RIVIC
Research Institute of
Visual Computing

School of Computer Science
and Informatics
Cardiff University

Recent Research at Cardiff

R. R. Martin and colleagues

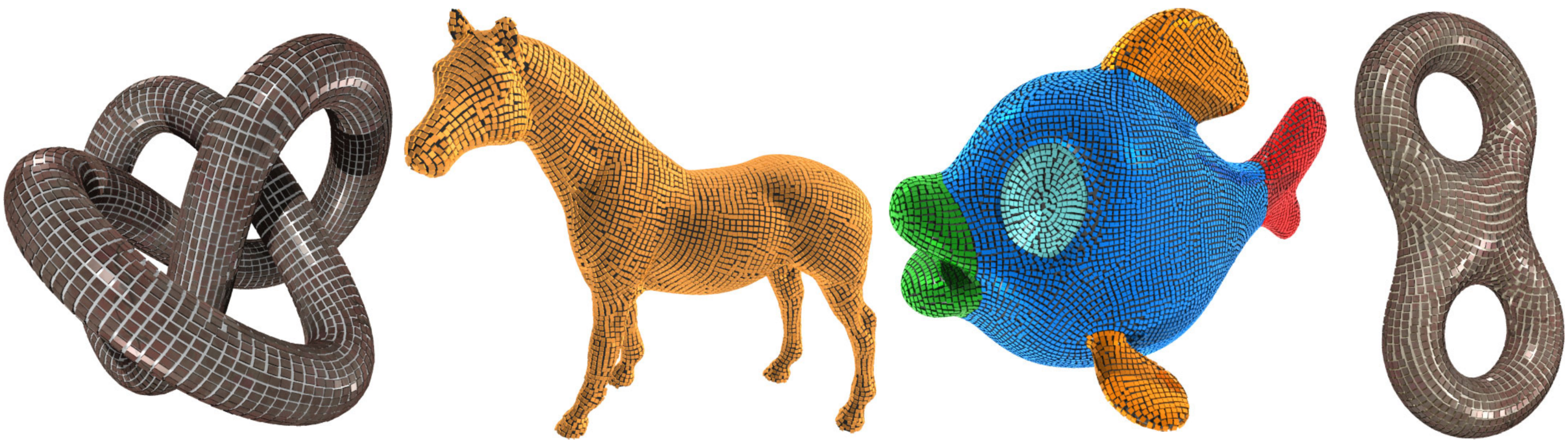
Geometric Texture Transfer

- Geometric Texture Transfer
  - *Geometric textures*: fine-scale geometric patterns over surfaces.
  - Geometric textures are extracted from textured sample models and automatically transferred to new models.
  - Using *geometry images* representation to simplify the problem.
  - Synthesise and transfer geometric textures by adapting image texture synthesis algorithms.
  - Applications: stylisation, artificial texturing etc.

with Tsinghua University, China & Stony Brook University, USA

Surface Mosaics

- Surface Mosaics
  - A generalisation of traditional decorative mosaics.
  - Placing *equal-sized rectangular* tiles over surfaces, guided by a few control vectors.
  - Globally *optimising* a spring-like energy in the *Manhattan* metric.
  - Using *overlapping local parameterisations* for efficient computation.



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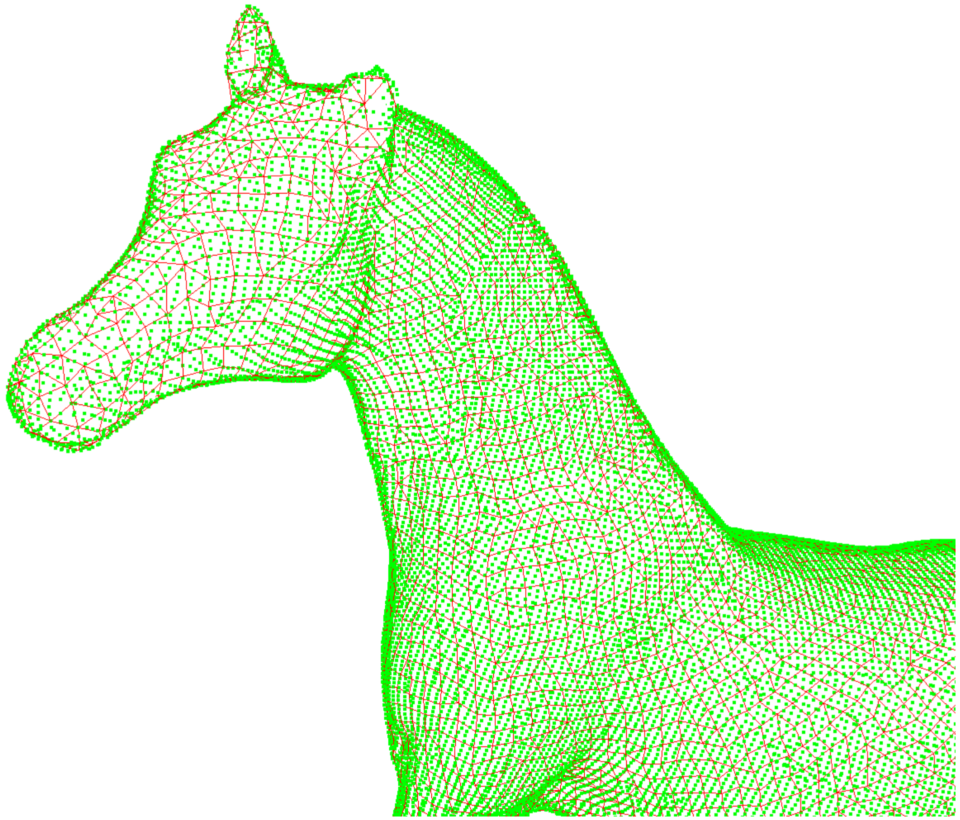
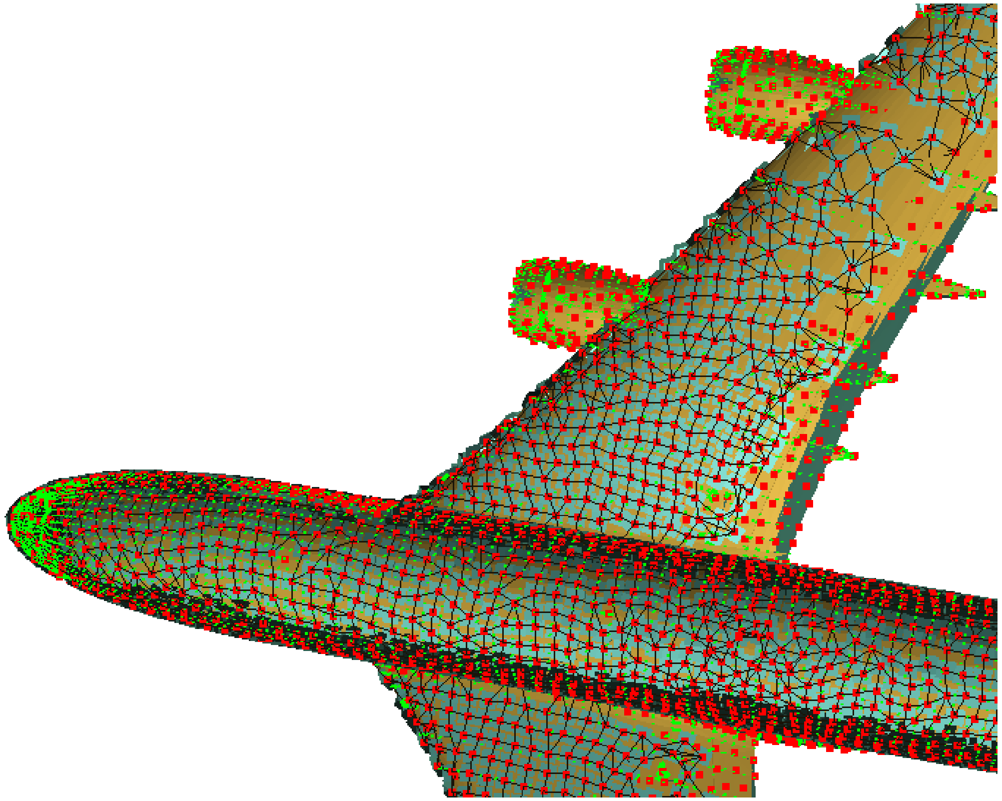
CFD and FE meshing

- Meshing for Computational Fluid Dynamics and Finite Elements
  - Builds on mosaic work to generate meshes for CFD, FE analysis.
  - Place mesh point at center of each tile, join to give mesh.
- Need to generalise for:
  - mesh size control, anistropic mesh, singularity control, 3D meshes.

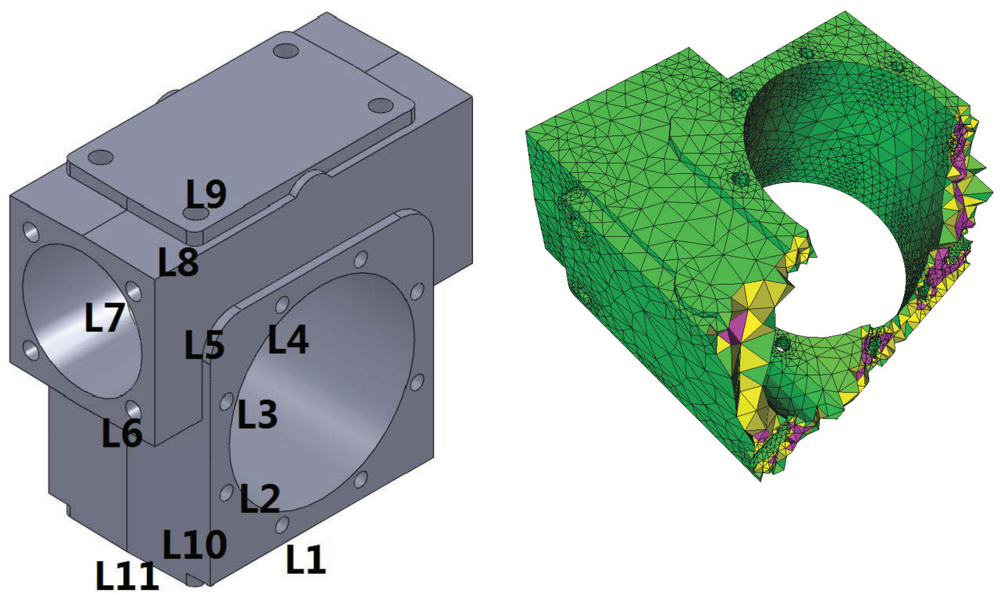


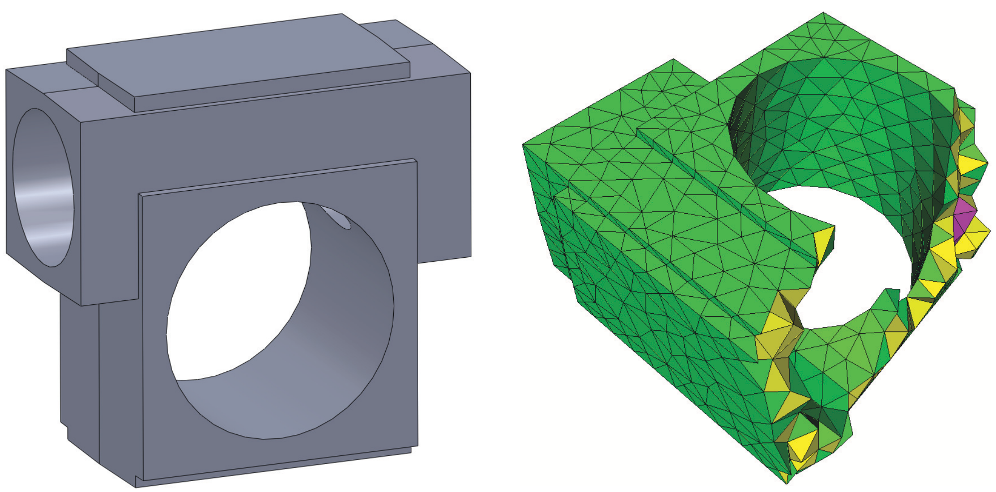


with Airbus

Defeating Models for FE Analysis

- Analysis of CAD models using FE or CFD methods requires meshing
  - meshing can take much longer than analysis itself
- Removing small features with little effect on analysis can be beneficial
  - meshing uses fewer, larger elements, is quicker, is more robust
- Future project—computational tools to let engineers specify the kind of features to find and remove
- Current work—mathematical methods to estimate the effects on analysis results of removing a feature, without expensive calculation

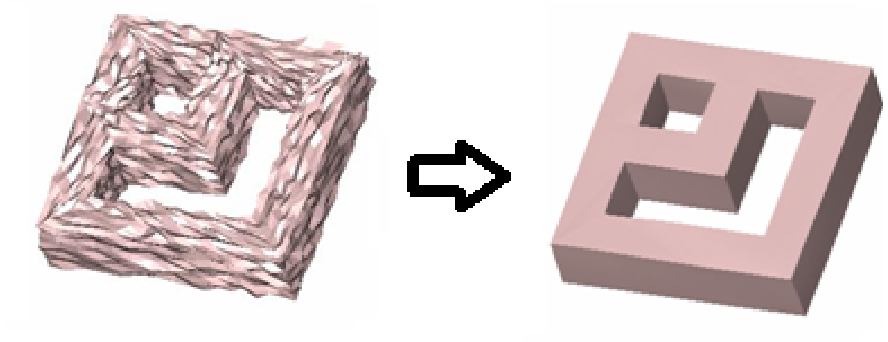




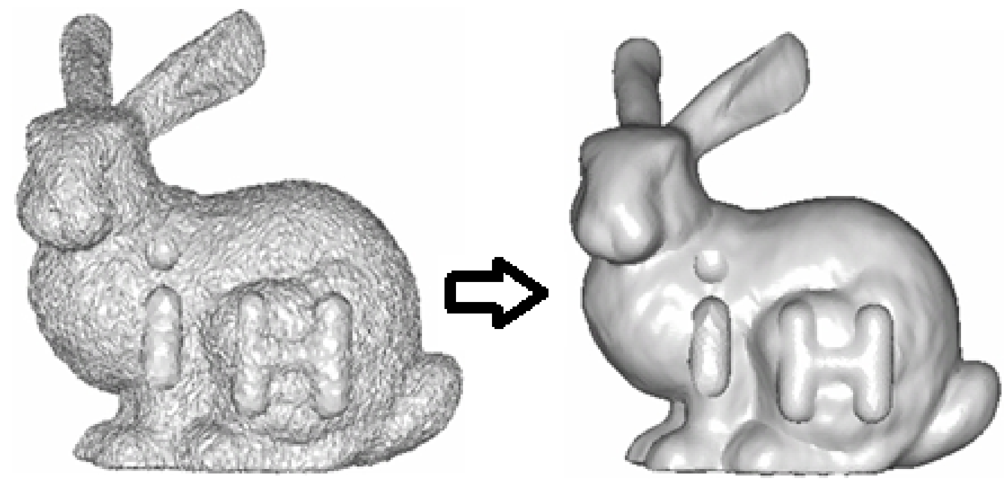
with Zhejiang University, China and others

Feature-Preserving Mesh Denoising

- Aim: remove mesh noise while preserving its features
  - sharp edges
  - corners
  - . . .



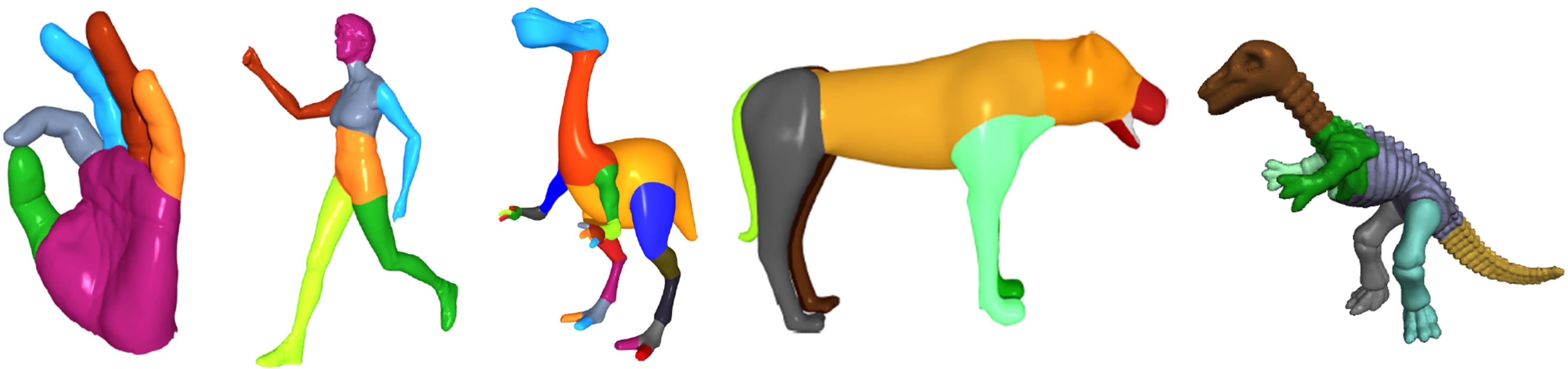
- Two-step approach:
  - normal filtering
  - vertex position updating
- Fast mesh denoising:
  - quadratic weight function with thresholding in normal filtering



- Random walk for mesh denoising
  - weight function determined by random walk probability

Efficient 3D Model Segmentation

- 3D Model Segmentation
  - Decompose a model into *disjoint*, intuitively *meaningful* pieces
  - A step towards model understanding
  - A *random walks* based approach for *interactive* and *automatic* model segmentation
  - Significantly *faster* than traditional methods
  - Comparable quality to state of the art



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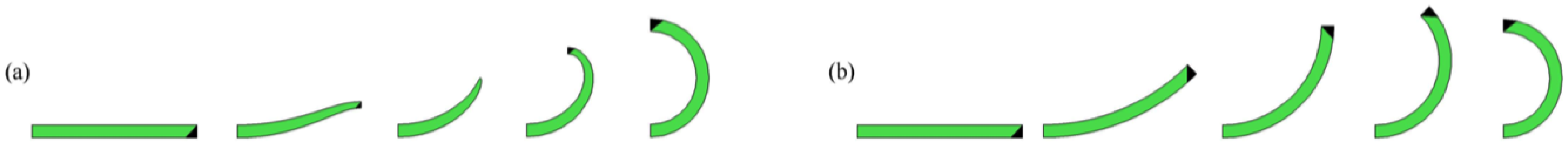
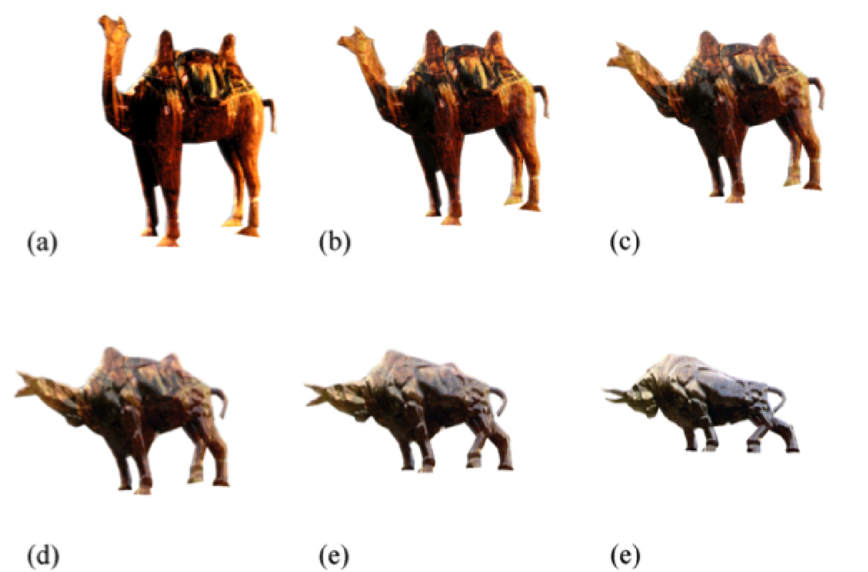
Y. Lai, R. Martin, P. Rosin

Morphing by Strain Field Interpolation

- Aim: *morph* one shape into another
  - Need to find in-between shapes and textures
  - Linear interpolation of meshes clearly goes wrong: note narrowing of curved end



  - Instead, produce compatible meshes for both shapes
  - Use concepts from mechanics: interpolate *strain field* to get good results



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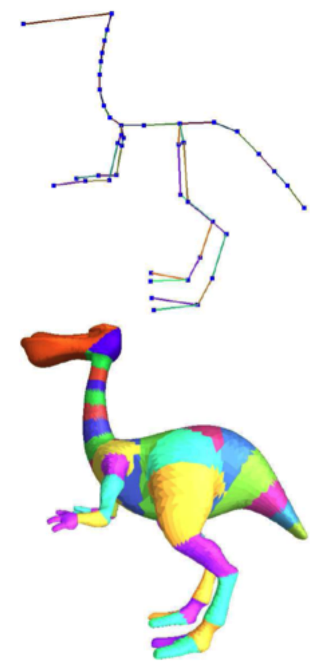
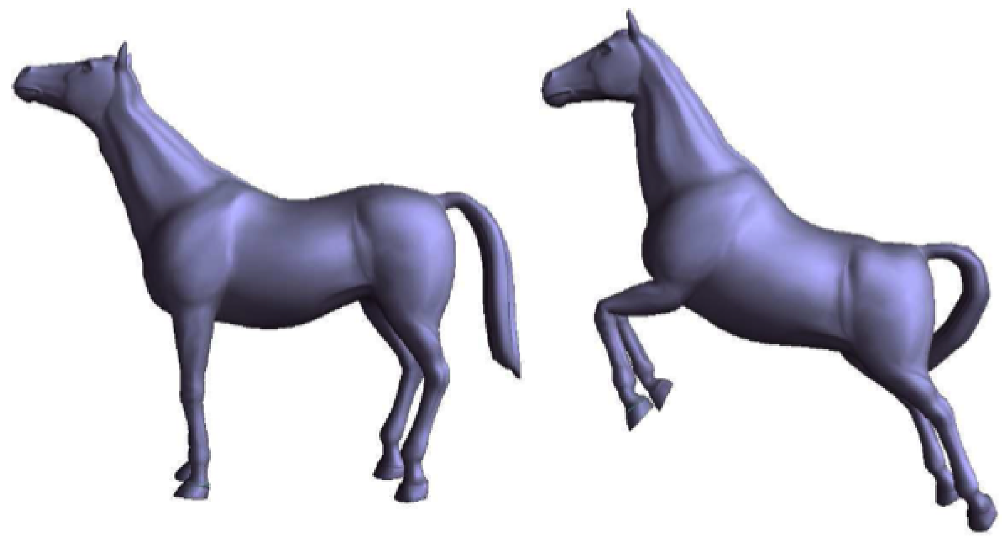
Morphing Based on Skeletons

- Aim: *morph* one shape into another
  - Skeleton is divided into bones
  - Surface mesh triangles (or volume mesh tetrahedra) are allocated to skeleton bones
  - Previous methods transform *vertices* and need tedious-to-specify weights
  - *Triangles* try to follow bone transformations
  - Automatically spreads error throughout mesh after optimisation





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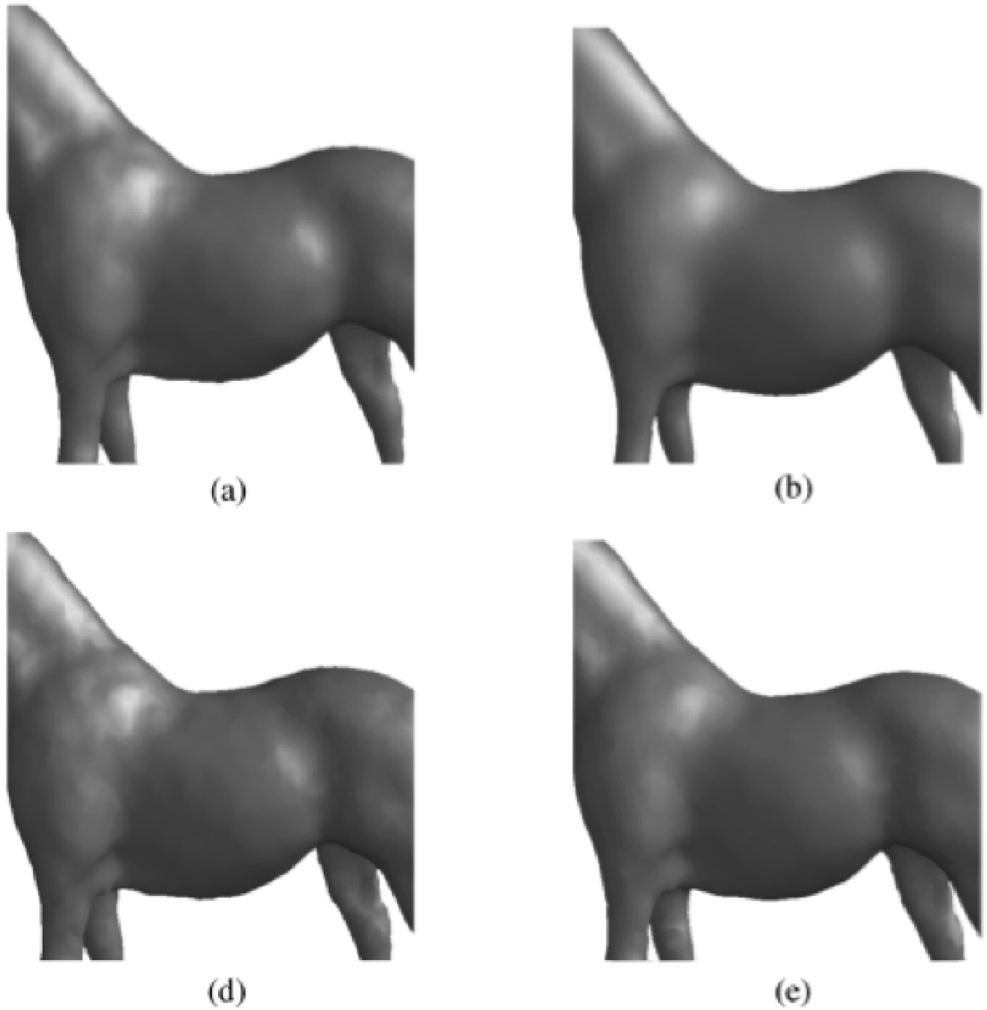
Measuring Small Mesh Differences

- Watermarking is a form of *Digital Rights Management*
  - information is hidden in *small shape changes*
- To compare watermarking algorithms, we need to see how obvious the mesh changes are
  - To avoid costly human trials, try to find a formula which gives similar results
  - *Strain field energy* is surprisingly well correlated with human opinion



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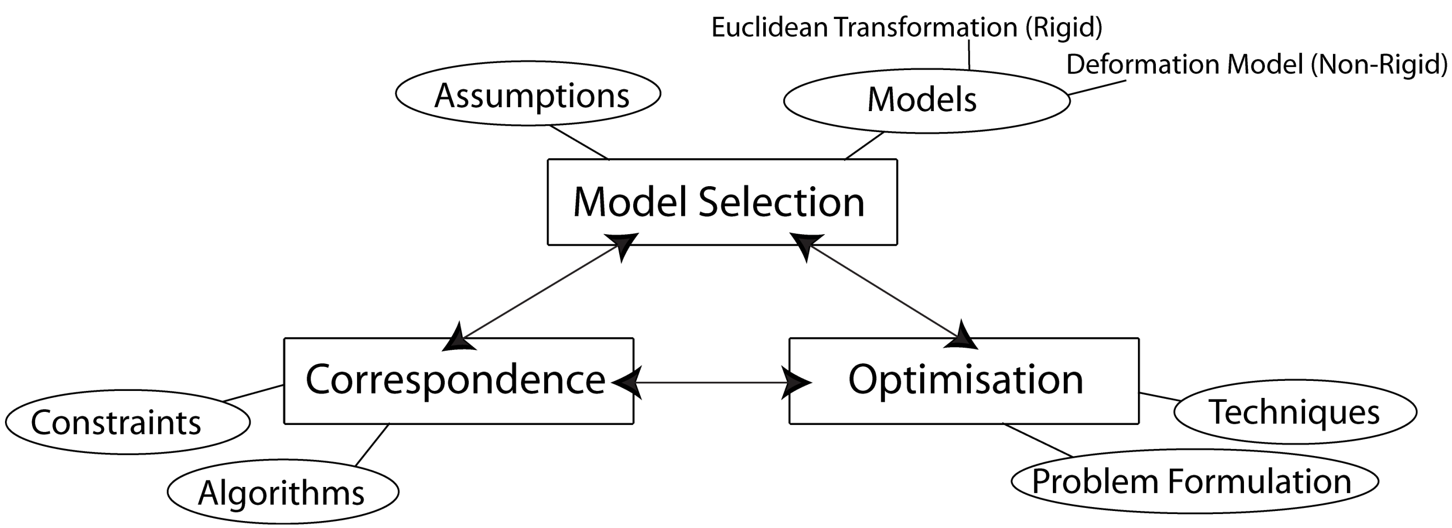
Rigid and Non-Rigid Registration

- Survey written
- Various areas investigated
  - Overlap Area Detection
  - Rigid Registration
  - Non-rigid Registration
  - Surface Integration
- Overlap Area Detection based on
  - ICP, histograms, multiple closest points



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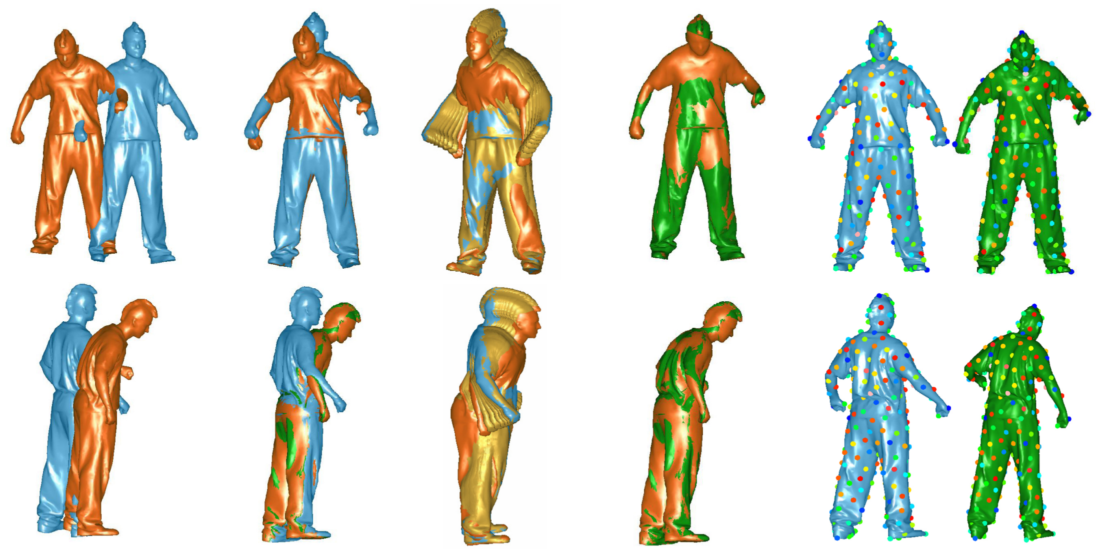
Non-rigid Registration

- Aim: register instances of a surface which moves and deforms over time
  - Registration is performed using a global-to-local framework
  - Shapes are embedded in a 3D implicit vector space
    - Global alignment is found by non-linear optimization over vector distance function
    - Non-rigid transformation is represented by cubic B-spline free form deformation
    - Local non-rigid registration is found by energy minimisation, with closed form solution



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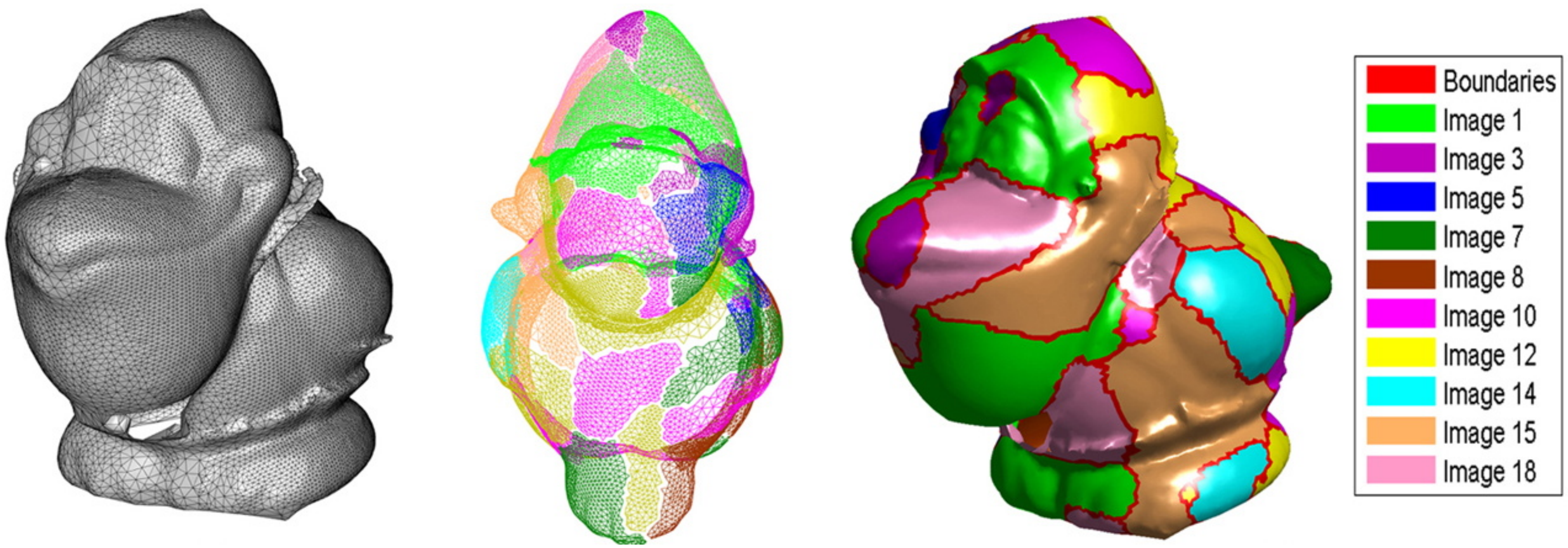
Surface Integration

- Multiple surface scans are captured and registered into a single frame of reference
- They must then be *integrated* into a single high quality surface
  - Must take care to get the correct topology and neighborhoods
    - A *higher order* Markov Random Field is used to ensure geometric smoothness
    - Result clusters points from individual inputs



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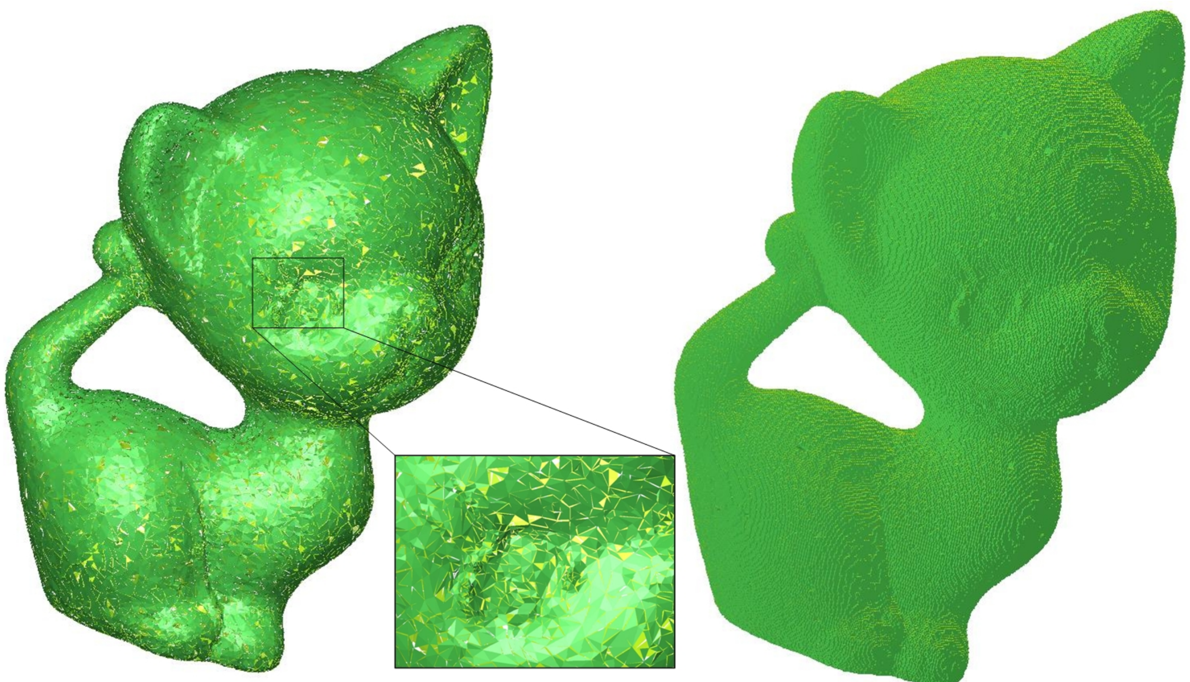
Polygon Models to Voxel Models

- Aim: convert polygons models to voxel models
- Issue: polygon model may have gaps, internal triangles, other errors
- Idea: use *Faraday cage* concept from electrostatics to make a field outside the polygons, not inside
  - Zero contour of field gives a surface which can be voxelized by marching cubes
    - Iterate process to get tight Farady cage, better results



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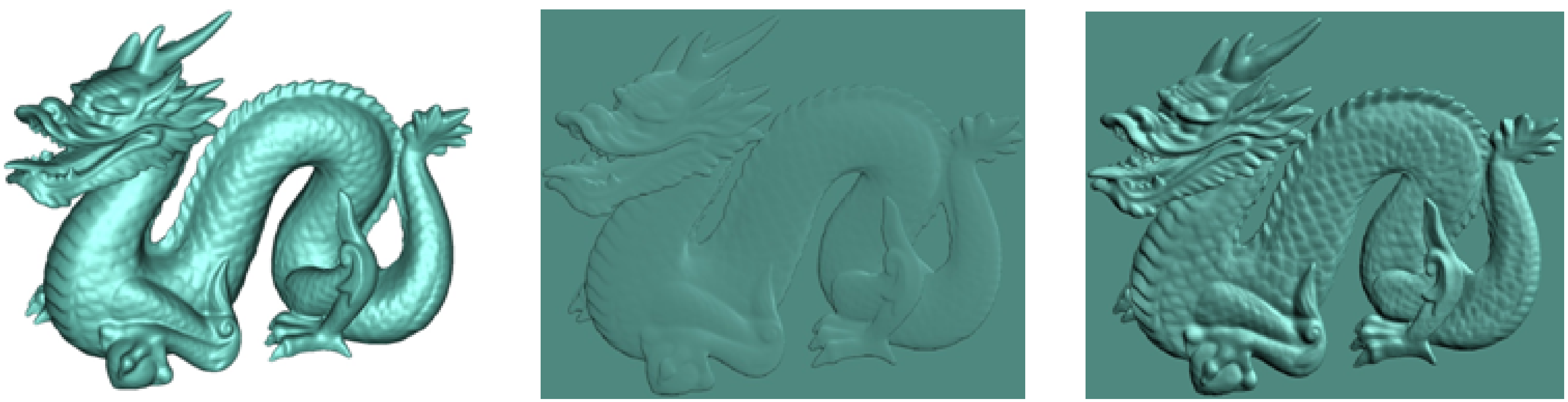
Automatic Bas-relief Generation

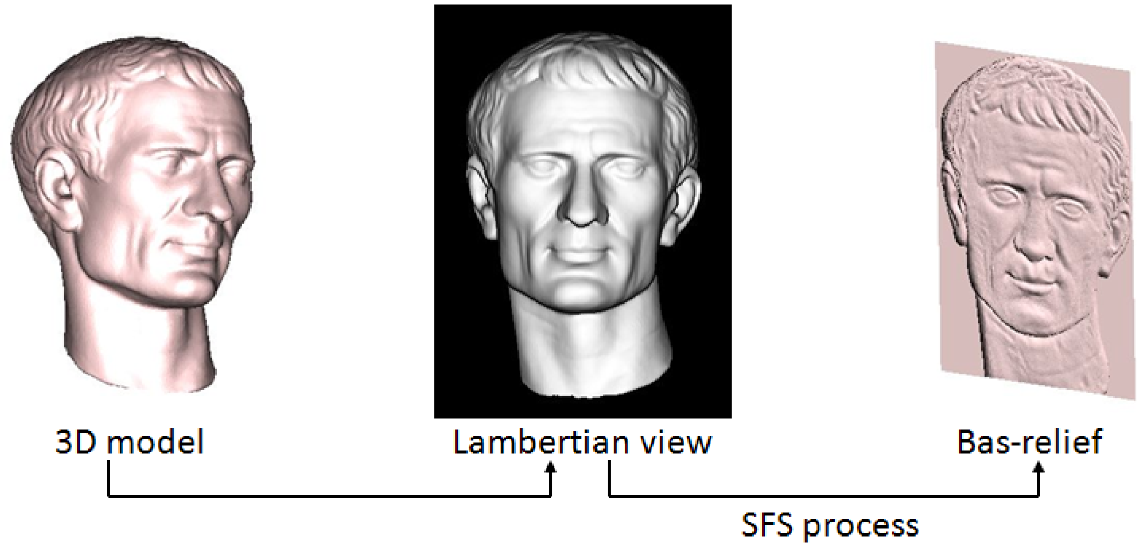
- Aim: generate a compressed height field for bas-relief from
  - 3D mesh model
  - non-compressed height field
- Method: modification on adaptive histogram equalisation (AHE)
  - AHE with gradient weights
  - Limitations on height-dependent scaling factors



(a) 3D mesh input (b) linearly scaling down (c) our result

Bas-Relief Generation Using SFS

- Idea and key issues
  - Generate a Lambertian view from the 3D model
  - Then recover a bas-relief from the Lambertian view using SFS

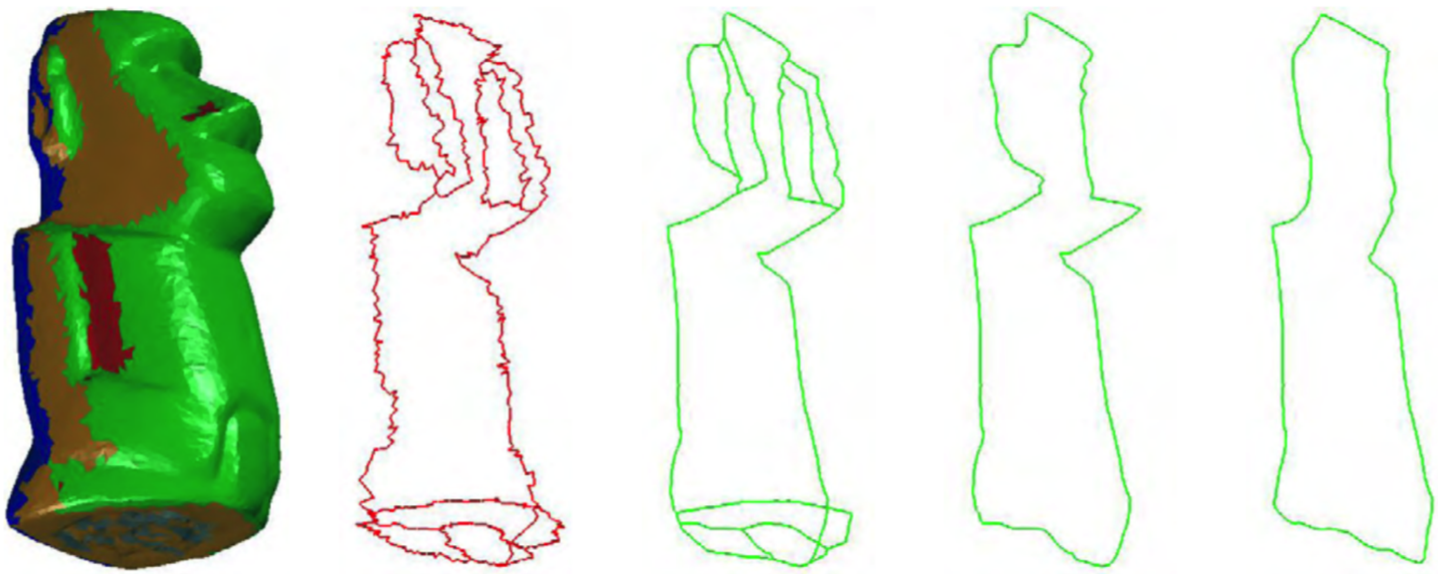


- How to incorporate surface compression into SFS?
- How to reserve salient features?

- Compared to bas-relief generation from 3D models
  - Retain the appearance of a surface from a given view-point
  - Generate bas-reliefs from 2D images

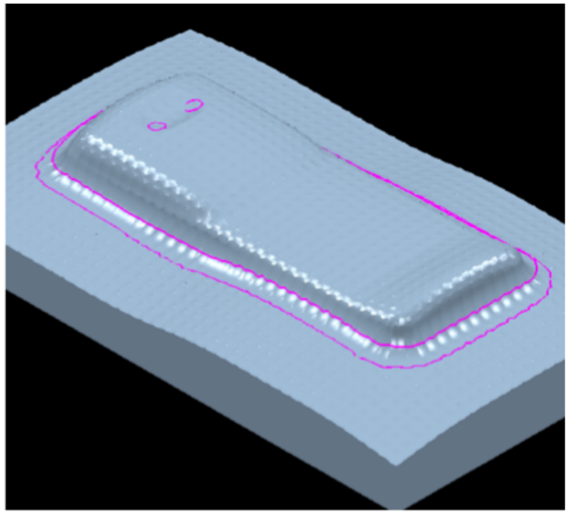
Generating Smooth Parting Lines

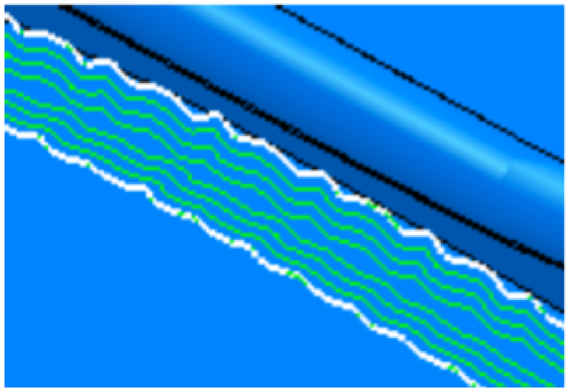
- Many plastic toys, souvenirs, etc are *moulded*
  - *exact* object shape is not too important
- For technological reasons, *split line* for mould should be smooth
  - analyse possible paths for parting line
  - simplify possible paths for parting line
  - choose optimal topology
  - simplify parting line geometry
  - update object mesh

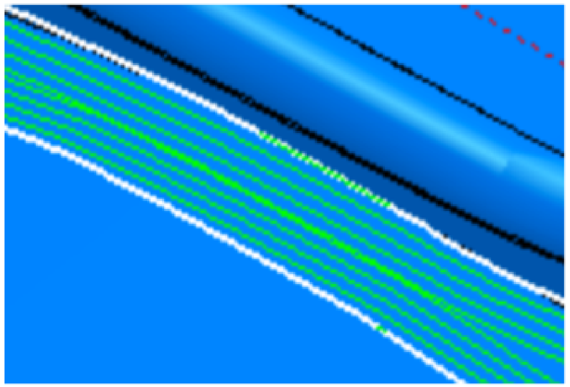


Boundary Curve Smoothing for Machining

- *Machining* is often done in multiple steps
  - *rough* cuts first, *finishing* cuts later
- Algorithms produce final cutter locations from roughed geometry
  - this leads to curves which may be
    - *fragmented, rough*
- *Merging* fragmented curves and *smoothing* them
  - allows faster machining
  - reduces tool wear
  - improves surface finish

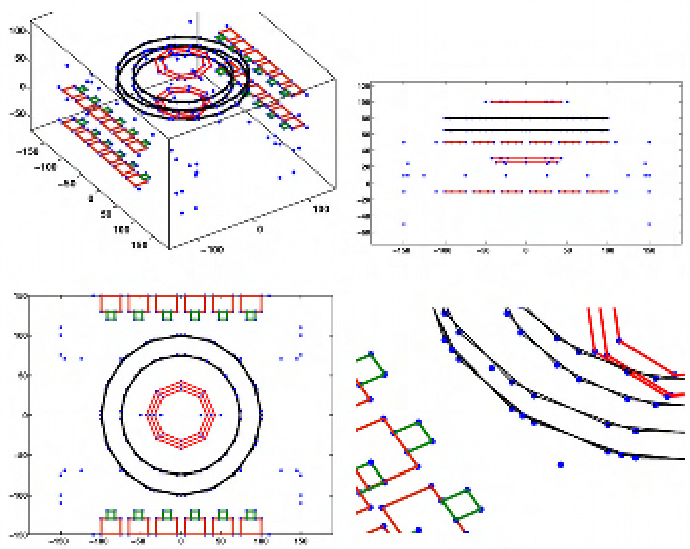


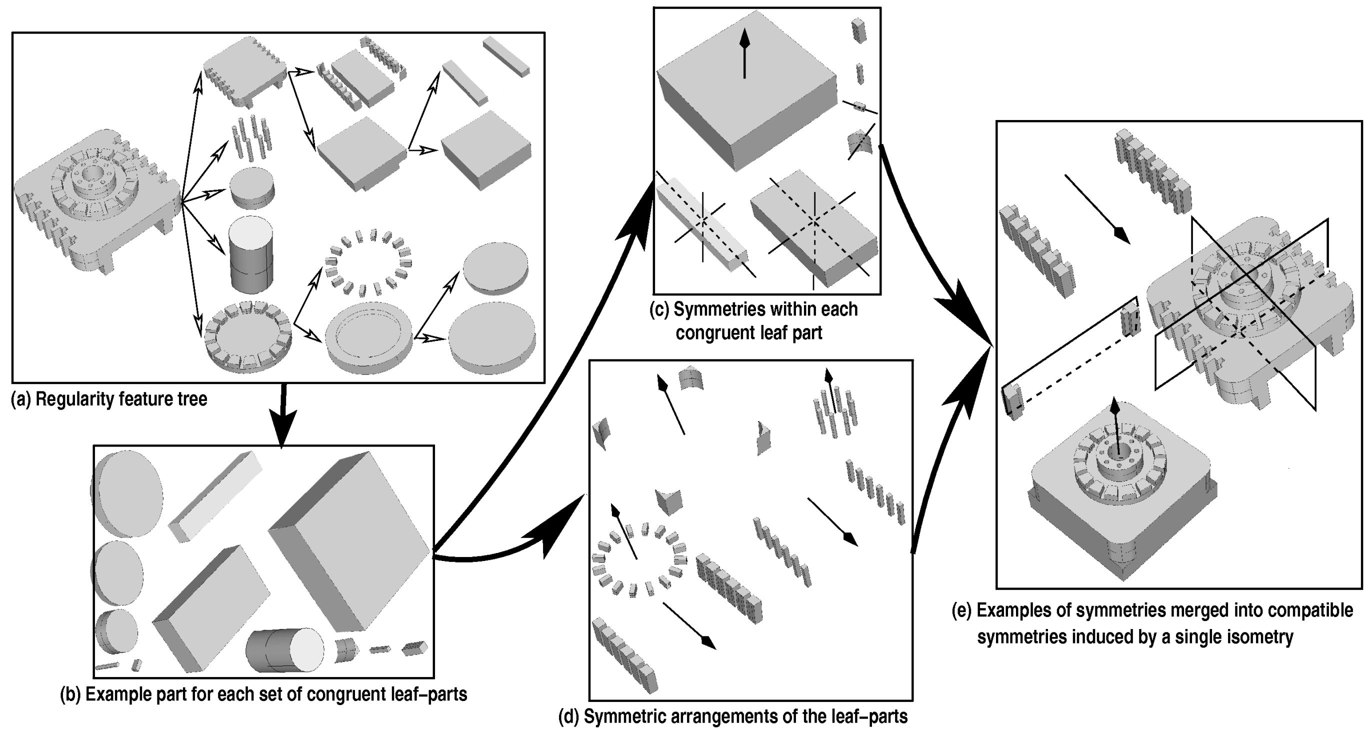




Design Intent & Approximate Symmetry

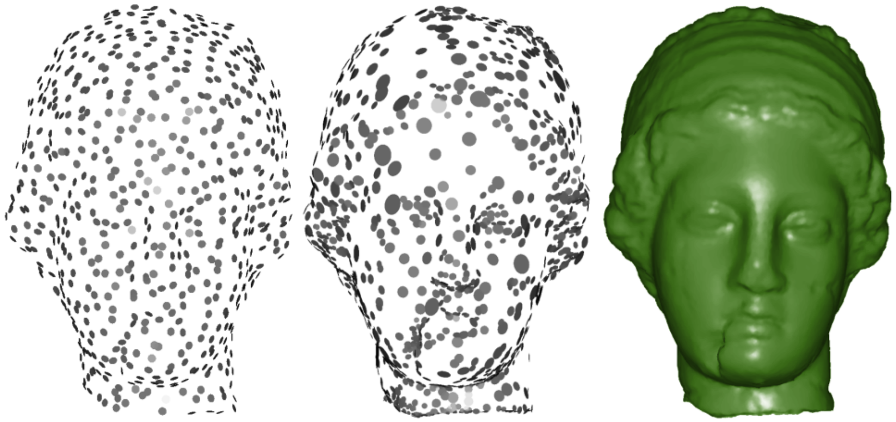
- *Intended geometric properties* of approximate CAD models
  - For creating, editing, analysing, inspecting, . . . models
  - Describe underlying ‘engineering *concepts*’ of an artifact
- Approximate regularities and features based on *symmetries*
  - Exact notion of approximate invariants for *efficient detection* of *well-defined approximate regularities*
- Geometric constraints

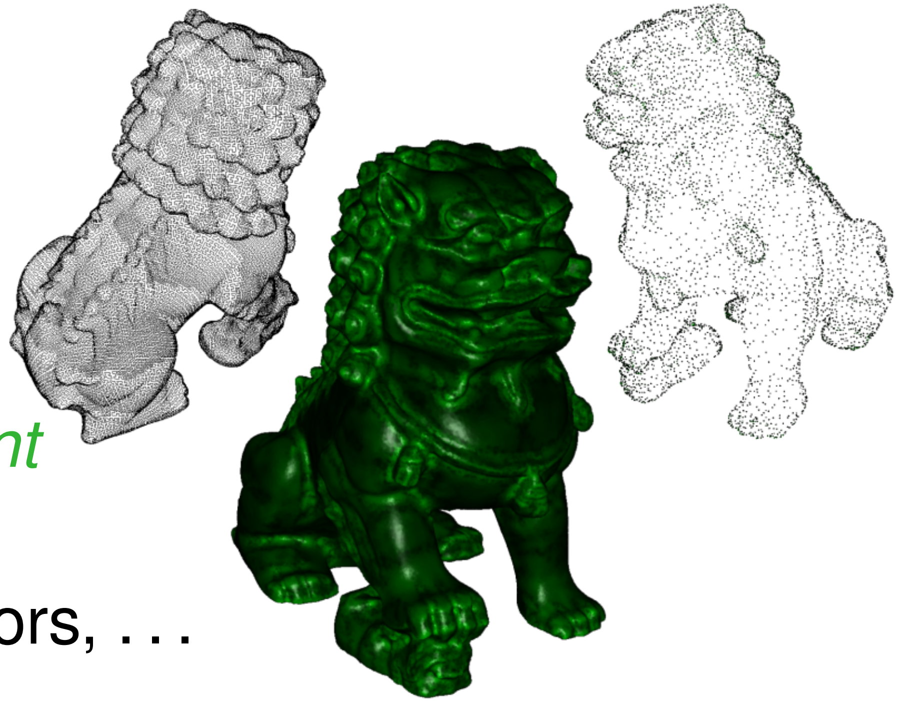




Point-based Modelling

- *Density-controlled low-discrepancy sampling*
  - For rendering, continuous LOD, silhouettes, remeshing, . . .
  - *Anisotropic* sampling
  - *Higher-dimensional* domains
- *Mesh-free differential equation solvers*
  - Truly mesh-free methods
  - GPU acceleration
  - For simulations of physical systems, biochemical reaction networks, . . .
- *Robust* differential geometry on *point representations* of manifolds
  - Curvature estimation, discrete operators, . . .





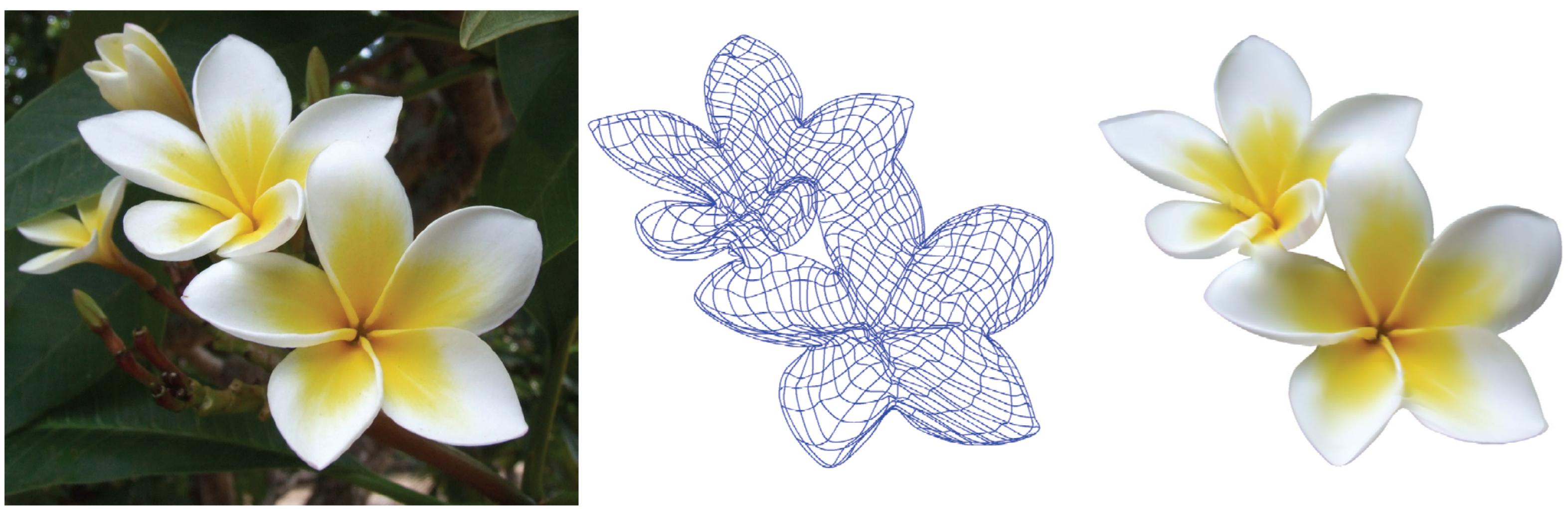
with Aberystwyth University

Facial Caricature using 2D and 3D Data

- Aim: produce a *caricature* of a face using
  - *geometric* information from 3D scanner
  - *texture* information from a corresponding photo
- Some features are best derived from geometry
  - *silhouette, nose shape*
- Some features are best derived from texture
  - *eyebrows, lips*
- Use deviation from a mean face to *exaggerate* features

Image Vectorisation

- Gradient Mesh
  - A vectorised representation of images: compact, easy-to-edit, widely supported by commercial software.
- Based on a novel *image parameterisation* approach, the proposed algorithm has the following advantages:
  - completely *automatic*: no user initialisation is required.
  - *general*: capable of dealing with regions containing arbitrary number of holes.
  - much *faster* than previous approaches.



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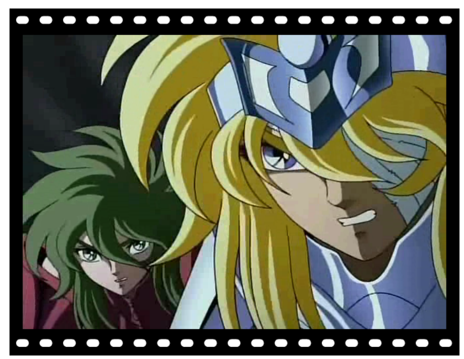
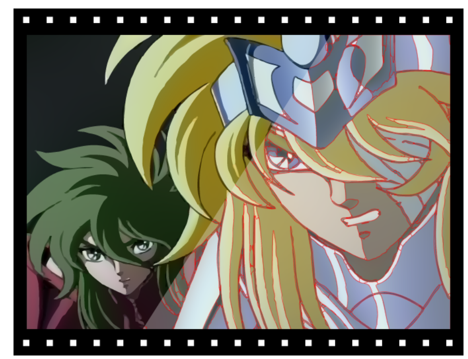
Cartoon Vectorisation

- Aim: take a video representing a cartoon, turn it into vector format
  - Vector format can be more easily edited, compressed, . . .
  - Can handle coloured *areas*, and coloured *lines*
- Universal background is reconstructed to give temporal coherence
- Moving objects are tracked, and segmented using *trapped ball* method
  - allows arbitrary colour model for regions, e.g. bicubic
  - is robust even with poor boundaries



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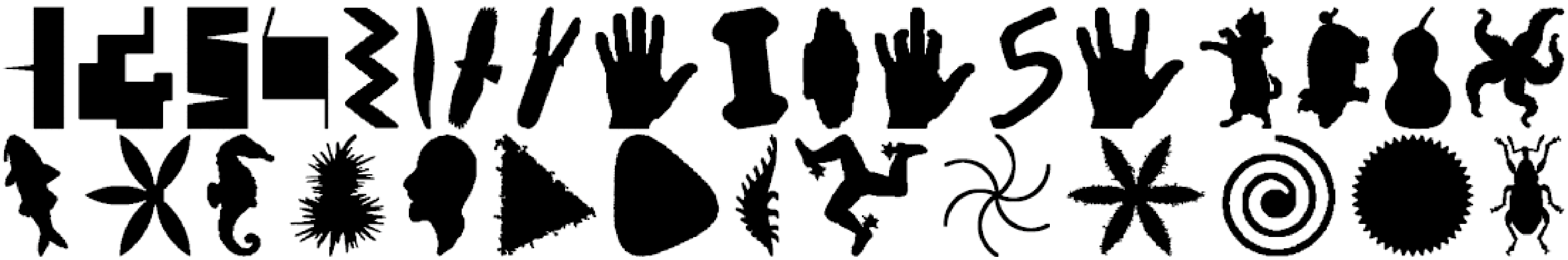
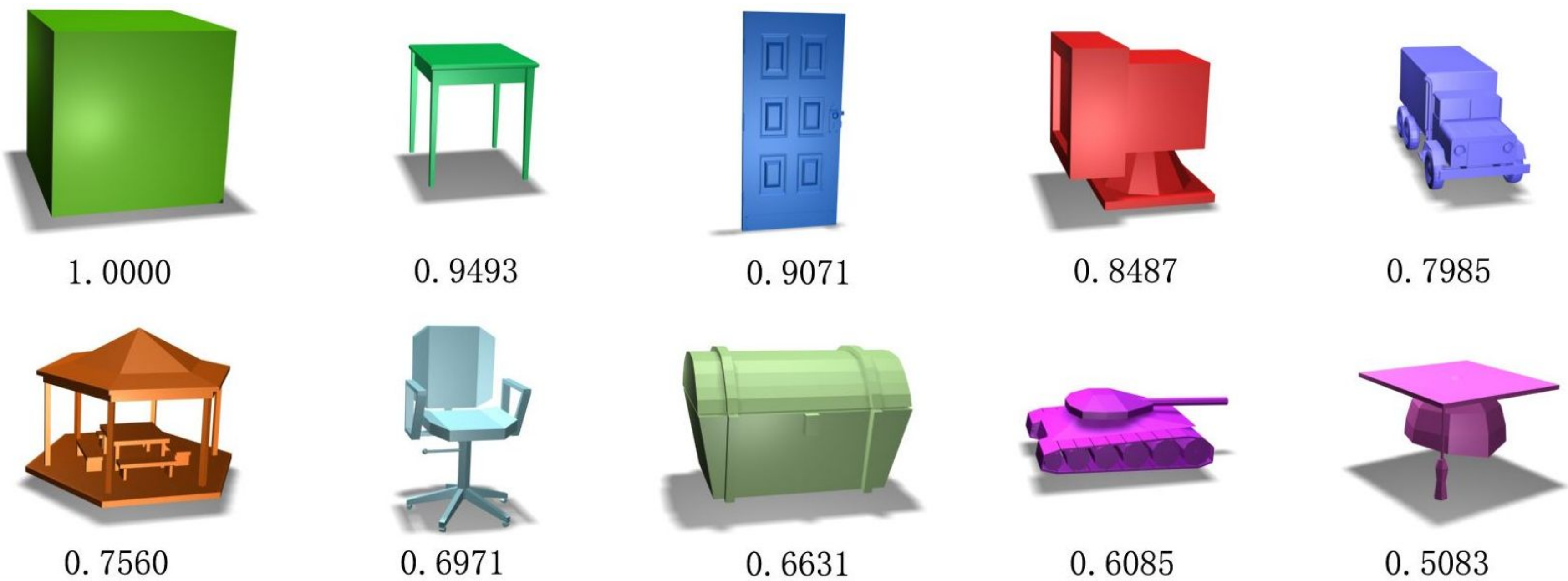
Shape Analysis

- Aim: to compute *shape measures* from 2D and 3D data
  - useful for classification, object retrieval etc.
  - example measures: convexity, rectangularity, rectilinearity





Video Completion

- Aim: *remove* unwanted items from *video*
  - e.g. plane flies across historical drama
- *Cut out* unwanted item
- *Search* for suitable other material in video which matches boundary of hole
- For speed
  - *track* moving objects to reduce search space
  - fill in *fragment-wise*, not pixel-wise
- Use *graph-cut* to hide seams, reduce blurring
- Guide filling by tracking to ensure *temporal coherence*

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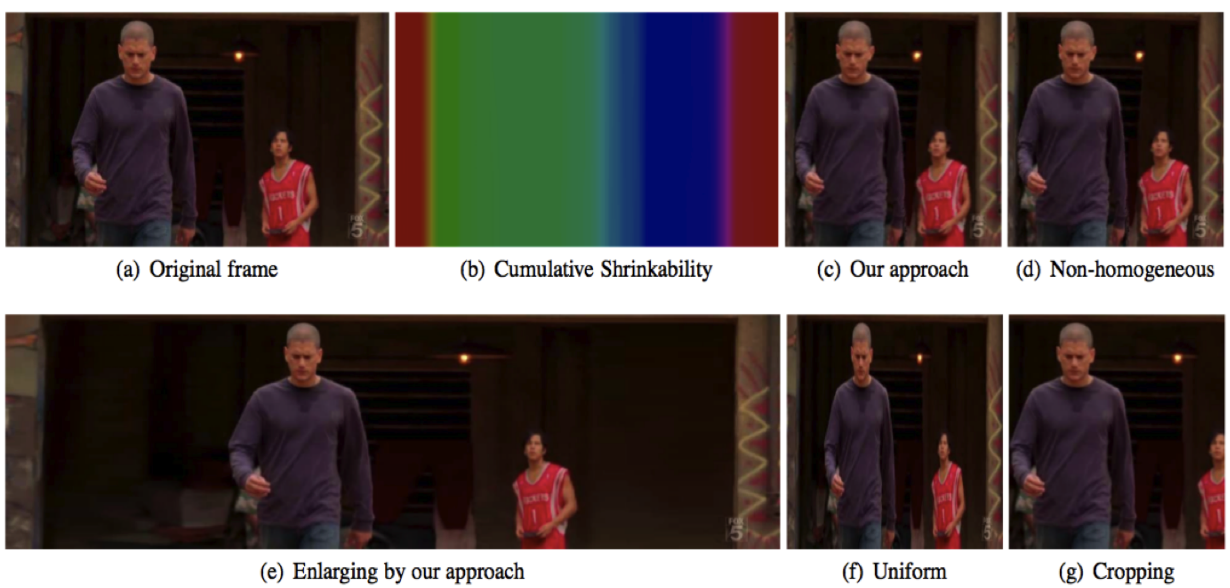
Video Resizing

- Aim: target video at device with *new aspect ratio*
  - non-uniform *scaling* introduces distortion
  - *cropping* fails if items of interest are at edges of scene
- Precompute a *shrinkability map* which takes into account
  - *importance* of scene elements
  - need for *temporal coherence* in result
- Shrinkability map is *precomputed* and stored with the video
  - it is *highly compressible* and allows retargeting on the fly



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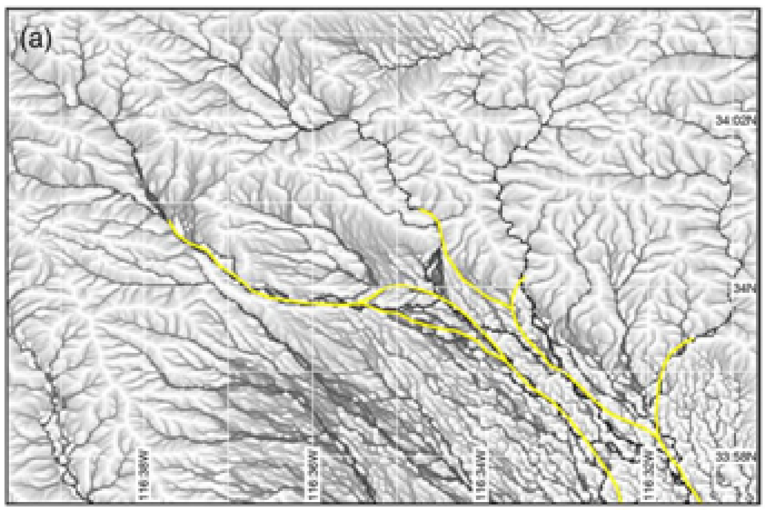
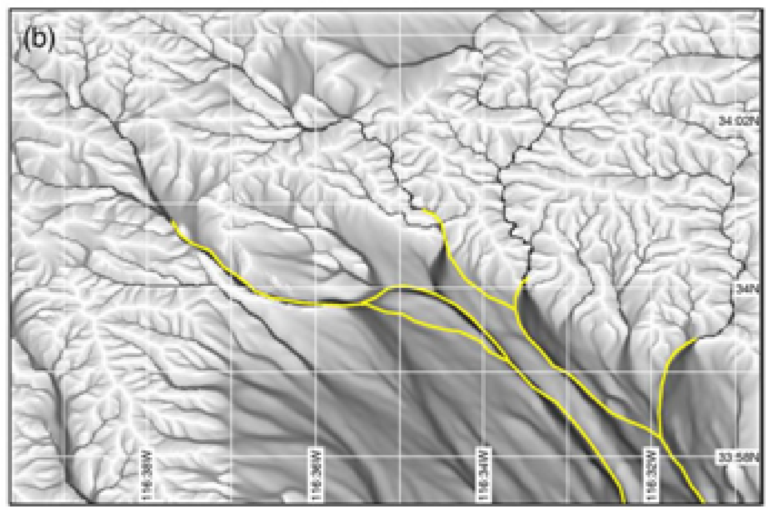
Application of Mesh Denoising Algorithm

- Aim: remove *noise* from topographic data
  - use feature-preserving mesh denoising algorithm
  - process SRTM and TOPSAR data
- Practical considerations:
  - data *triangulation*
  - selection of *threshold*
  - effect of number of *iterations*



(a) Input noisy SRTM



(b) Denoising result

with Earth, Atmospheric and Environmental Sciences, Manchester University

Opportunities for Collaboration

Thank you for your attention!

I’m happy to discuss these or any other topics

Other work can be found at

http://ralph.cs.cf.ac.uk/publications.html