

3D Bolus Reconstruction Workflow

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Summary: Reconstruct the 3D shape and motion of a contrast-enhanced solid or liquid bolus from XROMM data (biplanar videoradiography). Workflow uses custom Autodesk Maya scripts and allows the user to quantify in vivo bolus volume.

1. Download/install required materials

- a. Autodesk Maya (preferably version 2020 or later)
- b. [Maya Bonus Tools](#) (needed for volume calculation)
- c. J.D.'s [custom Maya scripts](#)
 - i. Snap, calcPolyVolume, and createBolusRig are required

2. Set up scene

- a. Create Maya scene and import X-ray cameras (via XROMM shelf → Xcam)
 - i. If desired, create lights in scene to optimize image/bolus contrast
- b. While in each xcam view, ensure “Wireframe on shaded” is enabled (Viewport → Shading → Wireframe on Shaded)
 - i. This will ensure we can see the 2D outline of the bolus as well as the X-ray image behind it
- c. Set viewport to “smooth shade all” with texture maps (press “6”)
- d. Set the time slider/window to the frame range of interest

3. Create 2D bolus outline

- a. In either Xcam view, go to your preferred start frame (i.e., beginning of frame range of interest)
- b. Select “Create Polygon” tool (from “Mesh Tools” dropdown of Modeling workspace)
- c. Left click to place vertices and create and outline of the bolus
 - i. *Be sure to:*
 1. Place them in order (as in a loop)
 2. Place an adequate number of vertices for the desired bolus resolution (the number of vertices is conserved across all frames and not editable later)
- d. When all vertices are placed, press enter/return to create the polygon.
- e. Give the polygon object a name (i.e., bolus_cam1)
- f. Apply a new lambert to the polygon (long right click, “assign new material”) and set it to be completely transparent.
 - i. With the “wireframe on shaded” on, we should still be able to see its outline

4. Create 3D rig

- a. Select (Shift+left click; in order) (1) the new bolus polygon, then (2) the camera plane immediately behind it
- b. In the MEL command line, run `createBolusRig;`
 - i. A series of locators and two new groups should appear in the outliner
 - ii. The visible set of locators are the ‘controllers’ for the vertices of the polygon; these are what you will move/keyframe to animate the bolus silhouette.

- iii. Note that the rig is set up such that the polygon's vertices are constrained to the image plane; while the vertex controllers are free to move wherever, the vertices themselves won't leave the image plane.
 - c. The function will also create a 3D version of the bolus model, for each camera plane. Hide this (select, then press "h") until you are done with step 6/7.
- 5. Repeat steps 3 and 4 in the other Xcam.**
- 6. Keyframe vertex control (locator) positions**
- a. Upon creation, the locators and 2D shape will likely be offset from their original position on the image plane--this is normal. The easiest way to adjust is to select all of the vertex controllers at once (in the outliner) and translate them together.
 - i. Importantly--only ever translate the locators in the plane of the xcam (when using the translate tool, click and hold the middle square, rather than individual axes.) As described in 4 iii, the vertices are constrained--but moving the controllers off the image plane can introduce annoying alignment issues
 - b. When you've adjusted the bolus shape to look good, select all of the controllers, and press "s" the keyframe hotkey.
 - c. Advance forward 5-25 frames, and adjust all of the controllers to fit the bolus silhouette. Once it looks good, select all of the controllers and set another keyframe.
 - i. I recommend erring on the side of larger initial gaps between successive keyframes. Then you can scrub back through the interpolated frames and assess when/where additional keyframes are needed.
- 7. Repeat step 6 for other Xcam, if you haven't yet**
- 8. Calculate intersection of two camera planes**
- a. Un-hide (select, "h") the two 3D bolus models that you hid when you first ran `createBolusRig`;
 - b. Select both of them at once (shift select) and perform an "Intersection" Boolean operation (Modeling workspace → Mesh → Booleans → Intersection)
 - i. You should now see the bolus in 3D
 - c. The bolus model is dynamic, in that you can refine the vertex keyframes at any point, and the changes will be reflected in the 3D bolus model
 - i. A consequence of this is that step 8 could just as well be performed prior to any keyframes being set
- 9. Calculate bolus volume**
- a. Turn the Poly volume heads up display (Bonus Tools → Poly Volume)
 - b. Decide what frame range you wish to run the calculation on
 - c. Select the 3D bolus model, and run `calcPolyVolume(startframe,endframe)` ; where startframe and endframe are just frame numbers (e.g., `calcPolyVolume(550,1000)` ;)
 - d. The volume data (in units of the calibration object, cubed (likely cm³)) will be stored in a new locator as its X-position.
 - i. You can then visualize the volume in the graph editor, or export using the XROMM exp function as you would with any other data stored in a locator.