A Practical Method to Model Complex 3D Geometries with Non-Uniform Material Properties Using Image-based Design and COMSOL Multiphysics

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Introduction: Geometries with heterogeneous material properties are typically defined as a set of multiple parts, each part representing a different material[1,2,3,4]. However, assembling or defining the individual parts of complex geometries can be difficult[1,5].

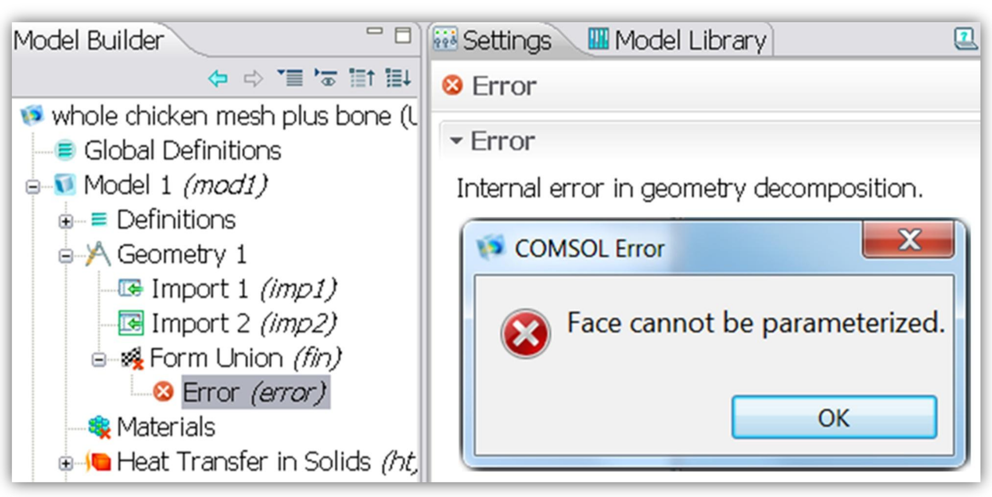
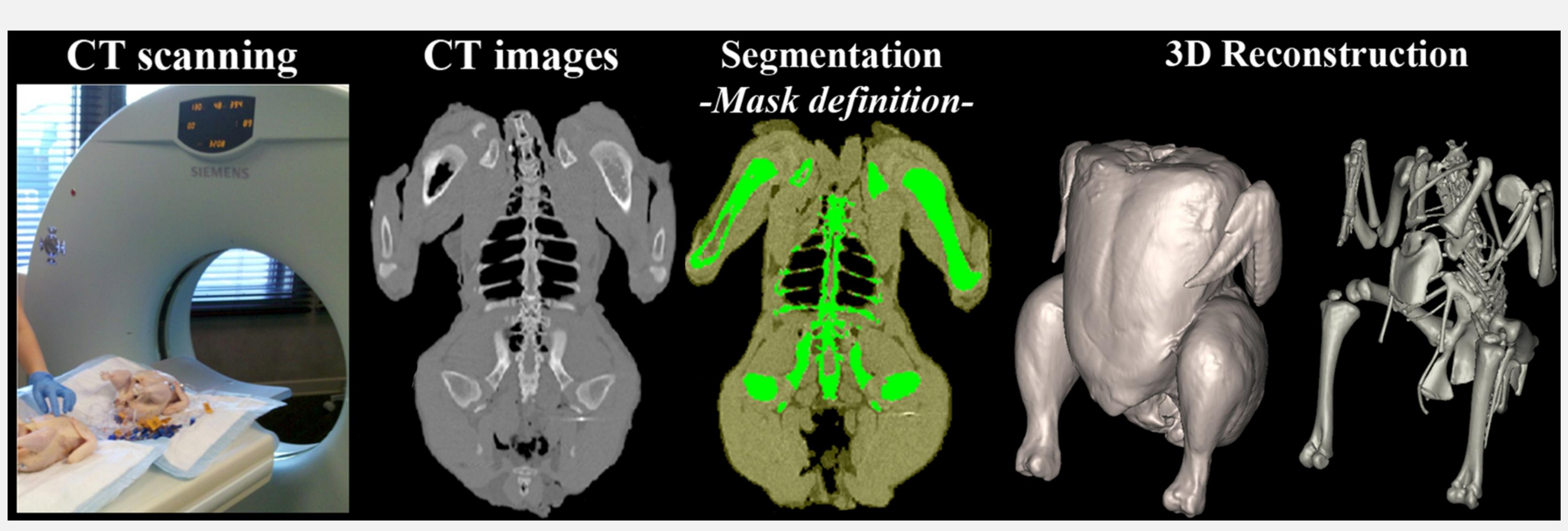


Figure 1. Potential issues when importing complex geometries.

The following method can be used for meshing complex geometries with heterogeneous material properties:

STEP 1 - Scanning and 3D reconstruction[5]



- Build 3D surface geometries for the object as a unit, and for each sub-part separately

STEP 2 - Meshing

- Mesh object as a unit, and each subpart separately
- Export meshes as COMSOL native mesh files (.mphtxt)

STEP 3 - Material labeling

- Create look-up table for materials using custom algorithm

```
Read Mesh of Object
Read Meshes of Subparts
For Each Subpart
     For Each Node in Subpart
          -Find   Nearest   Neighbor
             Node in Object Mesh
          -Label the Node in Object
             Mesh with Corresponding
             Material
     Next Node in Subpart
Next Subpart
```

Labeled Nodes.txt

x [m]	y [m]	z [m]	Material	k [W / m K]	Cp [J / kg K]	ρ [kg / m³]
1.30E-01	1.14E-01	2.78E-02	Meat	0.265	2,021	1,040
1.33E-01	1.15E-01	2.98E-02	Meat	0.265	2,021	1,040
1.77E-01	5.69E-02	5.48E-02	Round Bone	0.265	2,021	1,040
1.05E-01	7.71E-02	7.06E-02	Air	0.026	1,005	1.2
7.16E-02	6.97E-02	-1.98E-02	Rib Bone	0.265	2,021	1,040
7.26E-02	6.55E-02	-1.73E-02	Rib Bone	0.265	2,021	1,040

STEP 4 - Define material properties by interpolation

- Import only the mesh for the object as a unit

Property	Name	Value	Unit
Thermal conductivity	k	k1(x,y,z)	W/(m*K)
Density	rho	rho1(x,y,z)	kg/m^3
Heat capacity at constant pr...	Cp	Cp1(x,y,z)	J/(kg*K)

Case Study: Modeling air-cooling of a chicken carcass.

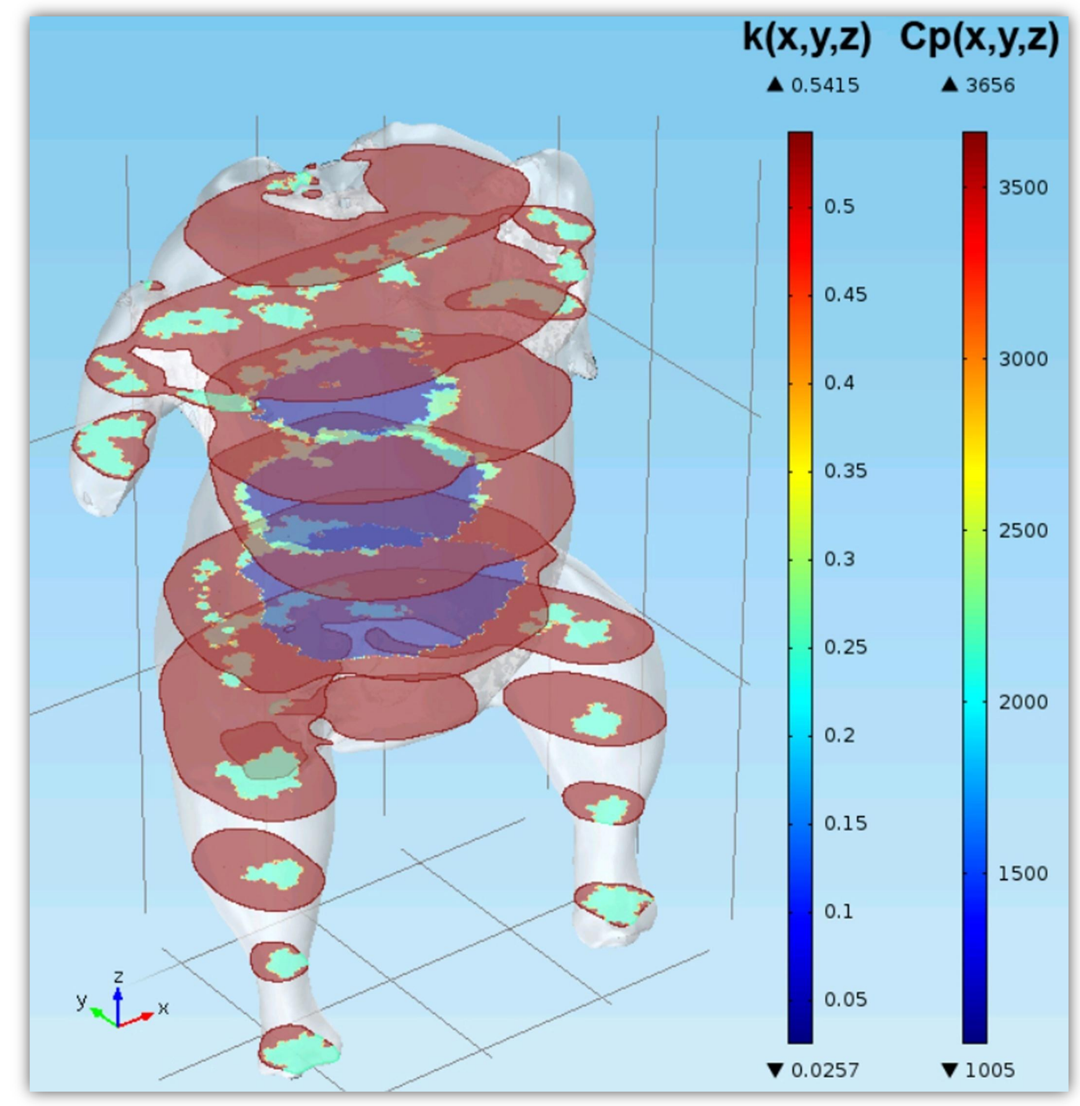


Figure 2. Heterogeneous material properties of the chicken carcass defined using image-based meshing (with Materialise Mimics) and interpolation functions of COMSOL Multiphysics.

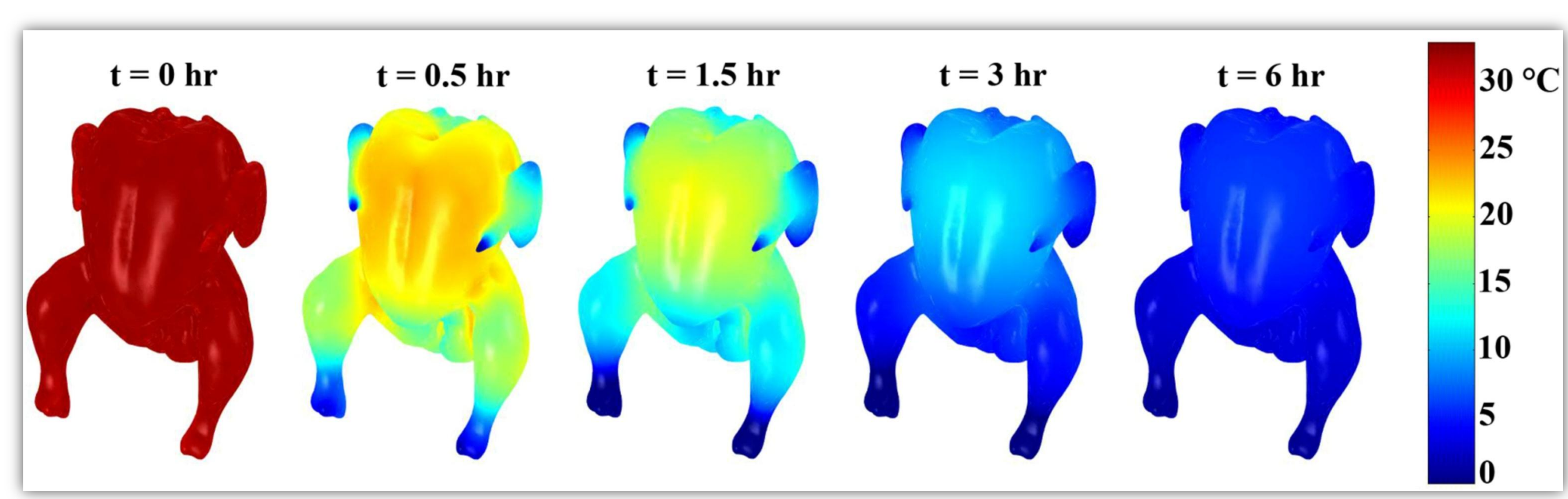


Figure 3. Simulation of air-cooling of a poultry carcass using the COMSOL modules for *Heat Transfer in Solids*, *Transport of Diluted Species*, as well as the *LiveLink for MATLAB*. Model was validated in a poultry processing plant[6].

Conclusion: The proposed method can be used to mesh complex geometries and to assign heterogeneous material properties in COMSOL Multiphysics without the challenge of assembling complex multipart geometries.

References:

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