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

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#### CRS4

Center for Advanced Studies, Research and Development in Sardinia EIP – GEMMS Group:

Energy and Chemical Process - Geometric Modelling & Montecarlo Simulations



- SPIE's Medical Imaging 2003-

#### Summary

#### Rapid Prototyping

– Uses and examples

#### Application carried out

- Clinic application
- Work Pipeline
- Conclusions



## Examples **RP**

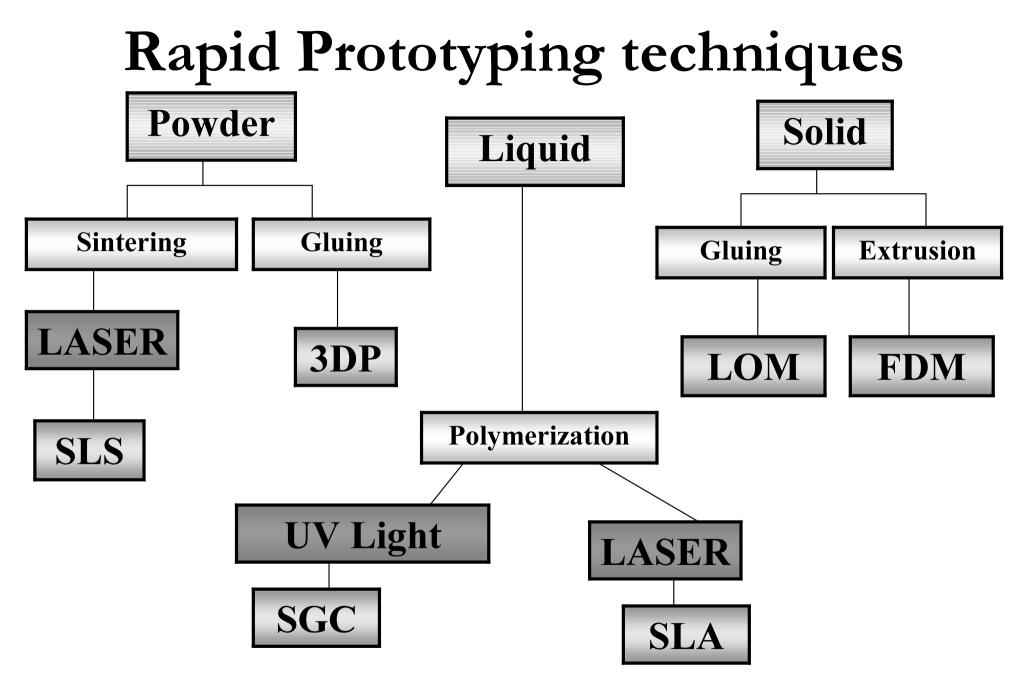








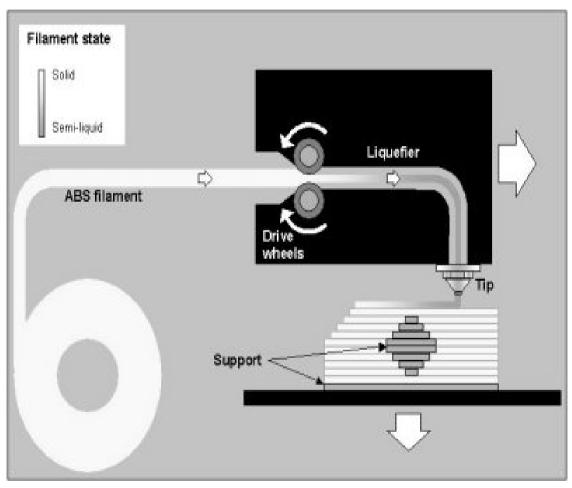
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## **RP – FDM technique** (1/2)

- 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;





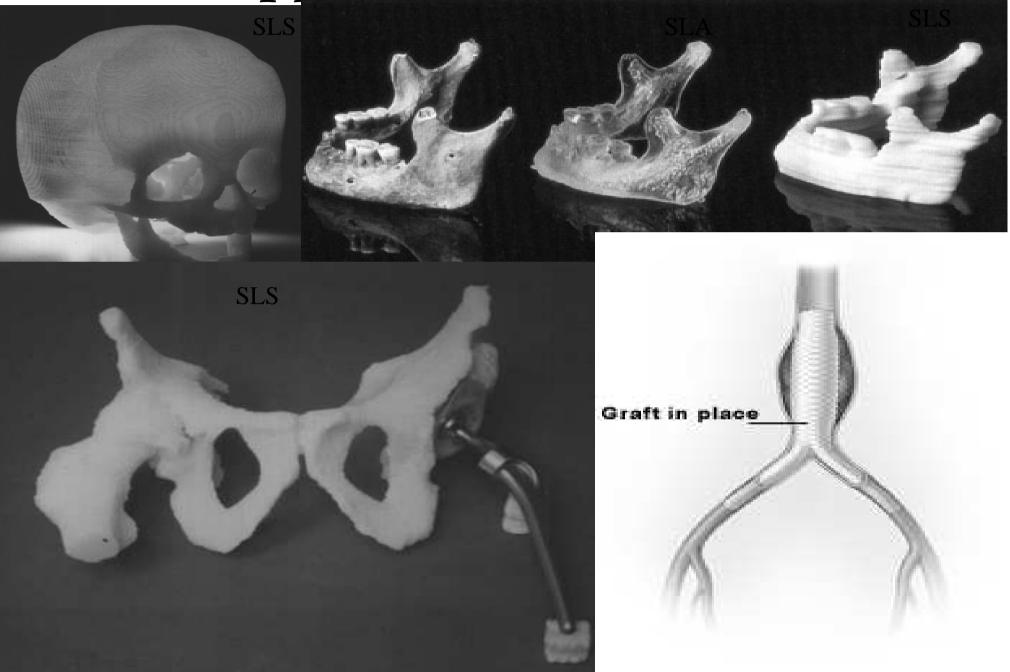
## **RP – FDM technique** (2/2)

- Advantages: •
  - good variety of materials availa- Seam line between layers; ble;
  - 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:
  - - 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;

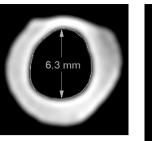


### **RP** applications in medicine



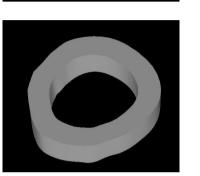
#### Pipeline: from Computer Tomography to RP







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



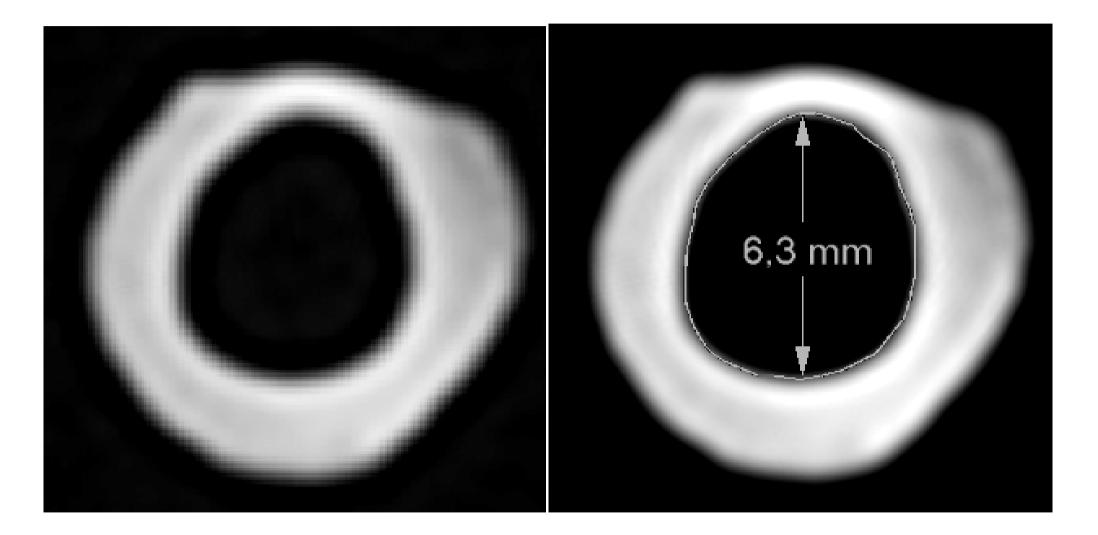




- •Image segmentation
- •*Offset* to get manufacturing thickness;
- •Lumen reconstruction with B-Spline curve (continuity C2);
- •Wall reconstruction with B-Spline surface(continuity C2);
- •Gluing of surfaces and check of the obtained *Boundary-Representation* (BRep);
- •Output: file stl;
- •Elaboration with QuickSlice;
- •3D printing with FDM technique;

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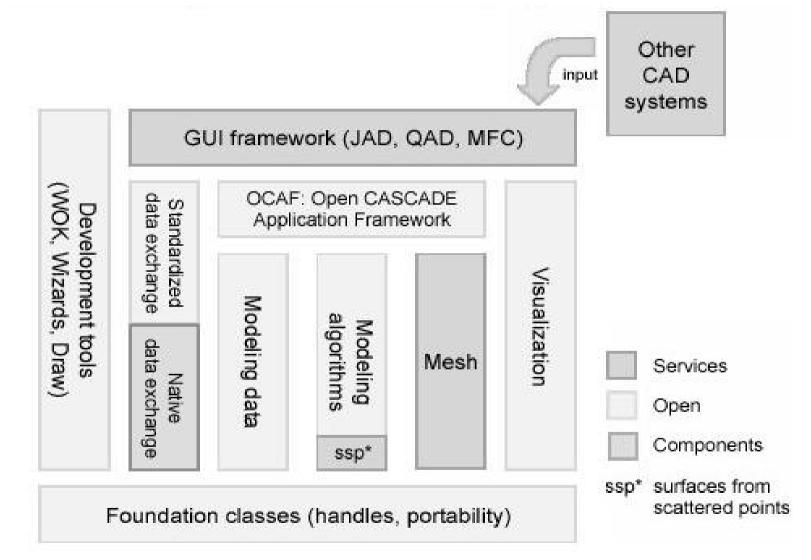
### Image Acquisition and Segmentation





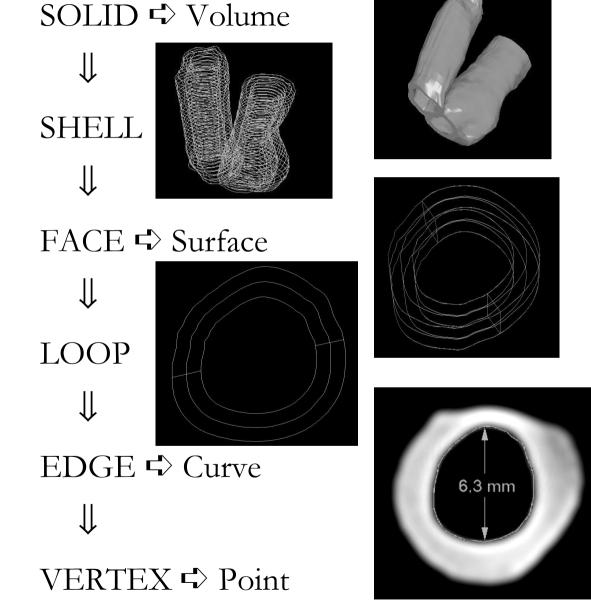
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## Geometric Reconstruction: Open Cascade





#### Geometric Reconstruction: Boundary REPresentation

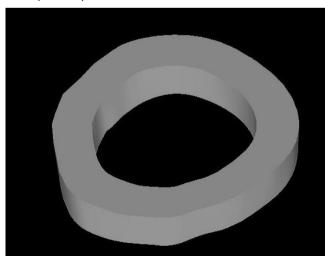


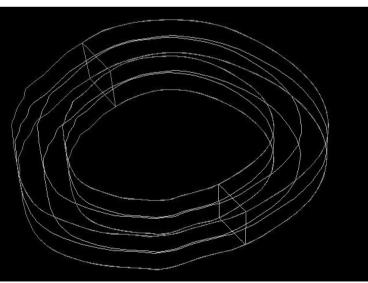


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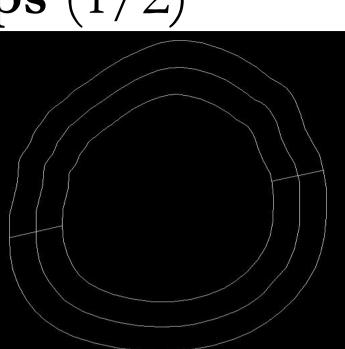
## **Reconstruction steps** (1/2)

- 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)



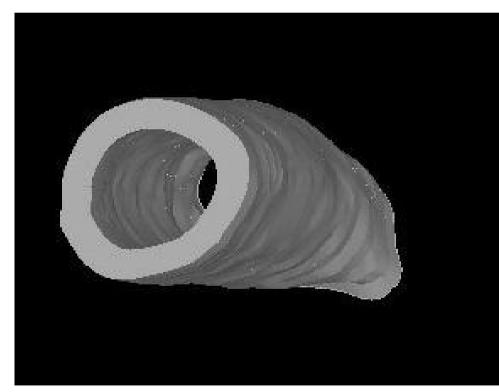


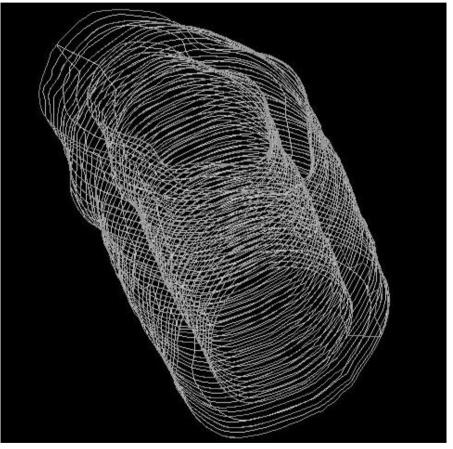




## **Reconstruction steps** (2/2)

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



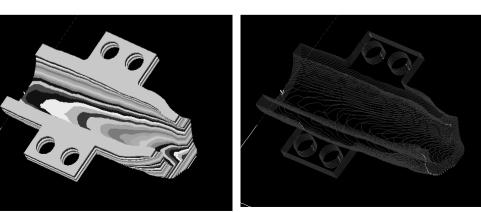




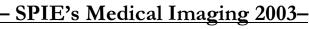
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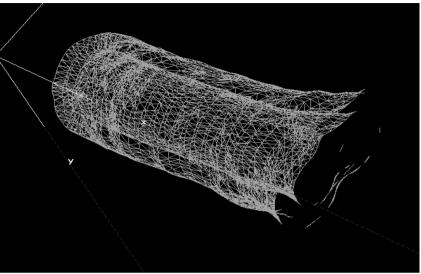
## Towards 3D printing with FDM (1/2)

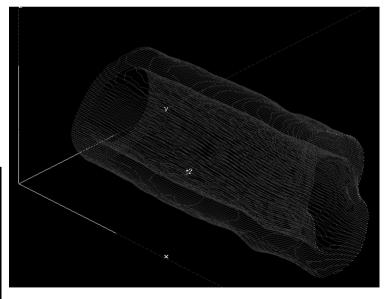
- Acquisition of the .stl file;
- QuickSlice=> Orienting it along the manufacturing direction;
- Slicing into plane curves;
- Creation of the SSL (StrataSys Layer interface) file;
- Consistency evaluation for the object to print;
- Error correction;





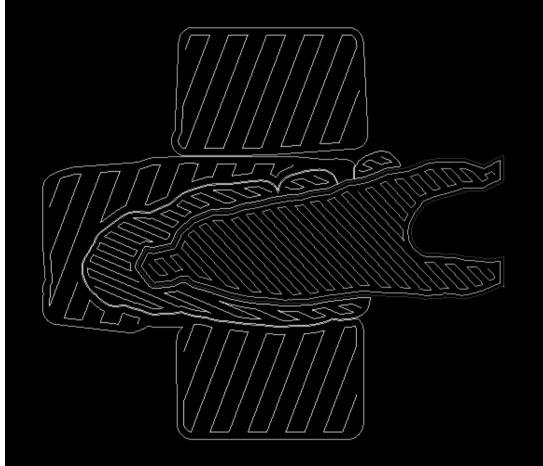






## Towards 3D printing with FDM (2/2)

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



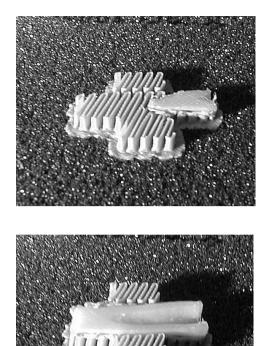


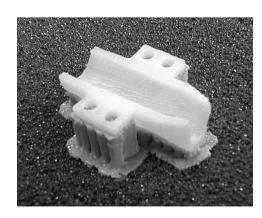
## **3D print** (1/2)

- Stratasys FDM2000
- Work volume: 254\*254\*254 mm<sup>3</sup>
- Slices thickness: 0.178<d<0.500 mm
- Tolerance 0.0127 mm
- Material: ABS resin.

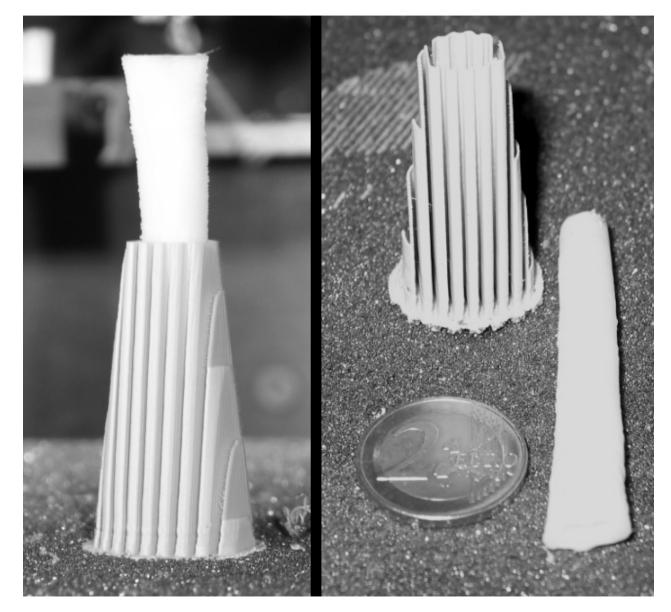








## **3D print** (2/2)



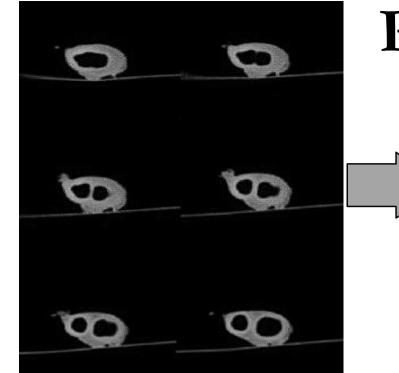


### Conclusions

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 twoparts piece.





### Planned Works



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;



CT data