From Active Contours To Active Surfaces

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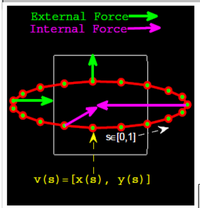
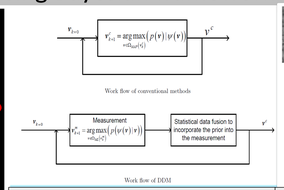
Background

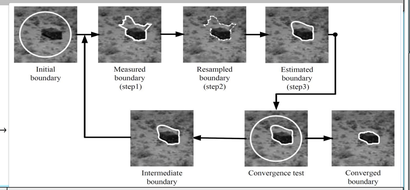
Active contour (AC)[TS] evolves in a solution space to minimize the total energy of a spline. The conventional AC energy minimization technique is slow and is sensitive to outliers. To address these issues, decoupled active contour [DAC] efficiently optimizes the total energy of the conventional active contours using Bayesian framework.



Deformation of traditional snake.



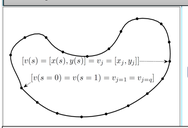
Representation of traditional and decoupled deformable model in a statistical framework.

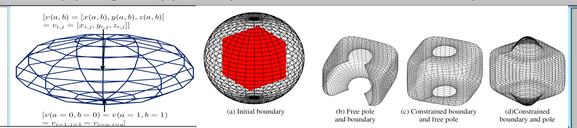


Steps involved in the decoupled active contour (DAC). The external energy and internal energy are termed as measurements and priors.

Extending the decoupled model from 2D to 3D is non-trivial.

Step 1. 3D to 2D mapping is typically not a one-to-one map.



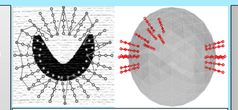


Representation of a 2D and 3D.

Different boundary conditions.

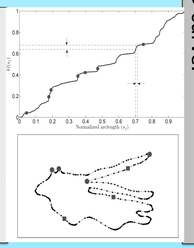
Step 3. Importance sampling is a difficult task in 3D, as parametric representation of surface is more difficult than 1D curve.

Step 2. Implementing the Viterbi algorithm to estimate the measured boundary in 3D is a difficult task than in 2D, as defining next and previous in 3D is not trivial.



Trellis in 2D and 3D, vertical lines are normal to the initial solution. In 3D defining a valid solution space is hard

Importance sampling in 2D. Few high curvature points are marked using circles



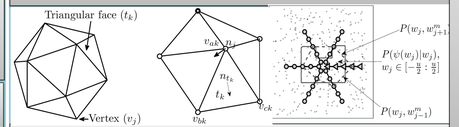
Step 4. To solve $\hat{x} = \mu_x + (R+Q)^{-1}R^{-1}(x^m - \mu_x)$ using direct matrix inversion approach 3D problems is computationally demanding.

These four issues have been addressed by formulating a new model, decoupled active surface(DAS).

Decoupled Active Surface (DAS)

DAS follows the theory of DAC, however uses discrete approximate techniques to implement the three steps of DAC in 3D as presented next.

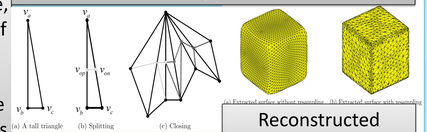
Step 1 and 2. The surface is represented as a closed discrete graph. Iterative quasi random search is used as an alternative to the Viterbi search to estimate the measured surface.



Left, discrete graphical representation of a surface, and vertex and surface normal, right, illustration of iterative quasi random search (IQRS). In IQRS, a vertex normal is chosen randomly (from a quasi random sequence) and optimized based upon the measurements of its neighbours. This procedure is repeated until convergence. A simple neighbour distance constraint is used.

Step 4. Modified conjugate gradient approach is applied to solve the Bayesian estimation problem without storing A.

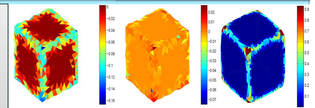
$$\hat{x} = \mu_x + (R^{-1}+Q)R^{-1}(x^m - \mu_x)$$
$$A\tilde{x} = b,\ \tilde{x} = \hat{x} - \mu_x,$$
$$A = (R^{-1}+Q)R,\ b = x^m - \mu_x$$
$$A = circulant(h) + diag\left(\frac{1}{r}\right),$$
$$A = f(h,r)$$



Iterative split based surface resampling.

Reconstructed surface without and with resampling.

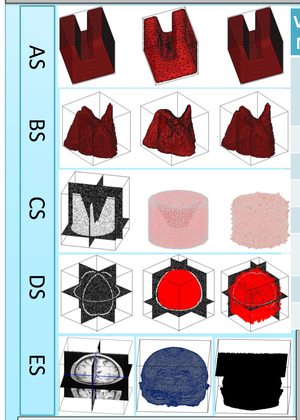
Step 3. Computing curvature and performing sampling in 3D are difficult, therefore DAS computes pseudo curvature and performs an iterative split algorithm based on this pseudo curvature and distance from its neighbours to generate more sample near high curvature regions than smooth regions.



Left to right : Gaussian curvature, principal curvature, pseudo curvature used in DAS. DAS's methods of curvature computation is more robust .

Experimental results

The performance of DAS compared to a non-parametric model is demonstrated using five volumetric images (AS, BS, CS, DS and ES) and two temporal image sequences (FS and GS).

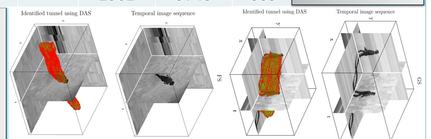


Left to right: volumetric image, extracted surface using DAS (middle) and LSHYB(right), respectively. LSHYB is more sensitive to noise than DAS.

Volume/ Method	LSHYB		DAS		
	No. vertices	ET (sec)	Initial No. Vertices	Final no. vertices	ET(sec)
AS	24900	1980	642	1981	323
BS	21284	2383	642	3684	187
CS	18910	2542	642	2432	297
DS	78888	3323	1281	1842	123
ES	4999044	15623	1281	4987	315
FS	-	-	2562	7096	512
GS	-	-	2562	9748	539

The quantitative comparison of DAS and a parametric model. DAS is two order faster and provide more accurate surface extraction performance.

Matlab 6 and P4, 1Gb RAM and 2.5 GHz machine are used in the testing.



Set of33 temporal images are stacked with each other to form volumetric image. The extracted tunnel using DAS are shown in red.

References

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