Active Binocular Range Sensing and Interpretation for Clothing Manipulation

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Structure

- Metric Range Sensing under Dynamic Gaze Control (Dynamic Calibration)
- Accelerated stereo matcher and point cloud computation
- Clothing Surface Topology Analysis:
  - Wrinkles fully specified in terms of shape, length, local orientation and width to allow grasp point detection and selection.
- HexHOG descriptors for 2D contour localisation

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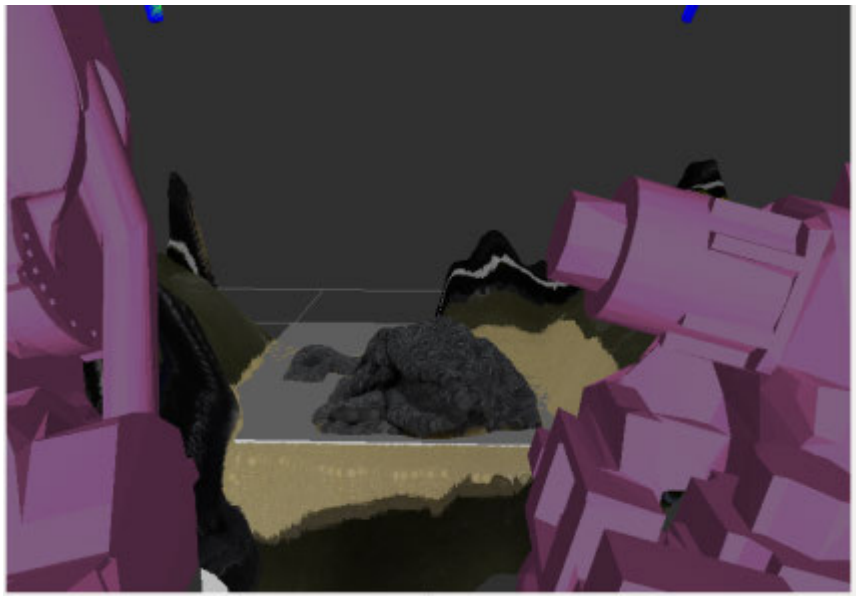
Dynamic Calibration

- Dynamic calibration allows metric ranging under active gaze control
- Hand eye calibration based on Tsai's approach
  - R.Tsai, R.K.Lenz "A new Technique for Fully Autonomous and Efficient 3D Robotics Hand/ Eye calibration", IEEE trans. on robotics and Automation, Vol.5, No.3, June 1989



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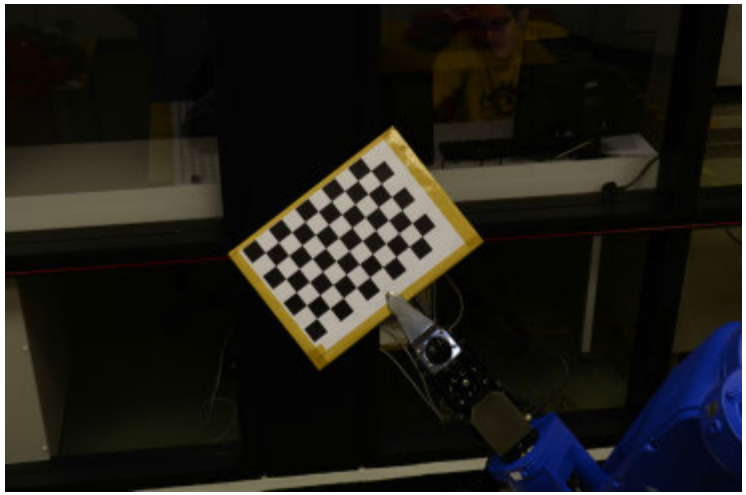
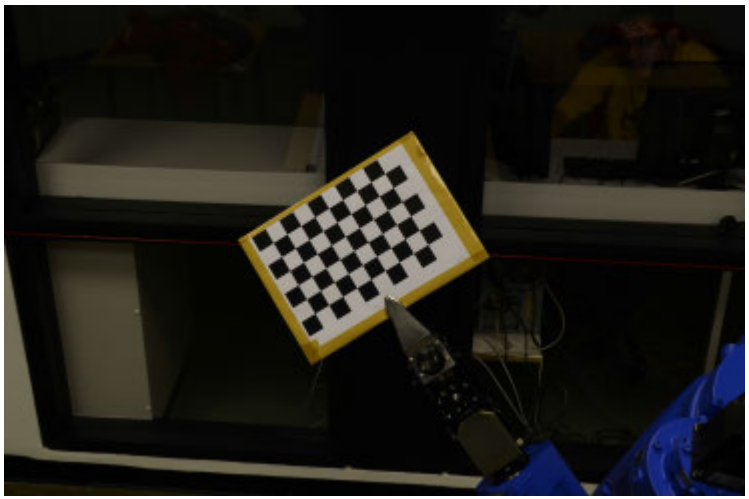
Dynamic Calibration

- Validation:
  1. Compare the reconstruction residuals between the calibrated stereo system and the updated extrinsic camera parameters, and,
  2. verify the accuracy of the reconstructed geometry by measuring the RMSE between a known 3D (ground truth) measurement on the real object and the 3D reconstructed model.



Left



Right

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Dynamic Calibration

Residual errors (in millimetres) between stereo calibration and dynamic calibration of the extrinsic camera parameters. 3D coordinates are expressed with respect to the world reference frame of the robot head.

Pose #	X	Y	Z
1	0.17	-1.03E-02	-3.02E-02
2	1.50E-02	6.37E-02	-4.68E-02
3	2.04E-02	5.14E-02	3.76E-02
4	0.671	-6.69E-02	-0.201
5	0.792	-8.60E-02	-0.111
6	7.82E-02	1.85E-02	-3.47E-02
7	0.427	-3.67E-02	-0.119
8	6.95E-02	1.16E-02	-6.94E-03
9	0.381	-3.22E-02	-6.90E-02
10	0.322	-2.60E-02	1.50E-02
Mean	0.294	-0.0113	-0.056
1 Std	0.275	0.0257	0.06

RMSE (in millimetres) between estimated 3D reconstructed points and ground truth.

Pose #	Mean	1 Std
1	0.1008	0.0772
2	0.0904	0.0349
3	0.1279	0.0674
4	0.3171	0.0725
5	0.0567	0.0601
6	0.1257	0.0679
7	0.2292	0.0776
8	0.2204	0.0778
9	0.0570	0.0577
10	0.3463	0.0699
Overall	***0.1671***	***0.1050***

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GPU Acceleration

Image matching timings

Colour image 24bit, 16MP (3264x4928pixels):

from ~20 minutes to 12.88sec

Pyramid generation timings

Pyramid with 14 level, colour for 16MP takes: **0.46sec**

NOTE: the GPU matcher uses a slightly different approach for iterating over the pyramid levels than the C3D matcher.

Level 1: 2 iterations
Level 2: 4 iterations
Level 3: 6 iterations
Level 4-N: 22 iterations

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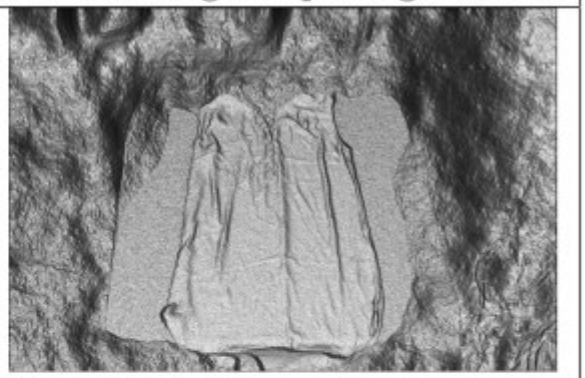
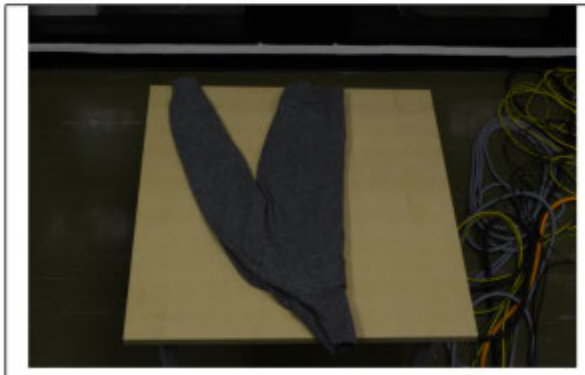
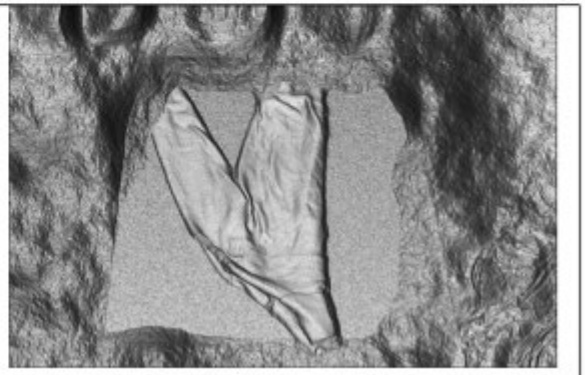
GPU Acceleration

Input Left and Right Images and Range Image for full resolution matching (16 MP images)
Images from: https://sites.google.com/site/ugstereodatabase/

Left image	Right image	Range map image
		
		

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Foveated matching on GPU

Foveated matching timings

Colour image 24bit, 615x407pixels: **3.66sec**

Pyramid generation timings

Pyramid with 14 level, colour for 16MP takes: **0.47sec**

Create foveated pyramid to 615x407pixels takes: **0.0064sec**

NOTE: the foveated matcher is using 16MP (3264 x 4928 pixels) images to generate 615x407pixels foveated images.

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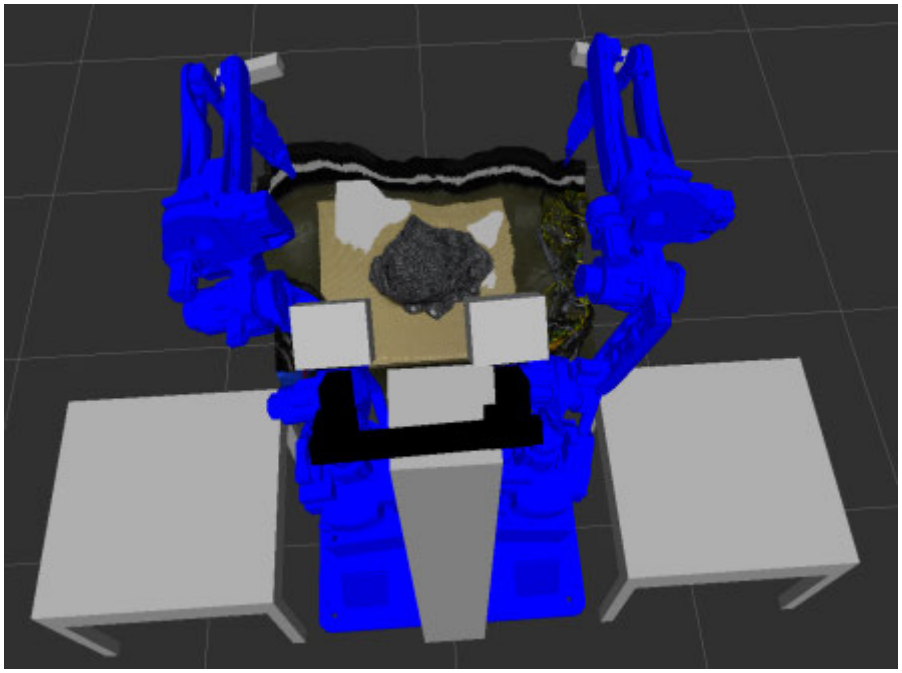
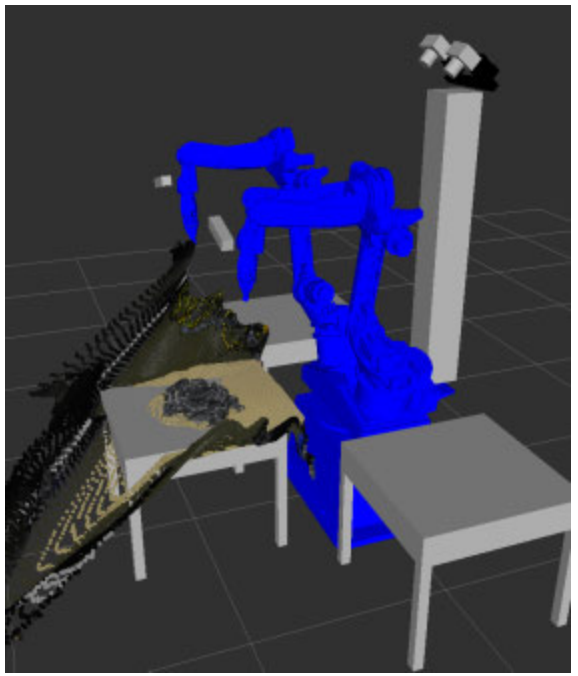
Point cloud acceleration

- Before: ~15 mins to generate a dense point cloud from a 16MP disparity map
- Now: ~500 ms using a simplified least-square stereo reconstruction solution





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Clothing Surface Topology Analysis

- Surface Topology representation:
- Surface regularisation using B-splines
- Shape index grouping categorisation
- Concave-convex boundary with ridge umbilical point detection
- Grouped 2D spline representation for ridges
- Wrinkles fully specified in terms of shape, length, local orientation and width to allow grasp point detection and selection.

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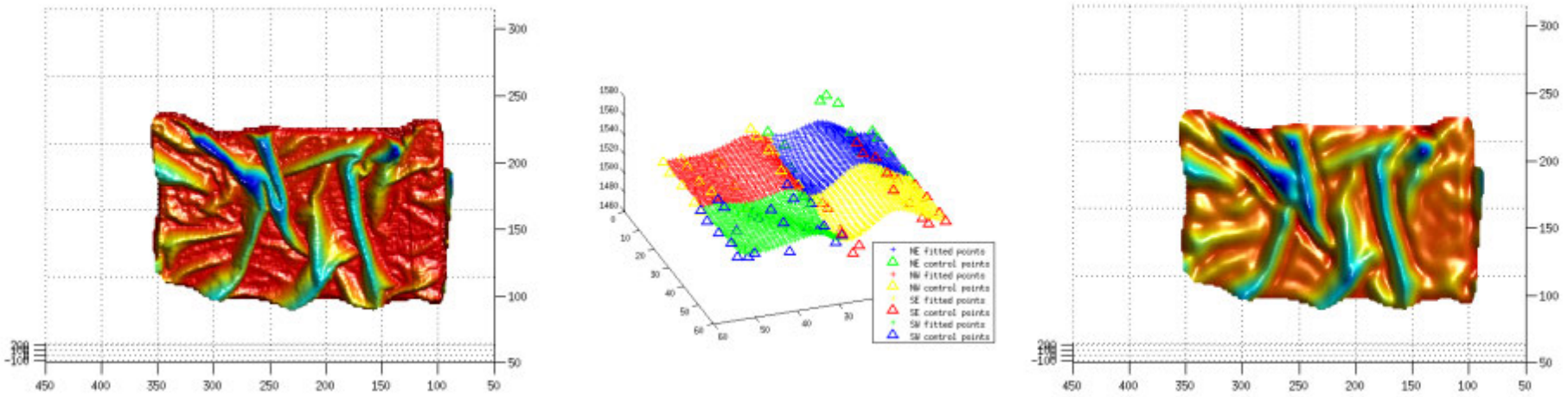
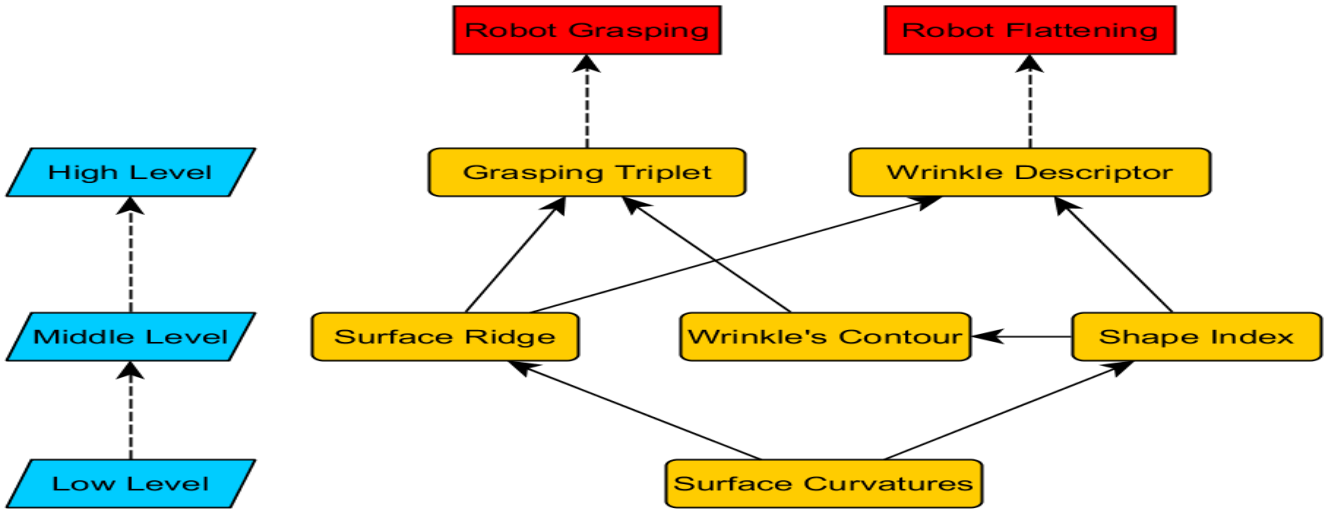
Clothes Surface Topology Analysis

- Piecewise B-Spline Surface Fitting



- Hierarchical Feature Structure



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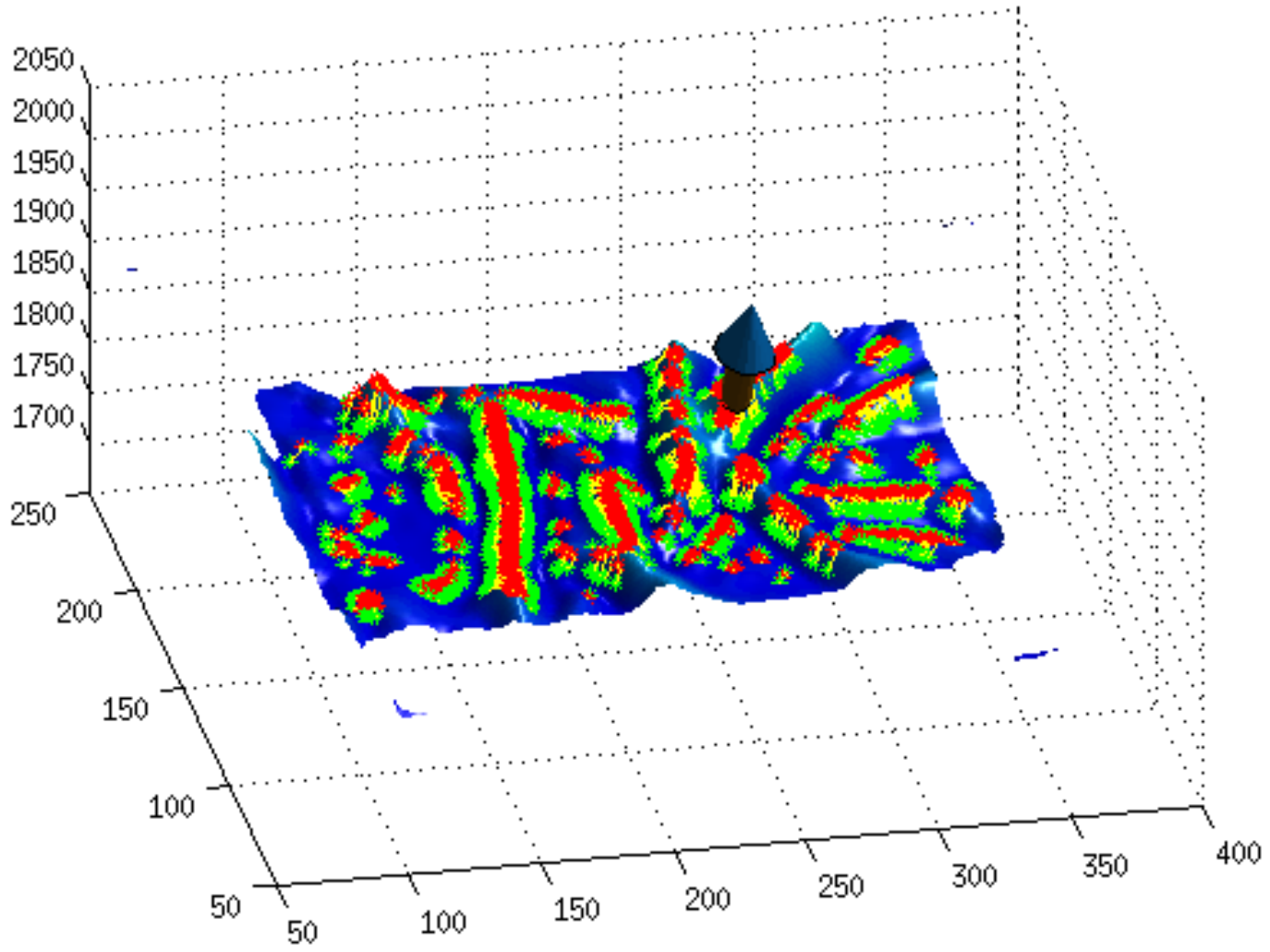
Clothes Surface Topology Analysis



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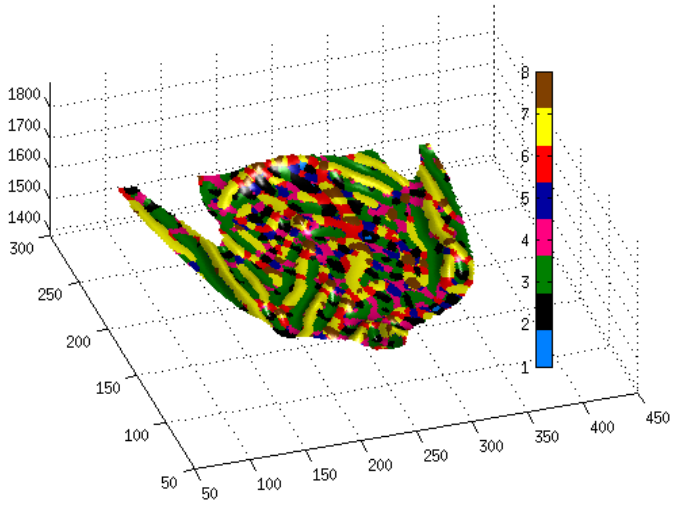
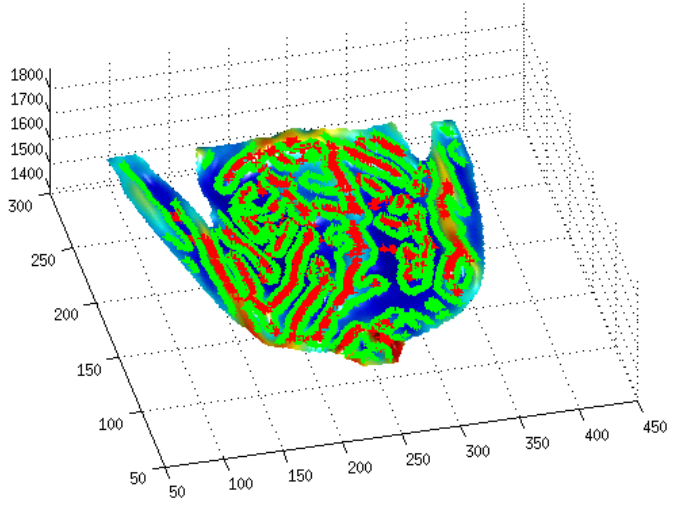
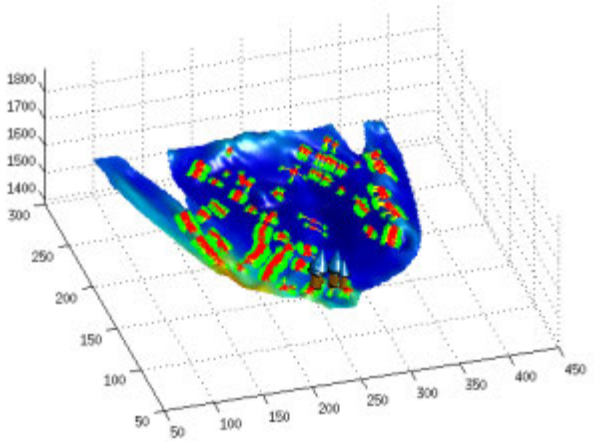
Clothes Surface Topology Analysis

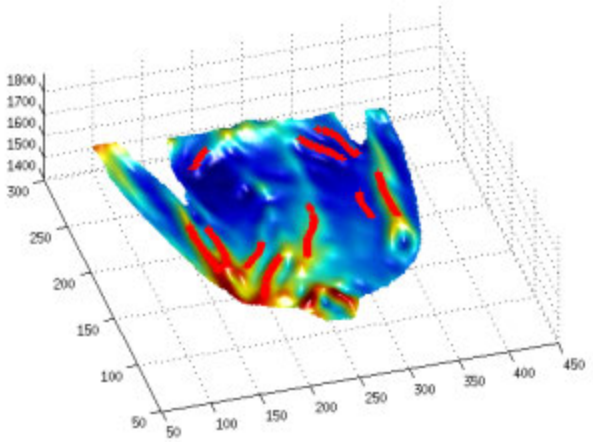
- Surface Shape and Topology





- Grasping Candidates and Fitted Wrinkles





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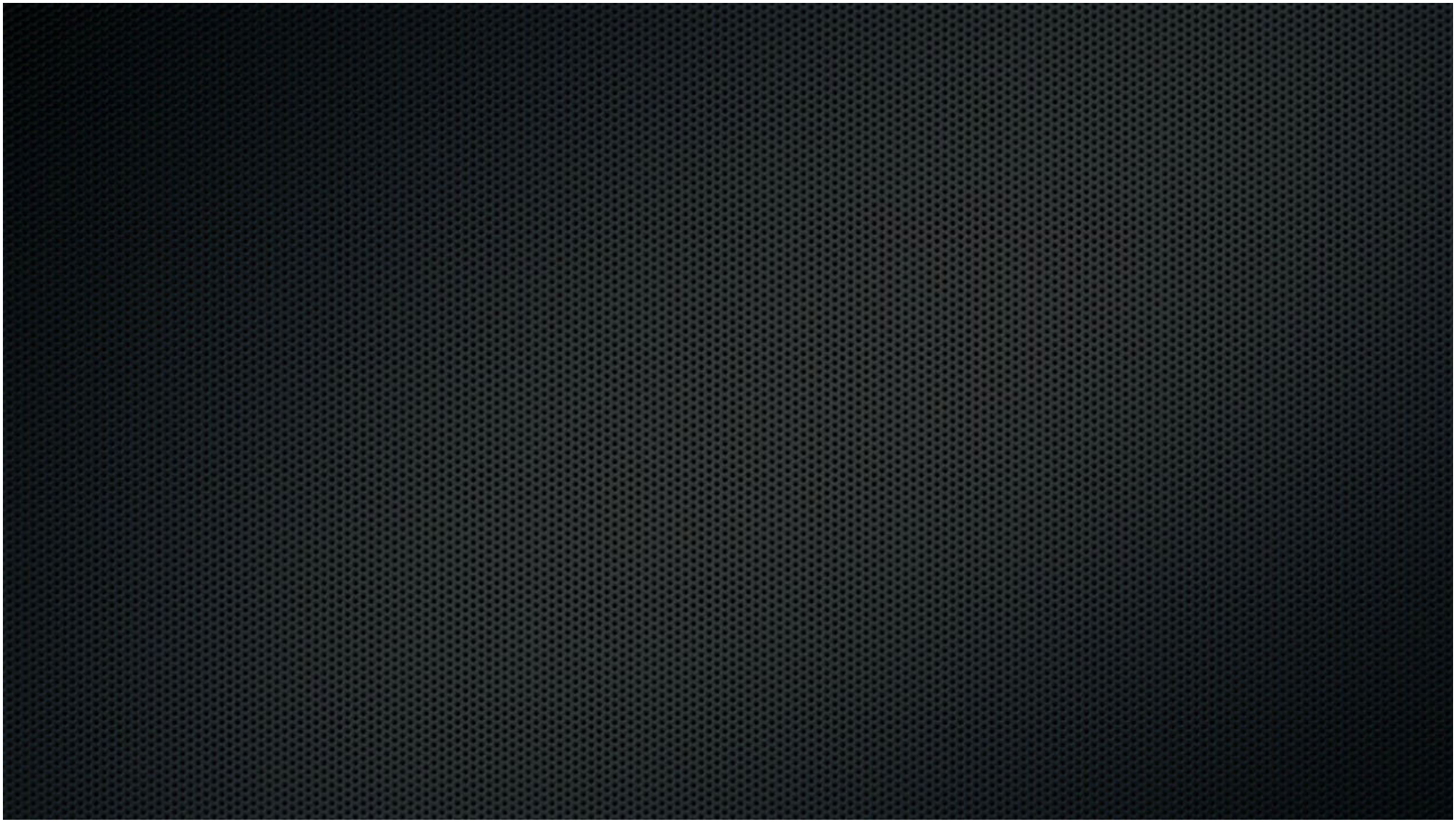
Range sensing and grasping a garment on the table



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Flattening

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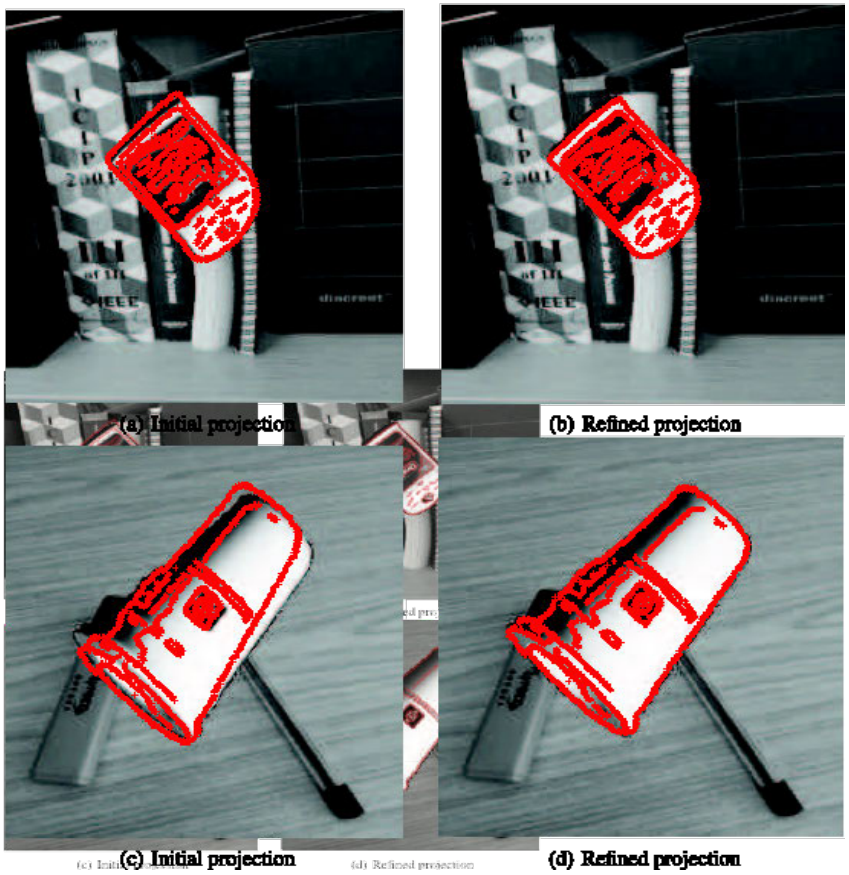
HexHOG descriptors for contour localisation

- A new feature descriptor, HexHoG, based on a hexagonal, hierarchical grouping mechanism that confers it with sufficient reliability and distinctiveness to enable it to be used to sample the image at all detected edge positions (as opposed to only corner locations).
- Yuan Liu, J Paul Siebert. ‘Contour Localization Based on Matching Dense HexHoG Descriptors‘. VISAPP2014



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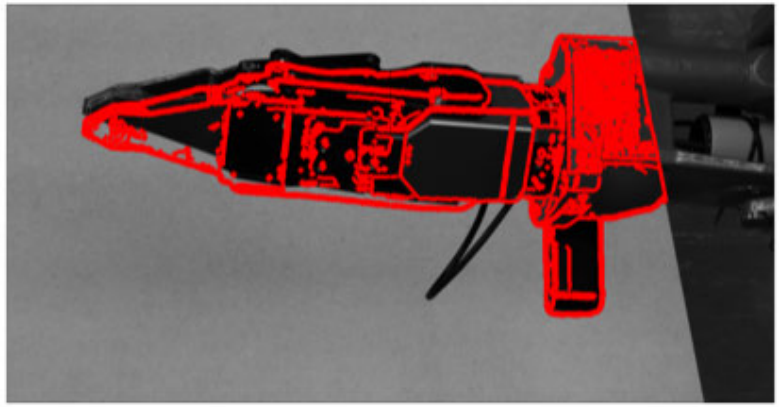
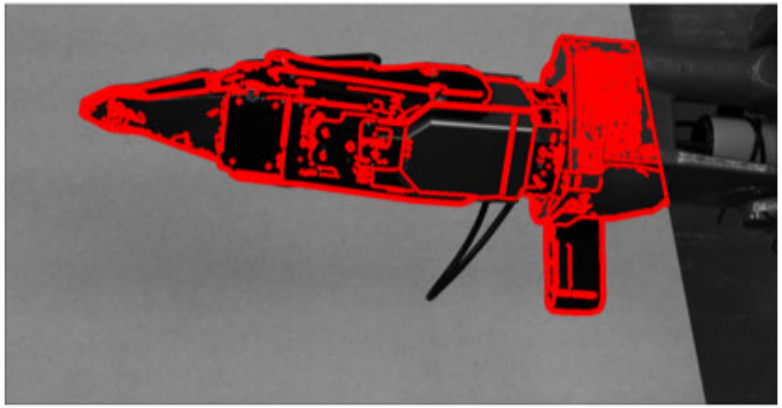
Demonstrator

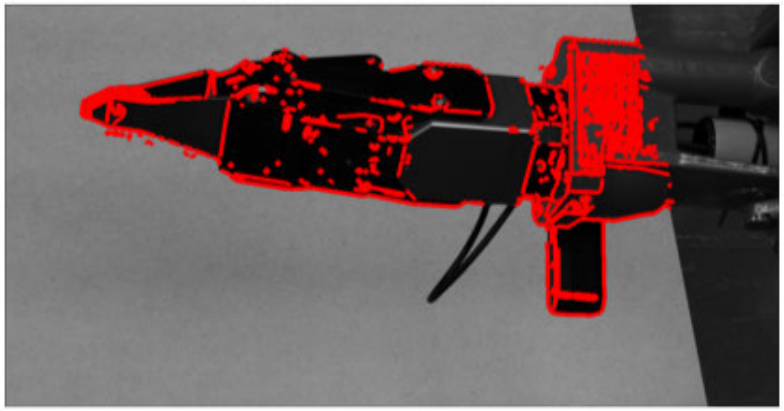
Pose estimation by SIFT, the red contours are the projection from the reference image



Pose refinement result by HexHoG



Edge labeling result by HexHoG 3 levels combination



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Ongoing & Future Work

- Dynamic Focus Control:
  - Extend the dynamic in-focus working range
- Robust Matcher Development:
  - Integrate segmentation to mask images prior to matching to suppress artifacts at boundaries
  - Integrate improved bilateral filtering to suppress artifacts at unmatchable regions
- Range Surface Representation & Analysis:
  - 2.5D “Primal Sketch”: Extend the representation to include ruts as well as ridges and consider junctions/saddles as well.
- Accelerate Range Surface Representation & Analysis
- Integrated Gaze control and Manipulation:
  - Develop fully foveated analysis & gaze control.
  - Integrate range topology-based clothing flatting algorithm with robot manipulation

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Publications

1. Aragon-Camarasa, G.; Oehler, S. B.; Liu, Y.; Li, S.; Cockshott, P. and Siebert, J. P. (2013), 'Glasgow's Stereo Image Database of Garments', arXiv preprint arXiv: 1311.7295.
2. Sun, L., Aragon-Camarasa, G., Siebert, J.P. and Rogers, S. (2013) 'A Heuristic-Based Approach for Flattening Wrinkled Clothes,' in Towards Autonomous Robotic Systems, TAROS 2013, University of Oxford, 20-30 August, 2013
3. Cockshott, W.P., Oehler, S., Aragon Camarasa, G., Siebert, J., and Xu, T. (2012) 'A parallel stereo vision algorithm'. In: Many-Core Applications Research Commu- nity Symposium 2012, 29-30 Nov 2012, Aachen, Germany.
4. Liu, Y. and Siebert J.P., (2014) 'Contour Localization Based on Matching Dense HexHoG Descriptors', VISAPP 9th International Joint Conference on Computer Vision Theory and Applications, Lisbon, 5-8 January, 2014.
5. Sun, L., Aragon-Camarasa, G., Rogers, S. and Siebert, J.P. (2014) 'Feature Extraction for Deformable Clothes Manipulation', submitted for review to IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS 2014).

THANK YOU!