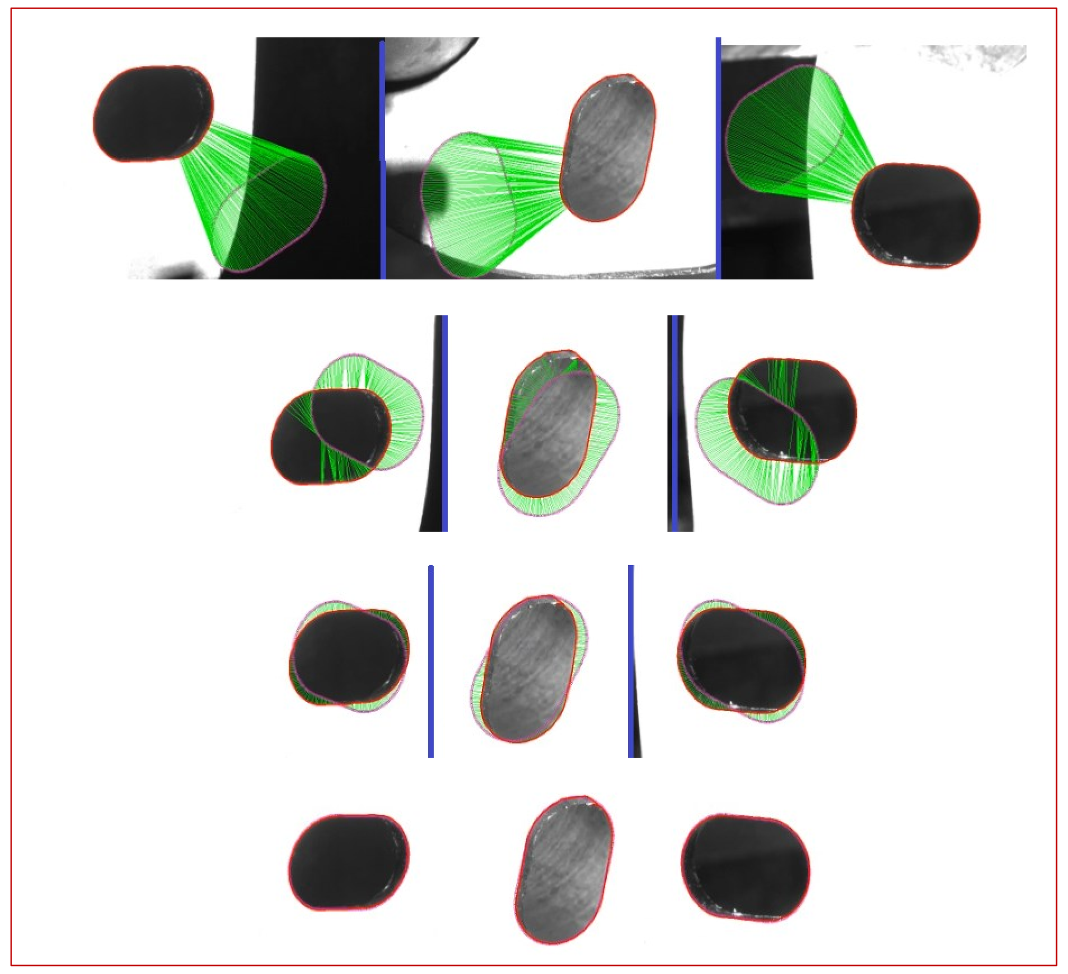


Figure 7. Iterative convergence of CAD fitting

Numerical

NO	Coord.	CMM	Measured	[+/-] Tol	[+/-] Dev	Result
1	X	2205.92	2205.72	0.60	-0.20	OK
1	Y	-790.61	-790.55	0.60	0.06	OK
1	Z	2214.88	2214.68	0.60	-0.20	OK
2	X	2225.69	2225.76	0.60	0.07	OK
2	Y	-815.06	-815.18	0.60	-0.12	OK
2	Z	1924.92	1924.95	0.60	0.04	OK
3	X	2206.44	2206.49	0.60	0.06	OK
3	Y	789.06	788.87	0.60	-0.19	OK
3	Z	2215.10	2214.95	0.60	-0.15	OK
4	X	2225.71	2225.74	0.60	0.03	OK
4	Y	816.16	816.02	0.60	-0.14	OK
4	Z	1924.92	1924.97	0.60	0.04	OK
5	X	2070.01	2070.17	0.60	0.16	OK
5	Y	-440.01	-439.93	0.60	0.08	OK
5	Z	2132.41	2132.56	0.60	0.15	OK
6	X	2371.60	2371.45	0.60	-0.16	OK
6	Y	15.31	15.18	0.60	-0.12	OK
6	Z	2207.72	2207.59	0.60	-0.13	OK

Figure 1.Results compaaring CMM and our system

Graphical

Our results show that the measurement accuracy is clearly below 0.2mm, which is even below the defacto standard of 3D coordinate measurement.