Physical human lumen carotid reconstruction: life-size models by rapid prototyping

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Summary

- **Rapid Prototyping**
 - Uses and examples
- **Application carried out**
 - Clinic application
 - Work Pipeline
 - Conclusions

Examples RP

LOM

SLS

SGC

Rapid Prototyping techniques

RP – FDM technique (1/2)

- A specialized operator computer-slices the .stl file into horizontal layers, generates the required supports and creates tool paths for the extrusion head;
- The head extrudes and deposits the material in layers onto a fixtureless base lowered step by step as each layer is added (270° C);
- A second nozzle at the same time creates a supporting structure as required;

RP – FDM technique (2/2)

- Advantages:
 - good variety of materials available;
 - easy material change;
 - low maintenance costs ;
 - thin parts produced fast;
 - tolerance of +/- 0.005" overall;
 - No supervision required;
 - No toxic materials;
 - Very compact size;
 - Low temperature operation;
- Disadvantages:
 - Seam line between layers;
 - The extrusion head must continue moving, or else material bumps up;
 - Supports may be required;
 - Part strength is weak perpendicular to build axis;
 - More area in slices requires longer build times;
 - Temperature fluctuations during production could lead to delamination;

RP applications in medicine

Pipeline: from Computer Tomography to RP

- Image segmentation
- *Offset* to get manufacturing thickness;

- Lumen reconstruction with B-Spline curve (continuity C2);

- Wall reconstruction with B-Spline surface(continuity C2);

- Gluing of surfaces and check of the obtained *Boundary-Representation* (BRep);

- Output: file stl;

- Elaboration with QuickSlice;

- 3D printing with FDM technique;

- Solid modelling reconstruction with *OpenCascade*
- Physic Prototyping of me-chanical parts with the device for Rapid Prototyping: *Fused Deposition Modelling* (FDM2000)

Image Acquisition and Segmentation

Geometric Reconstruction: Open Cascade

Geometric Reconstruction: Boundary REPresentation

SOLID $\Leftrightarrow$ Volume

SHELL

FACE $\Leftrightarrow$ Surface

LOOP

EDGE $\Leftrightarrow$ Curve

VERTEX $\Leftrightarrow$ Point

Reconstruction steps (1/2)

- Reading points coordinates
- Scaling to get manufacturing thickness
- Inner and outer interpolation with B-Spline curves
- Consistency check
- B-Spline surface creation between adjacent slides (C2)

Reconstruction steps (2/2)

- Phase 1 application along the whole lumen in the main trunk of carotide
- B-Rep solid creation

Towards 3D printing with FDM (1/2)

- Acquisition of the .stl file;
- QuickSlice=> Orienting it along the manufacturing direction;
- Slicing into plane curves;
- Creation of the SSL (StrataSys Layer interface) file;
- Consistency evaluation for the object to print;
- Error correction;

Towards 3D printing with FDM (2/2)

- Support structure generation;
- Consistency check;
- Machining paths creation;
- Export in .sml format;

3D print (1 / 2)

- Stratasys FDM2000
- Work volume:
 $254*254*254 \text{ mm}^3$
- Slices thickness:
 $0.178 < d < 0.500 \text{ mm}$
- Tolerance 0.0127 mm
- Material: ABS resin.

3D print (2/2)

Conclusions

The originality of this work is *the open source approach*, which allows access to the software code and consequently control the pipeline steps of the process.

The main result consists in establishing a manufacturing pipeline allowing *virtual* and *physical* reconstructions of lumen parts starting from CT datasets, by means of open source software and RP techniques. The output of this pipeline is a resin model of human carotid. Replicas come from the CT acquisition of an autoptic part and have been produced in two different ways: a single piece and a two-parts piece.

Planned Works

CT data

BREP of bifurcation

- reconstructions of anatomic parts starting from CT datasets of living patients and medical validation of the results;
- improving integration between segmentation and reconstruction modules;
- development an algorithm for the automatic reconstruction of the carotid lumen at the bifurcation region;
- replicas of anatomic human parts made using different materials and RP techniques;