Speeding Up Active Mesh Segmentation
by Local Termination of Nodes

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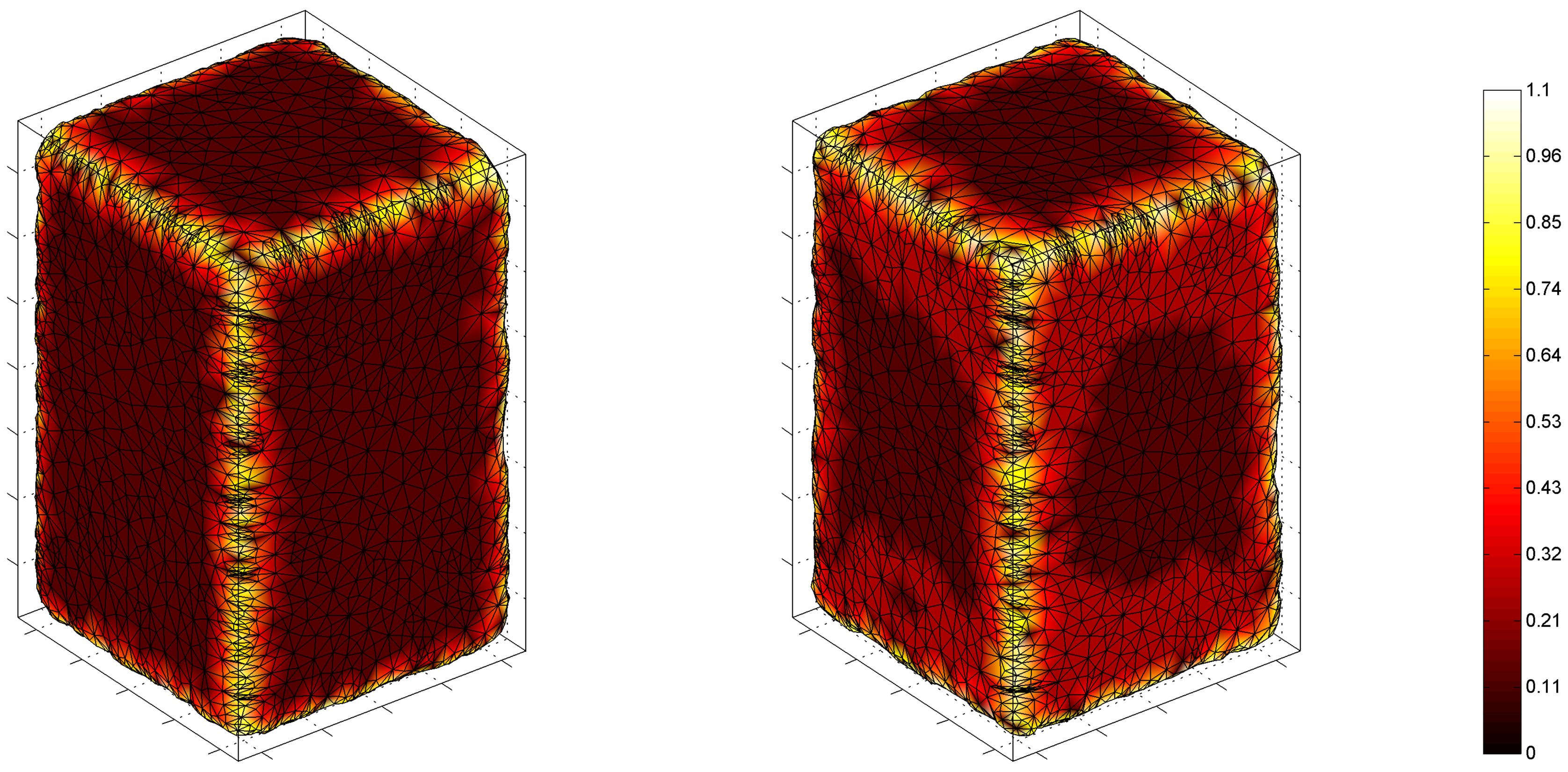
Abstract

This article outlines a procedure for speeding up segmentation of images using active mesh systems. Active meshes and other deformable models are very popular in image segmentation due to their ability to capture weak or missing boundary information; however, where strong edges exist, computations are still done after mesh nodes have settled on the boundary. This can lead to extra computational time whilst the system continues to deform completed regions of the mesh. We propose a local termination procedure, reducing these unnecessary computations and speeding up segmentation time with minimal loss of quality.

Introduction

Active meshes are deformable models that deform a triangular-faced mesh to some cost or energy minimisation in order to segment the boundaries of an object in 3D. With many optimisation techniques there may be no definite or optimal termination; as such, many systems are provided with an explicit stopping criterion in order to terminate the process.

One key feature of termination criteria that are mentioned in the literature is that they focus on the overall mesh, i.e. they are global termination criteria. Here we introduce local termination of vertices, a heuristic which speeds up segmentation and defines a stopping point for iterations.



(a) (b)

Figure 1: Comparison of globally (a) and locally (b) terminated meshes. Scale bar applies to both figures in voxels.

Local Termination of Vertices

We define whether or not a vertex should be terminated using the following cost function,

$$\boldsymbol{C_v} = \alpha \boldsymbol{C_I} + \beta \boldsymbol{C_G} + \gamma \boldsymbol{C_T}, \tag{1}$$

where α, β and γ are user-defined parameters and the first two terms, $\boldsymbol{C_I}$ and $\boldsymbol{C_G}$, are the value of the normalised image and gradient magnitude image, respectively. Finally, $\boldsymbol{C_T}$ is one if the vertex was terminated during the last iteration and zero otherwise. More advanced cost functions could look at the history or neighbourhood of the vertex in more detail.

We use a combination of the cost at the vertex and the average cost of its direct neighbourhood. So $\boldsymbol{T_v}$, the choice to terminate a vertex or not, is given by,

$$\boldsymbol{T_v} = \begin{cases} \texttt{TRUE} & \text{if } \mu \boldsymbol{C_v} + (\mathbf{1} - \mu)\frac{\sum_j \boldsymbol{C_j}}{\boldsymbol{N_v}} > \boldsymbol{c}, \\ \texttt{FALSE} & \text{otherwise;} \end{cases} \tag{2}$$

here, $\boldsymbol{N_v}$ is the size of the neighbourhood $\boldsymbol{C_j}$ is the cost at a neighbour, and μ is a user-defined parameter. The user-defined cost-level, $\boldsymbol{c}$, is a threshold above which a point is terminated.

During the next iteration we only deform vertices that are not terminated, decreasing computation time per iteration.

Shape (Vertices)	Reduction	
	Mean Time	Quality
Sphere (4,342)	62.4%	-0.3%
Cube (4,281)	79.2%	5.5%
Weeble (6,606)	53.0%	-0.6%
Tube (6,617)	84.9%	3.1%
Cuboid (3,694)	52.5%	4.4%

Table 1: Table showing reduction in time and quality of segmentation using local termination procedures.

Synthetic Data

To test the system we ran a globally terminated deformable mesh and a locally terminated deformable mesh on five synthetic shapes. The results (Table 1) show a dramatic reduction in running time with a small loss of segmentation quality.

Figure 1 shows distance maps from the segmentation mesh of a cuboid. The colouring at the surface shows the average distance between that region of the mesh and the true boundary of the synthetic shape.

We also ran our system on noisy, synthetic shapes with, for the cuboid, a decrease of 50 ($\pm$10)% in run time with only a 7.9 ($\pm$0.5)% decrease in quality compared to the global termination method.

Improving Segmentation Quality

Here we show two modifications of our local termination scheme that help to improve the quality of segmentation.

The first variation subtracts a pseudo-random value between 0 and 0.1 from the termination cost before comparison to $\boldsymbol{c}$; this causes some vertices that should be terminated this iteration to be left on for at least one more iteration.

In the second method a vertex must be classified as terminated for two consecutive iterations before it is actually terminated.

Local Termination...	Reduction from Global	
	Mean Time	Quality
with Random Benefit	79.4%	-1.6%
with Double Take	81.3%	-1.6%

Table 2: Results of variations upon the basic local termination method show equal reduction in time with less loss of quality.

Biological Data

We validated local termination on 3D CLSM images of DAPI-stained dehisced mature pollen grains obtained from wildtype *Arabidopsis thaliana* plants of the Columbia (Col-0) ecotype (Figure 2). On average segmentation was sped up by 51 ($\pm$**2**)%.

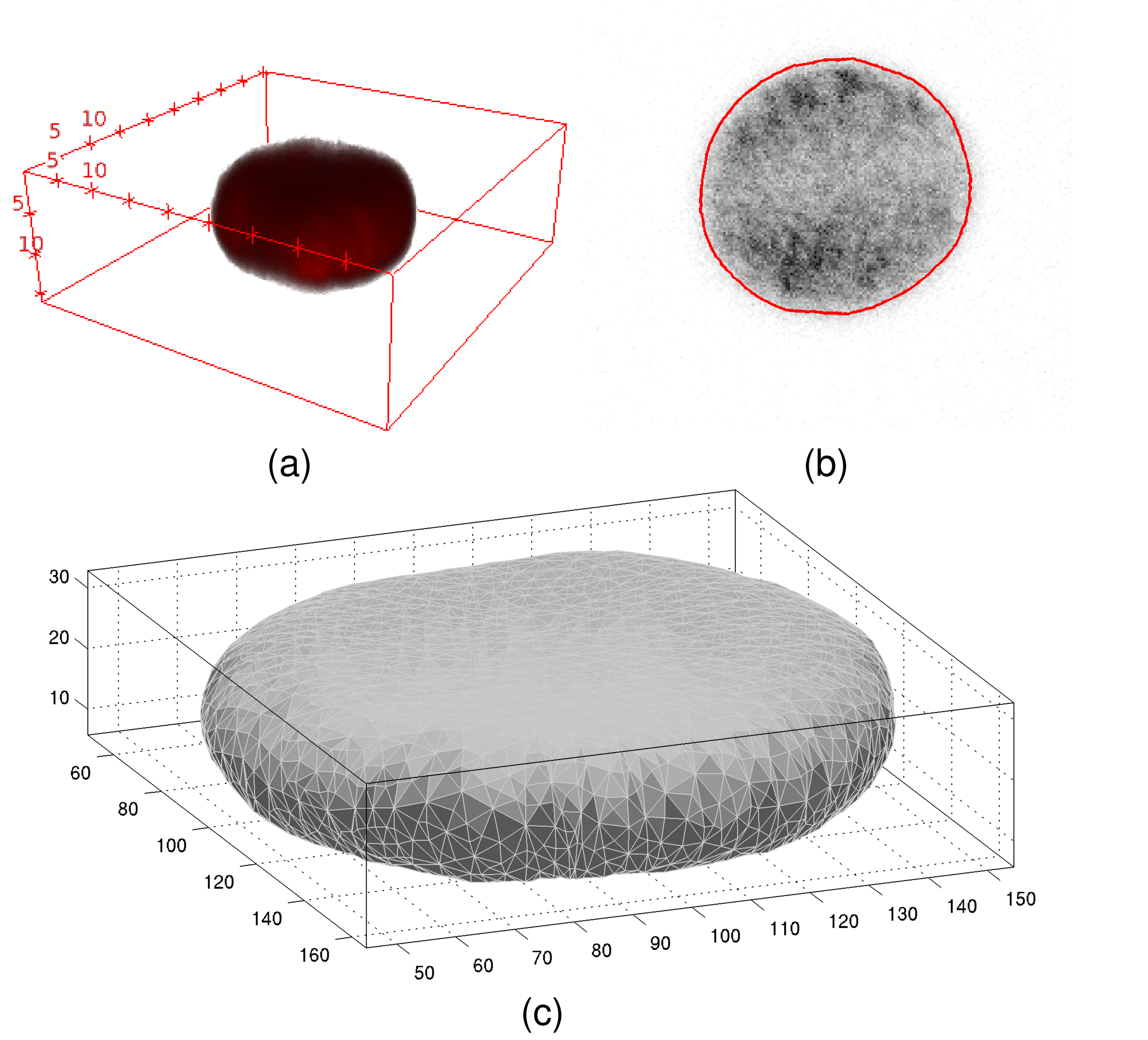


Figure 2: Mature pollen grain: (a) 3D volume rendering. (b) 2D contour and (c) 3D mesh representation of the segmentation results. Scale bar corresponds to 10μ**m**.

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