Browser Based Constructive Solid Geometry for Anatomical Models

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Group 16

Team Members

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Mentor

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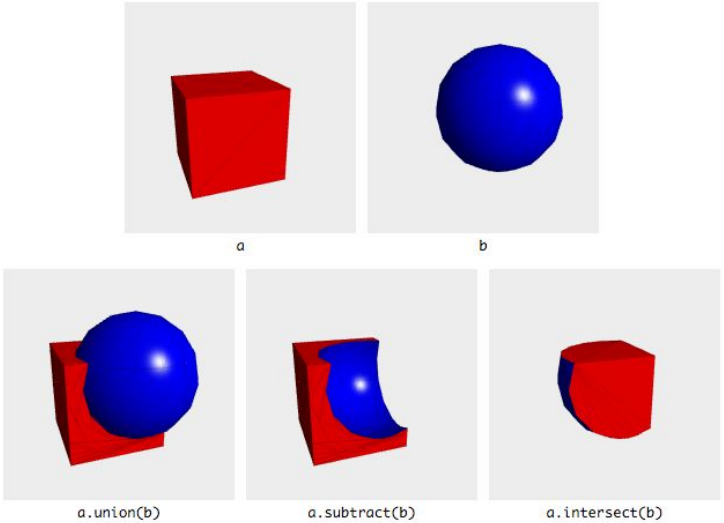
Motivation

- 1 in 323 children are born with cerebral palsy in US
- 2 in 3 could walk if they had proper orthotic devices
- Ankle foot orthotic device
  - Corrects gait and prevents deformities
- Create orthosis using scan
  - 10 hour process in SolidWorks
- Our goal: browser-based software to drastically reduce this time

Specific Goals

- Browser-based CSG application (demo later)
- Significantly reduce the amount of time required to design full cast
- Simpler and easier for clinicians



Original Deliverables

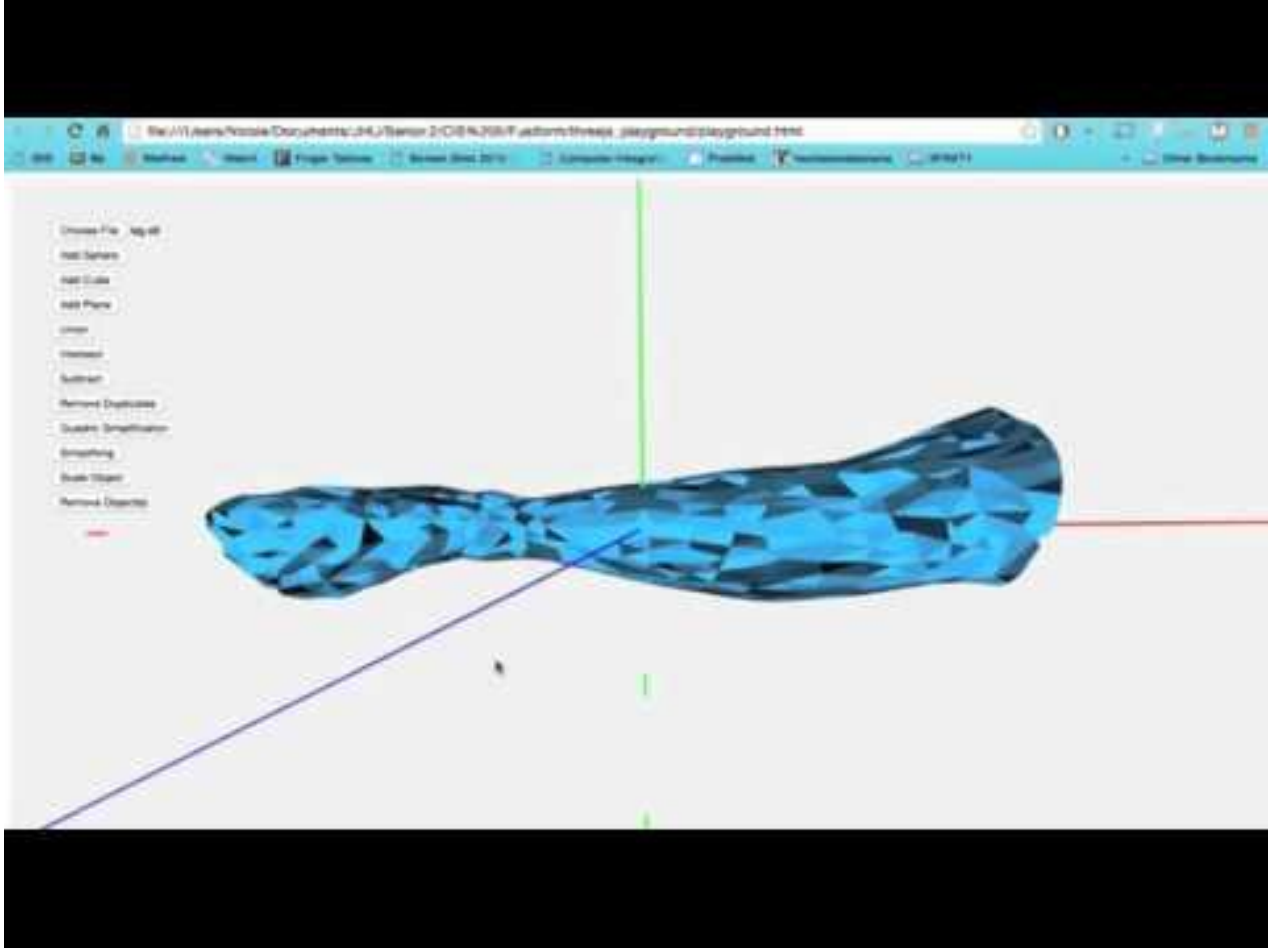
- Minimum
  - three.js ”playground” in browser using constructive solid geometry algorithms for simple objects (sphere, cube, prism, etc)
    - sphere/cube addition algorithm
    - CSG union algorithm
    - CSG intersect algorithm
    - CSG subtract algorithm
  - Mesh modification module for simple objects
- Expected
  - Mesh modification module for anatomical scans
    - Mesh cutting algorithm
    - Mesh smoothing algorithm
    - Mesh simplification algorithm
    - Watertight mesh algorithm
- Maximum
  - Test cast fabrication using a 3D printer and test “fits” on patients

New Deliverables

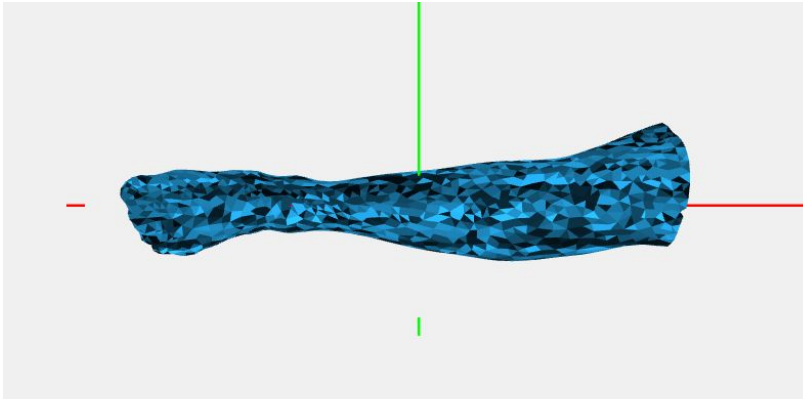
- Minimum
  - three.js ”playground” in browser using constructive solid geometry algorithms for simple objects (sphere, cube, prism, etc) ✔
    - sphere/cube addition algorithm ✔
    - CSG union algorithm ✔
    - CSG intersect algorithm ✔
    - CSG subtract algorithm ✔
  - Mesh modification module for simple objects
  - Playground with mesh importing (for .stl files)* ✔
- Expected
  - Mesh modification module for anatomical scans (in progress)
    - Mesh cutting algorithm (in progress)
    - Mesh smoothing algorithm ✔
    - Mesh simplification algorithm ✔
    - Watertight mesh algorithm (in progress)
    - Mesh scaling (in progress)*
  - Playground with mesh exporting*
- Maximum
  - Test cast fabrication using a 3D printer and test “fits” on patients
  - Playground with improved usability - sliders (to change parameters), rotation of objects independently of axis*

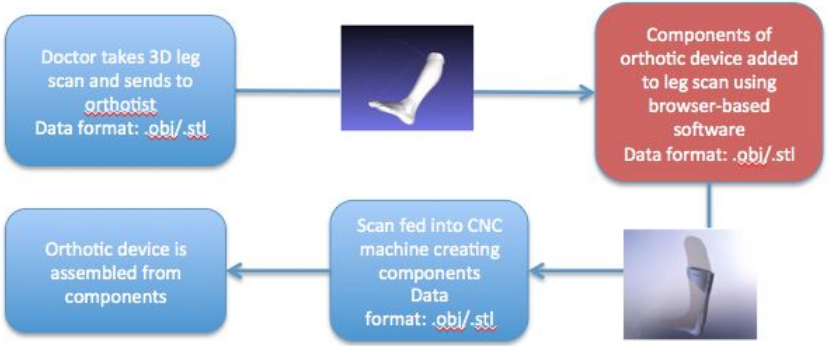
**Documentation found in Wiki

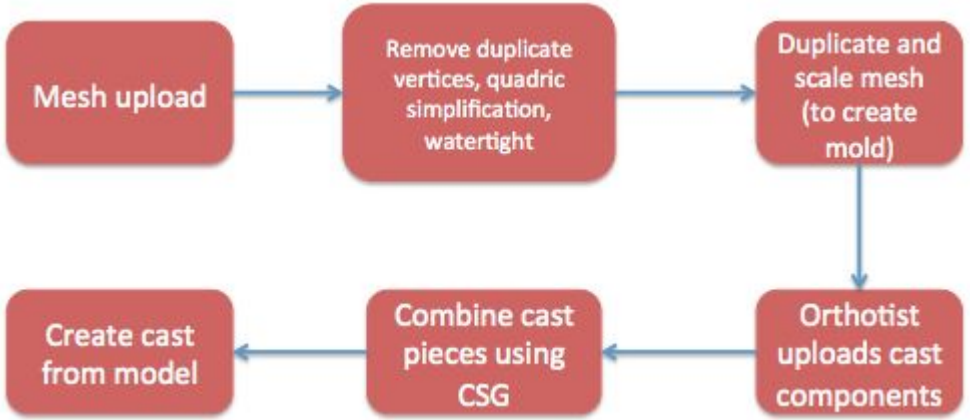
Demo



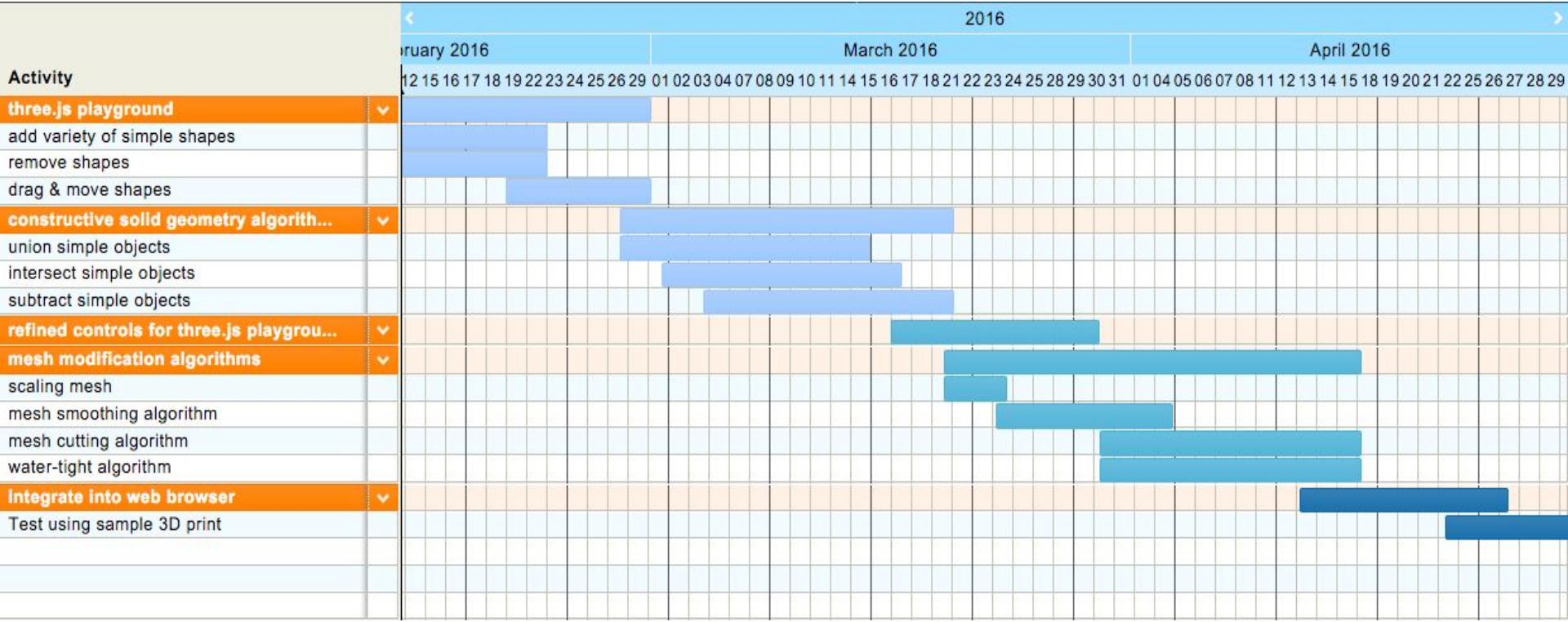
Framework



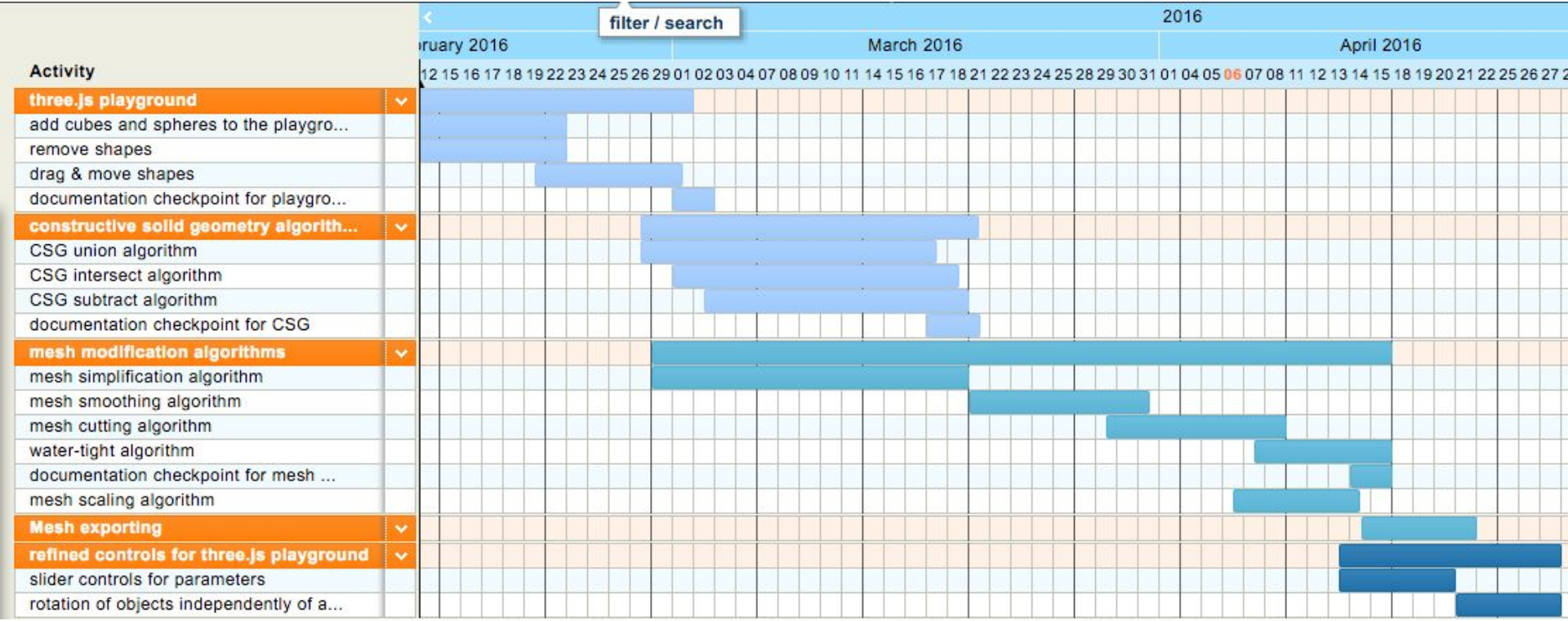

Doctor takes 3D leg scan and sends to orthotist
Data format: .obj/.stl
Components of orthotic device added to leg scan using browser-based software
Data format: .obj/.stl
Scan fed into CNC machine creating components
Data format: .obj/.stl
Orthotic device is assembled from components


Mesh upload
Remove duplicate vertices, quadric simplification, watertight
Duplicate and scale mesh (to create mold)
Orthotist uploads cast components
Combine cast pieces using CSG
Create cast from model

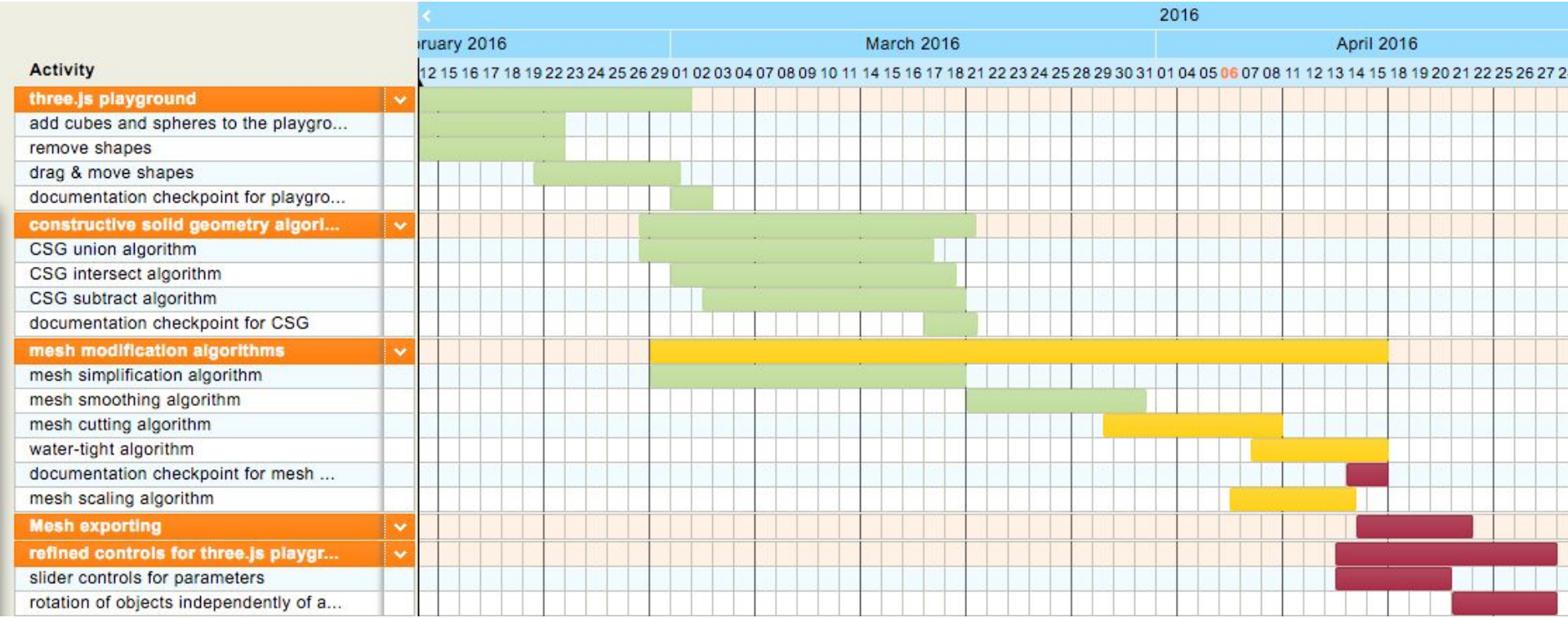
Old Milestones



New Milestones



Completed Milestones



Dependencies

Minimum/Expected:

- Three.js - 3D Javascript library used to interface with WebGL - Open Source library ✔
- Anatomical scans of legs using iPad mounted scanner - Mentors ✔
- The Visualization and Computer Graphics Library for mesh modification algorithms (in C/C++) - Available online ✔
- Emscripten to port C/C++ code to Javascript - Available online ✔
- ThreeBSP.js to perform CSG - Available online ✔

Remaining Challenges

- Memory issues when loading multiple large meshes
  - preallocate memory
- Speed issues when running CSG on large meshes
  - simplifying CSG
- Random points and faces appear inside of loaded meshes
  - propagate through mesh and delete disconnected points
- Mesh Color
  - calculating normals

Next Steps

- Water tight and scaling
- Improving UI and usability (exporting, sliders, rotation, inputs, etc)
- Automating process

Bibliography

1. Plato, Jan Von. "The Axioms of Constructive Geometry." *Annals of Pure and Applied Logic* 76.2 (1995): 169-200. Web.
2. Ricci, A. "A Constructive Geometry for Computer Graphics." *Computer-Aided Design* 6.1 (1974): 53. Web.
3. Thibault, W. C., & Naylor, B. F. (1987). Set operations on polyhedra using binary space partitioning trees. *ACM SIGGRAPH Computer Graphics SIGGRAPH Comput. Graph., 21*(4), 153-162. doi:10.1145/37402.37421
4. Cignoni, P., C. Montani, and R. Scopigno. "A Comparison of Mesh Simplification Algorithms." Computers & Graphics 22.1 (1998): 37-54. Web
5. Schroeder, William J., Jonathan A. Zarge, and William E. Lorensen. "Decimation of Triangle Meshes." ACM SIGGRAPH Computer Graphics SIGGRAPH Comput. Graph. 26.2 (1992): 65-70. Web.
6. Ciampalini, A., P. Cignoni, C. Montani, and R. Scopigno. "Multiresolution Decimation Based on Global Error." The Visual Computer 13.5 (1997): 228-46. Web.