A Feature-Based Matching Approach to Automated Object Reconstruction in Multi-Image Close-Range Photogrammetry

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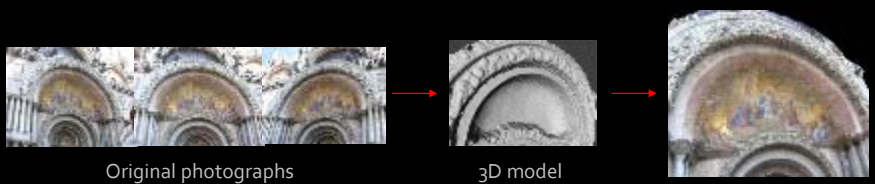
Presentation Outline

- Introduction to project
- Importance & relevance of work
- Image-based modelling overview
- Experimental testing program
- Results
- Concluding remarks

Close-Range Object Reconstruction: Image-Based Modelling

'The complete process, starting with image acquisition, and ending with a high-accuracy interactive 3D virtual model'



Original photographs

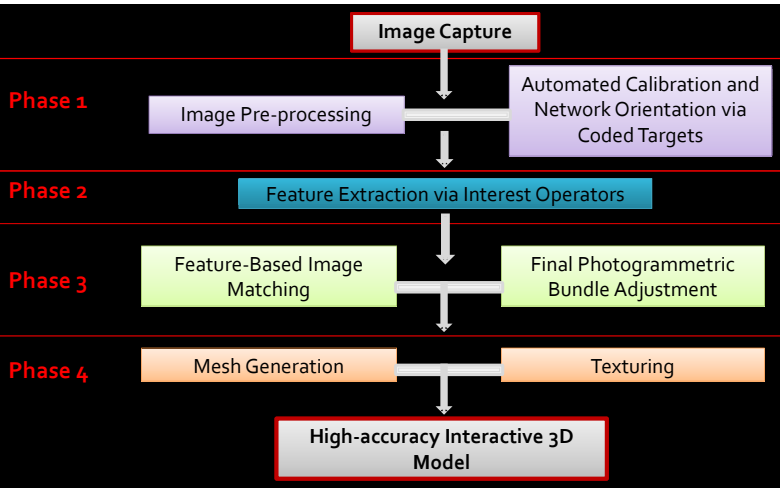
3D model (No texture)

Final 3D model

Figure: St Mark's Church, Venice (Fabio Remondino)

Project aims to develop an automated methodology for creation of high-accuracy 3D models from multiple convergent images, of high metric quality

Overview of Project



Importance and Relevance of this Work

- Current absence of practical methodologies to create high-accuracy 3D models of untargetted objects from convergent images

Applications:
- Cultural heritage archiving
- Visualization and animation
- Accident reconstruction & forensics
- Reconstruction surveys

Motivation:
- Documentation in case of loss or damage
- Interaction without risk of damage
- High accuracy surface measurement

Statue in Dresden Centre
(Fabio Remondino)

Importance and Relevance of this Work

- Current absence of available software systems to execute all phases required to create 3D model
- 3D data must be translated and interchanged between various measurement, modelling and visualization packages

The aim is to enable each phase of the 3D modelling process to be executed within a single software environment, fully automatically

Phase 1: Image Pre-Processing

- Wallis Filter – Algorithm that enhances the contrast levels of any given input image

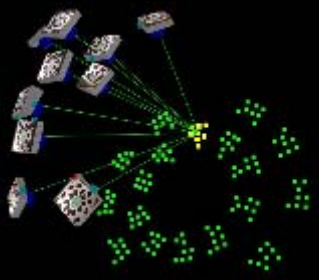
→ **Better contrast, greater detail**

Phase 1: Automated Camera Calibration & Network Orientation

- Coded targets for automatic camera calibration and network orientation

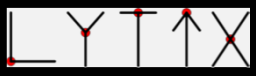
Red retro-reflective targets

Silver retro-reflective targets



Phase 2: Feature Extraction – Interest Operators

- Interest operators detect features of interest in an image, such as corners, edges or regions (Interest Points)



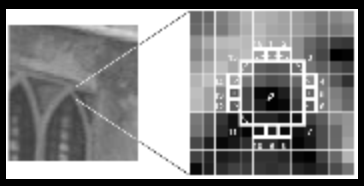
Distribution of feature points

Why do we need interest operators?

- To facilitate detection of feature points to support matching between multiple convergent images.

Phase 2: FAST Interest Operator

- Developed by Rosten & Drummond (2006)
- Designed for real time applications



How does it work?

- Based on the principles of the SUSAN operator
- Employs more efficient methodology and programming

Strengths: Excellent Speed – very fast algorithm, with good localization
Limitations: Often detects multiple features that are adjacent to each other

Phase 2: FAST Interest Operator

- Filtering function added to the FAST algorithm
- Assesses quality of interest points and eliminates all points below a user-defined quality threshold
- Works as a percentage filter:

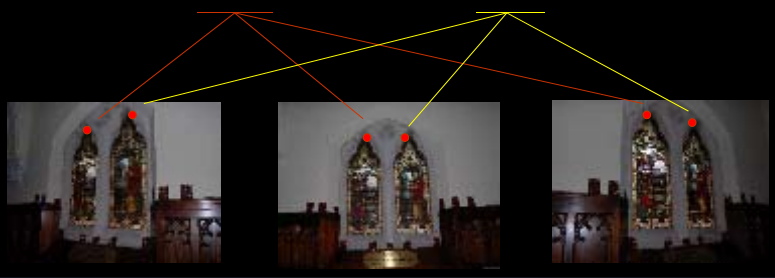
Filter value 90% = retain best 10% of interest points

- Ensures only interest points of optimal quality are used in subsequent feature-based matching

Phase 3: Feature-Based Image Matching

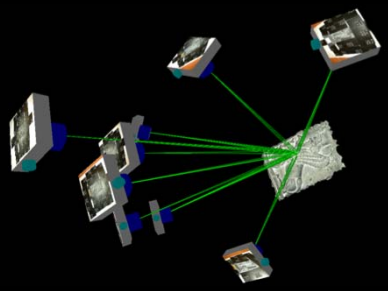
- Automatic identification and measurement of conjugate feature points in over lapping images
- Image point correspondence determination and subsequent spatial intersection

→ 3D point cloud comprising the successfully matched feature points



Phase 3: Why Feature-Based Matching?

- Highly convergent multi-image networks
- Geometric diversity and redundancy that presents difficulties in area-based matching is a distinct advantage in the feature-based matching approach



Phase 4: Poisson Surface Reconstruction

- Developed by Kazhdan et al. (2006)
- Expresses surface reconstruction as the solution to a Poisson equation
- Fast, resilient to noise, closely approximates input data with high level of detail

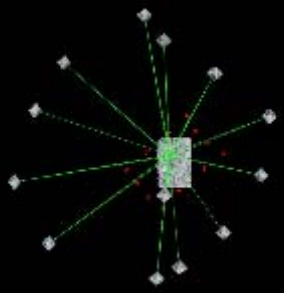
Implemented in the Computational Geometry Algorithms Library (CGAL, http://www.cgal.org)

- Texturing via back-projection of the mesh triangles into the most appropriate images of the network

Experimental Testing Program

- Deformed aluminium liner plate (used as protection layer in engineering)

Test object: aluminium plate



Photogrammetric Network

- Imaged in a convergent network of 13 images with coded targets
- Nikon D200 camera (18mm lens)

Experimental Testing Program

3-Phase Test Program

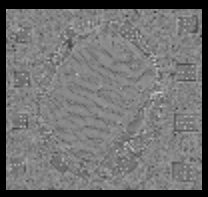
1. Wallis Filter – assess filtering enhances detection of interest points

2. FAST operator – assess based on:
   - Computational time
   - Detection rate, i.e. true interest points found versus points missed or wrongly detected
   - Localization, positional accuracy in image space

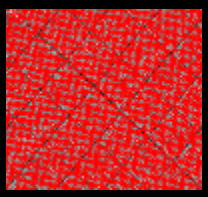
3. Poisson Surface Reconstruction – assess applicability for generation of a high-definition wireframe of potentially complex object shape

Results Image Enhancement

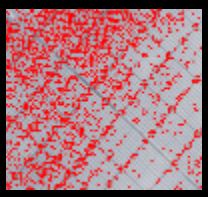
- Wallis filter is a necessary pre-processing function that enables FAST operator to find greater number of interest points



Wallis filtered image



Enlarged area – FAST operator results on filtered image



Enlarged area – FAST operator results on original image

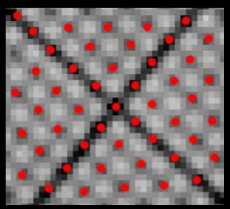
Original Image	Wallis Filtered Image
Detection Rate (#pts)	Detection Rate (#pts)
30578	208963

- On average, 7 times more points found on Wallis filtered images

Results FAST Operator

- 300,000 points in less than a second
- Very good localization (0.5-1 pixels)
- Results for a 121 pt, 11 x11 grid patch on the plate:

Total points detected	109 (90.1%)
Correct points detected	107 (88.4%)
Points missed	14 (11.6%)
Incorrect points detected	2 (1.8%)
Localization (pixels)	0.5 – 1
Localization (mm)	0.0031 - 0.0061



Enlarged area of plate showing FAST operator results

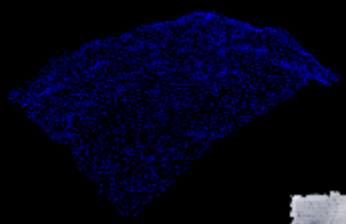
Results Feature-Based Matching

- With filtering value of 90% , relative object point accuracy of 3D matched points is 1:20,000

Quality filter value (%)	RMS of image coord residuals (pixels)	Mean std. error of 3D surface points (mm)	Relative object point accuracy	Number of 3D matched points from final bundle adjustment	Number of erroneous points
80	0.45	0.044	1:18,000	1518	36
90	0.33	0.040	1:20,000	895	4
95	0.28	0.038	1:21,000	504	0
99	0.28	0.029	1:26,000	193	0

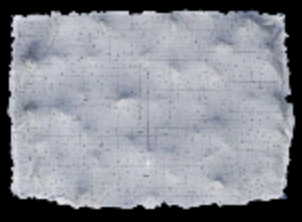
Object point accuracy for aluminium plate network

Results Poisson Surface Reconstruction



Poisson Surface Reconstruction Results
4131 Triangles

Texturing results: oblique view of plate section

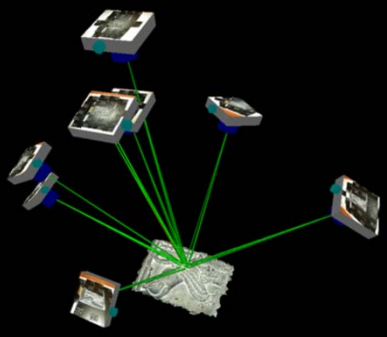


Texturing results: top-down view of plate section

Further Test Results: Cultural Heritage Artefact

- The Sphinx and the Palm Tree (15cm x 10cm)
- Nikon D200 camera, 8-station network configuration

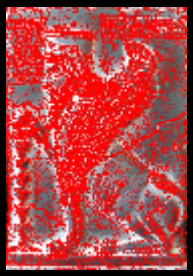
Test object: The Sphinx



Photogrammetric Network

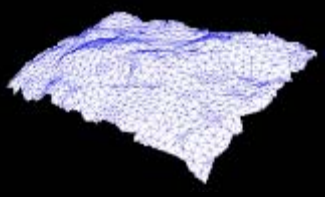
Further Test Results: Cultural Heritage Artefact

- Fully automated feature extraction, feature-based matching and mesh generation results



FAST operator results
10150 points

Feature-based matching results
923 matched 3D points from final bundle adjustment
Relative object point accuracy: 1:14000



Poisson Surface Reconstruction results
1032 triangles

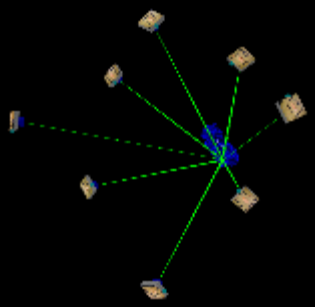
Further Test Results: Cultural Heritage Artefact

- View-dependant texturing of 3D model

Further Test Results: Forensics Footprint Reconstruction

- Forensic photogrammetry
- Nikon D200 camera, 8-station network configuration

Test object: Footprint cast



Photogrammetric Network

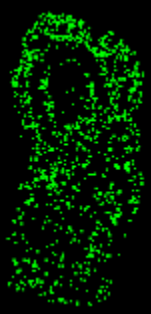
FAST operator results
13500 points

Further Test Results: Forensics Footprint Reconstruction

- Fully automated feature extraction, feature-based matching and mesh generation results

Feature-based matching results
821 matched 3D points from final bundle adjustment

Relative object point accuracy:
1:18700



Poisson Surface Reconstruction results
1785 triangles

Further Test Results: Forensics Footprint Reconstruction

- View-dependant texturing of 3D model

Concluding Remarks

- Aimed to automate 3D object reconstruction from multi-image networks
- Highlighted benefits of Wallis filter
- FAST operator optimal for feature-based matching
- Poisson Surface Reconstruction well suited to mesh generation
- Feasibility of a feature-based matching approach to high-accuracy surface reconstruction within convergent close-range photogrammetric networks demonstrated
- Future work: Automatic network orientation of unsignalized points

Thank you for your attention

Questions?

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