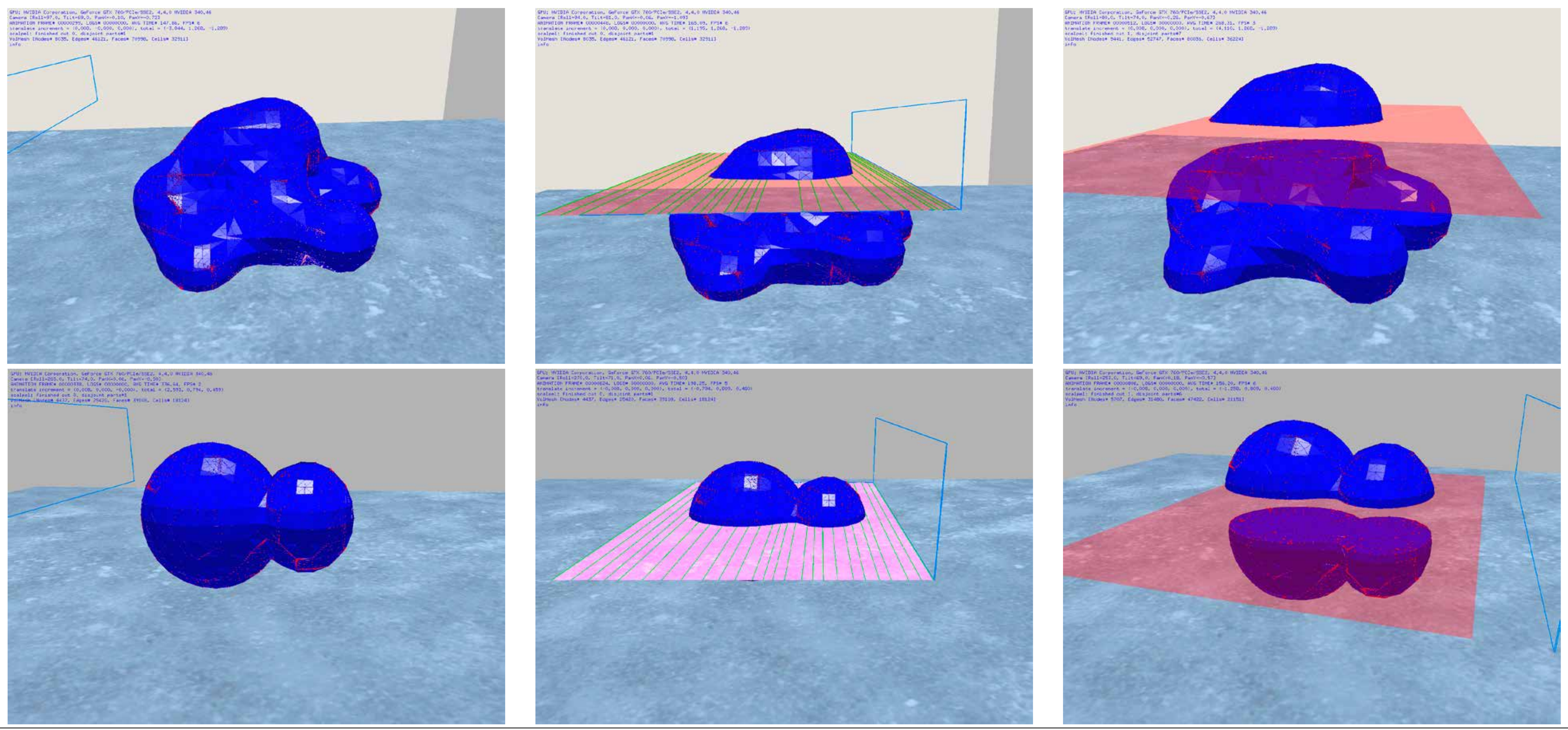
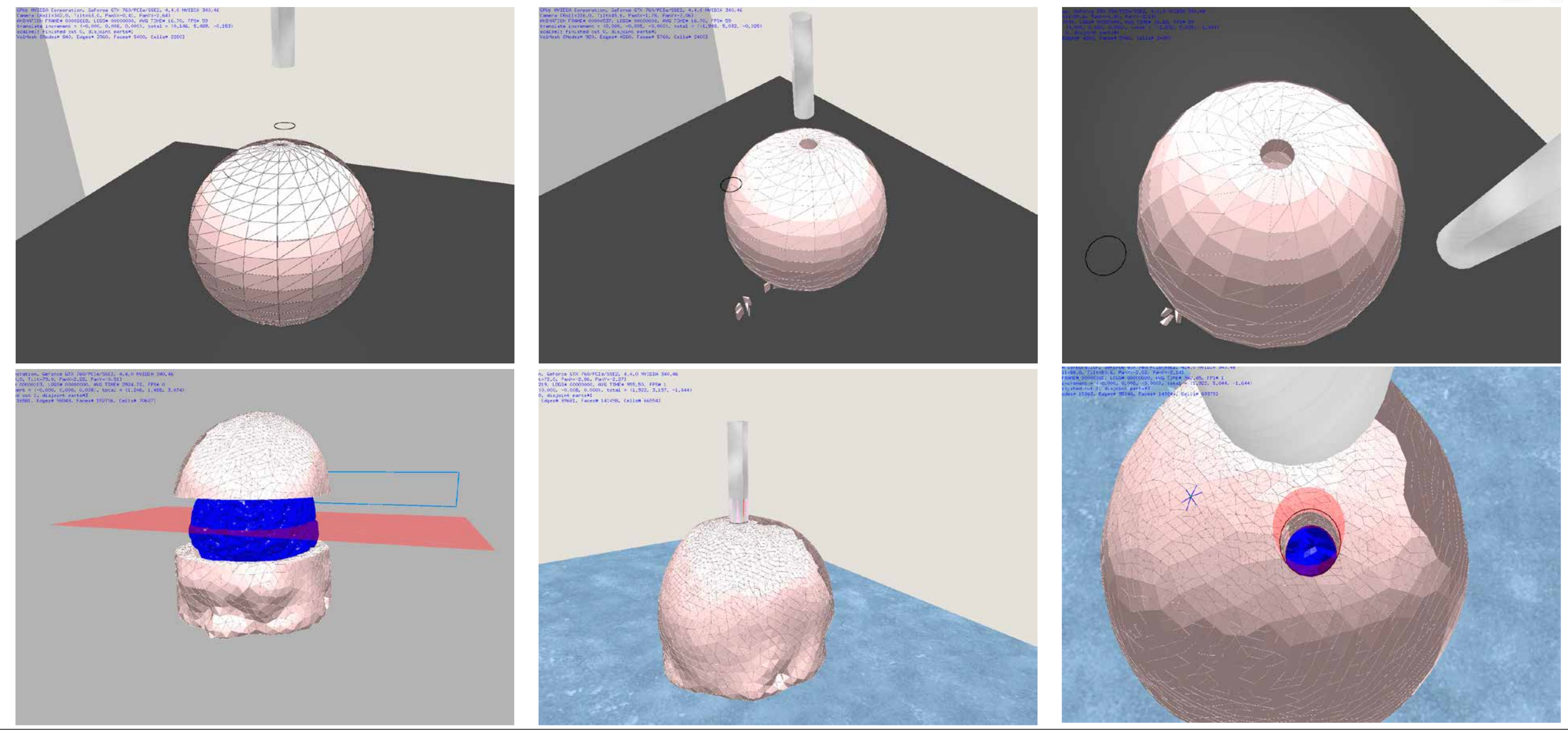
TOMORROW LAB GRAND2014

Interactive Cutting for Surgical Simulation Systems

Pourya Shirazian, Brian Wyvill, Roy Eagleson, Sandrine deRibaupierre

University of Victoria





Introduction

One of the main objectives of virtual reality based surgical simulation systems is the removal of pathologic tissues. Cutting imposes many challenges in the development of a robust, interactive surgery simulation, not only because of the nonlinear material behavior exhibited by soft tissue but also due to the complexity of introducing the cutting-induced discontinuity. We propose a high performance cutting algorithm for complex tetrahedral meshes. As a proof of concept we integrated our algorithm in a craniotomy simulation (figure: top-right 2nd row).

Research Contributions

1. State-of-the-art real-time cutting algorithm for large tetrahedral meshes
2. Novel scalpel-tissue collision detection technique using implicit surfaces
3. Ability to restrict cuts to specific areas of the tissue model

Craniotomy Simulation

For this simulation, the human head volume mesh is segmented into skull, CSF, white and gray matters. The skull is modelled as a rigid material with more than 66K tetrahedral cells.
The cutting tool is approximated by N line segments. The intersection of each segment and the mesh is performed at stage one in the algorithm (see next column)

Algorithm

CPU: Implicit Collision Detection:
Sample field at close-range surface vertices/

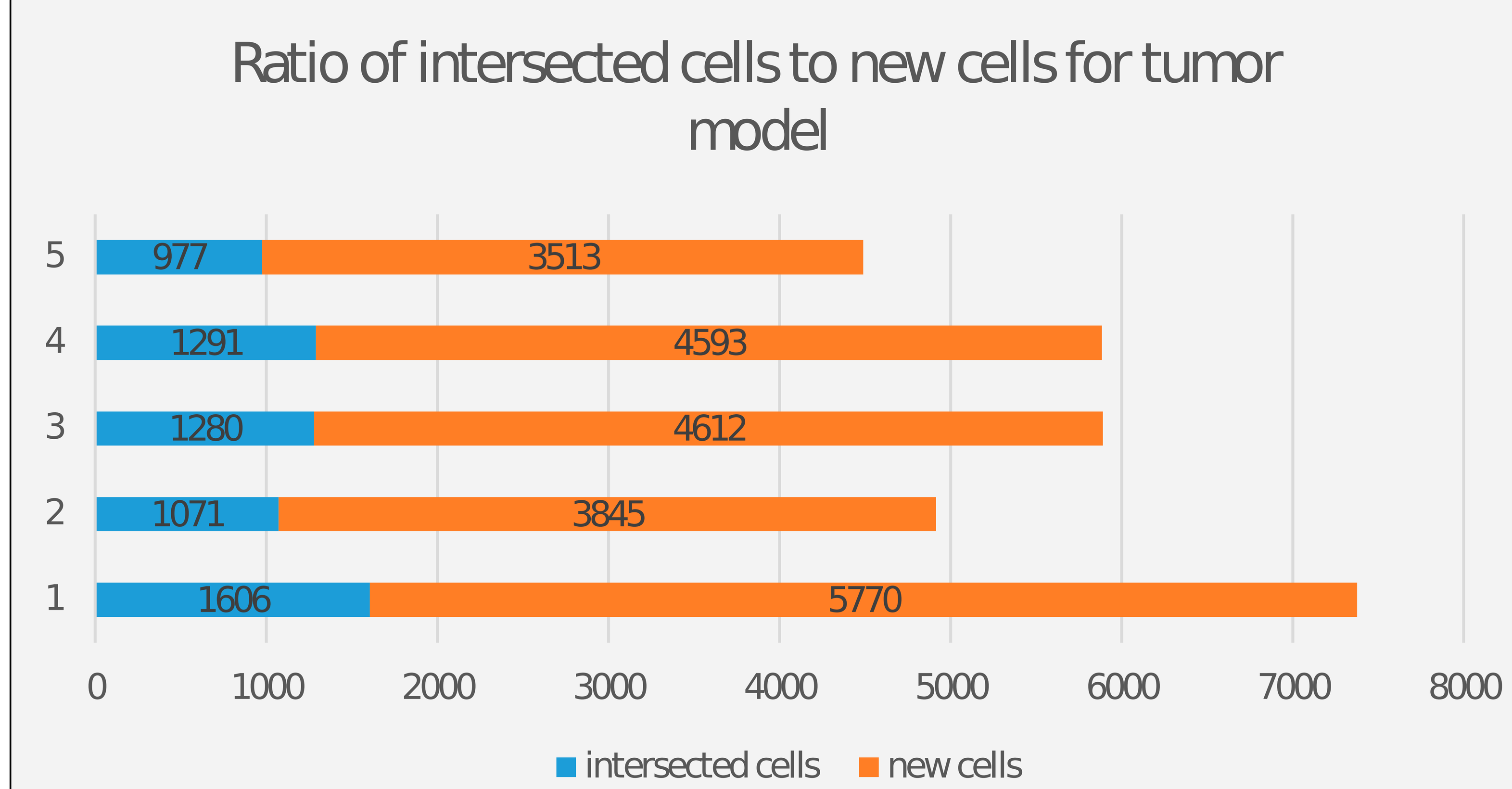
Continue on the pipeline if the field is higher than the threshold value T

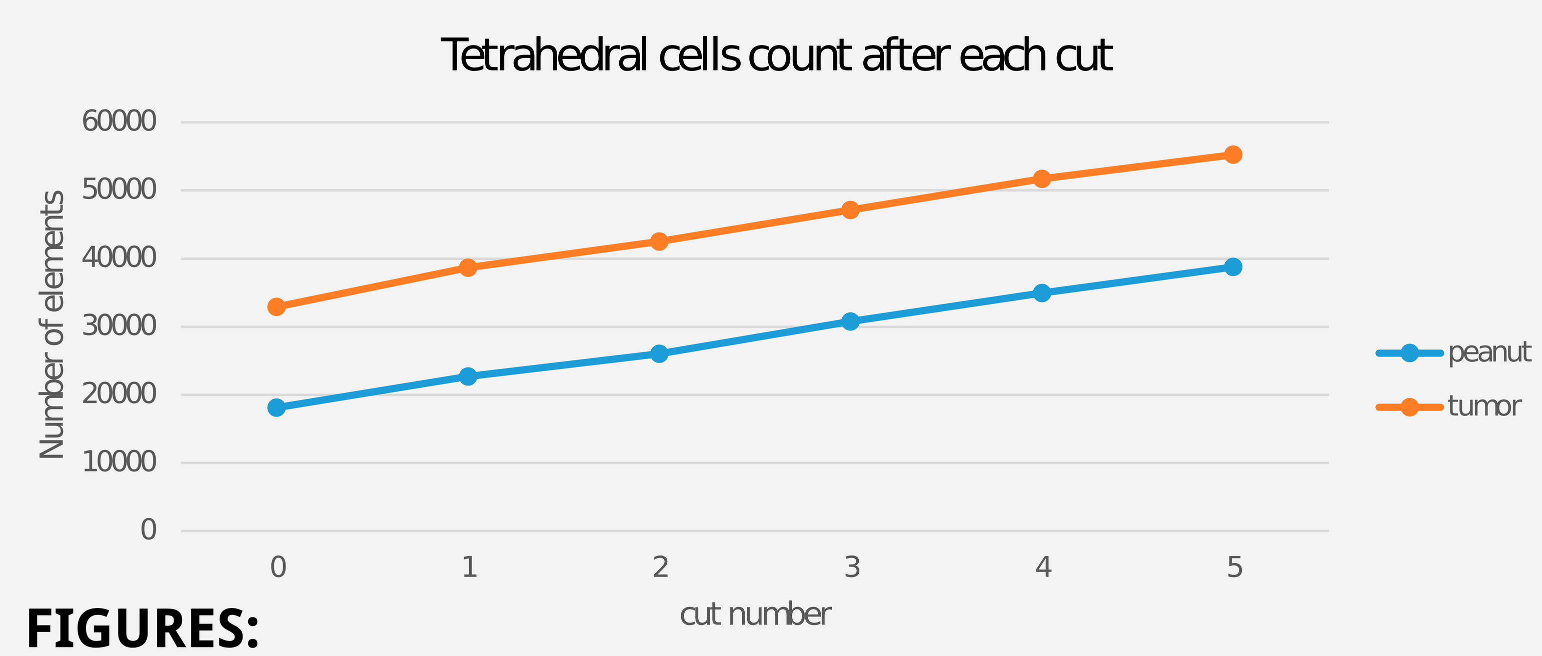
time

1. GPU Kernel: computeIntersectedEdges
2. CPU: produceCutNodeList
3. CPU: filterIntersectedEdges
4. GPU Kernel: identifyCellsToDivide
5. CPU: subDivideCellsUpdateMesh
6. CPU: updateMassStiffnessMatrices

1. A GPU kernel function is spawned per each sweep surface quad to find all the edges intersected with that quad.
2, 3. If an edge-intersection is too close to an endpoint then that edge is discarded from the list.
4. Compute tetrahedral cell configurations from a lookup table (LUT).
5. Subdivide elements according to the LUT.
6. Update Physics Simulation

Results





FIGURES:
top-left 1st row: Tumor model with 32K cells being cut
top-left 2nd row: Peanut model with 18K cells being cut
top-right: Craniotomy experimental eggshell mesh (1st row) and the brain mesh with skull, white and gray matters (2nd row).
RESULTS:
Ratio of intersected cells to new cells (top)
Element increase after multiple cuts (bottom).