

# Mid-Semester Checkpoint Presentation

Team 2: Can Kocabalkanli and Nico Lamaison

# Project Overview - Team 2

**Title:** Kinematic Simulation, Calibration, and Accuracy Assessment for the Galen Robot

**Team Members:** Can Kocabalkanli, Nicolas Lamaison

**Mentors:** Dr. Taylor, Dr. Munawar, Max Li, Henry Phalen

## Goals:

- 1. Successfully model the kinematics and dynamics of the Galen in a simulation environment
- 2. Calibrate the Galen to improve end effector tool tracking accuracy



[1]: Taylor, "The Galen Microsurgery System", 3/21/2019, LCSR Industry Day, Baltimore

# Changes and Updates to Our Plan

Team 2: Can Kocabalkanli and Nico Lamaison

# Updated Logistics

- All Galen employees are WFH and in-person company operations are paused
- Galen Mk. 2 is no longer in the Mock OR; at Galen HQ in downtown Baltimore
- Have (possible) access to Atracsys through Prof. Taylor
- Shelter-in order/possible lockdown prevents all in-person work on our end

# Updated Tasks

## Old Tasks:

- A. Modeling robot in Blender
- B. Learning to use AMBF package (write control script)
- C. Run simulation experiment
- D. Learning to run Galen software interface
- E. Develop real-world calibration experiment and evaluation metric
- F. Perform calibration experiment
- G. Use Experimental data to get correction function
- H. Test Galen robot with correction function
- I. *Galen Robot Simulation Tutorials (if time allows)*
- J. *Integration into research software (if time allows)*
- K. Prepare demo: Moving Galen, simulation, or *Virtual Fixtures (if time allows)*

## Current Tasks:

- A. Modeling robot in Blender
- B. Run simulation script to move Galen
- C. Complete calibration scripts (virtual & real)
- D. Develop experimental procedure and evaluation metric
- E. Complete virtual calibration pipeline test script
- F. Test and debug calibration pipeline with robot simulation
- G. *Galen robot simulation tutorials (if time allows)*
- H. Prepare virtual/simulation demo

Red - Cannot finish/is no longer relevant

Green - Added to project

*Italics* - Additional work (time permitting)

# Updated Dependencies

## Old

Date Needed	Dependency
February 14	Galen Kinematic Parameters, .stl files (Mk. 1 and Mk. 2)
Late March-April	The Galen Robot (Mark 1 & 2) Availability
March 14	Galen Python Interface
March 22	Calibration Equipment

## Updated

Date Needed	Dependency
February 14	Galen Kinematic Parameters, .stl files (Mk. 1 and Mk. 2)
X Late March-April	The Galen Robot (Mark 1 & 2) Availability
March 14	Galen Python Interface
X March 22	Calibration Equipment
April 4	Galen home position (physical dimensions)



Resolved



Pending (someone is actively working on it)



Unresolved



Not relevant to updated plan (no physical calibration)

# Updated Plan and Milestones

Start Date	End Date	Tasks	Dependency & Prereq.	February							March							April							May	
				11	15	18	22	25	29	3	7	10	14	17	21	24	28	31	04	07	11	14	18	21	25	28
02/13	03/02	A. Modeling robot in Blender	Galen STL, kin. param.	█							█															
03/02	03/04	B. Run simulation script to move Galen	Task A, home position								█															
03/16	04/04	C. Complete calibration scripts (virtual & real)	-								█															
03/18	04/04	D. Develop experimental procedure and evaluation metric	Task C, Atraxsys User Man.															█								
03/28	04/04	E. Complete virtual calibration pipeline test script	-															█								
04/05	04/16	F. Test and debug calibration pipeline with robot simulation	Task C,D,F															█								
04/24	05/01	G. Galen robot simulation tutorials (if time allows)	Task A,B,C																						█	
04/24	05/01	H. Prepare virtual/simulation demo	Task C																						█	

Complete	█
In Progress > 50%	█
Incomplete	█

# Updated Plan and Milestones

Task Start Date	Task End Date	Tasks	Dependency & Prerequisites	Status	Milestone Deadline	Milestone	Contacts for Help
02/13	03/14	A. Modeling robot in Blender	Galen STL & kinematic parameters	Complete	04/04	1.Galen model working in AMBF	Dr. Munawar
03/02	04/04	B. Run simulation script to move Galen	Task A	In Progress			Dr. Munawar
03/16	04/04	C. Complete calibration scripts (virtual & real)	-	Complete	04/04	2. Having a complete calibration script to be tested	Max Li, Henry Phalen
03/18	04/04	D. Develop experimental procedure and evaluation metric	Task C, Atraxsys User Manual	In Progress	04/04	3. Having an experimental procedure and instructions document	Anna Goodridge, Max, Henry, Kevin Gilboy
03/28	04/07	E. Complete virtual calibration pipeline test script	Task C	In Progress	04/07	4. Script to log transformations and data from simulation ready	Dr. Munawar, Max, Henry
04/05	04/16	F. Test and debug calibration pipeline with robot simulation	Task B, C, E	Incomplete	04/16	5. Calibration pipeline is ready to be used with data from the real experiment	Dr. Taylor, Max Li, Henry Phalen
04/24	05/01	<i>G. Galen robot simulation tutorials (if time allows)</i>	Task C,D,F	Incomplete	05/01	6.Tutorials online on AMBF Wiki	Dr. Munawar
04/24	05/01	H. Prepare virtual/simulation demo	Task A,B	Incomplete	05/01	7. Simulation Demo and Video	Dr. Munawar, Max, Henry



# Updated Deliverables

## Old Deliverables:

**Minimum:** Galen robot simulation developed, XYZ calibration, accuracy assessment

**Expected:** Minimum + wrist calibration

**Maximum:** Expected + simulation tutorials, integration of calibration pipeline into research software, demonstration on virtual fixtures

## New Expected Deliverables:

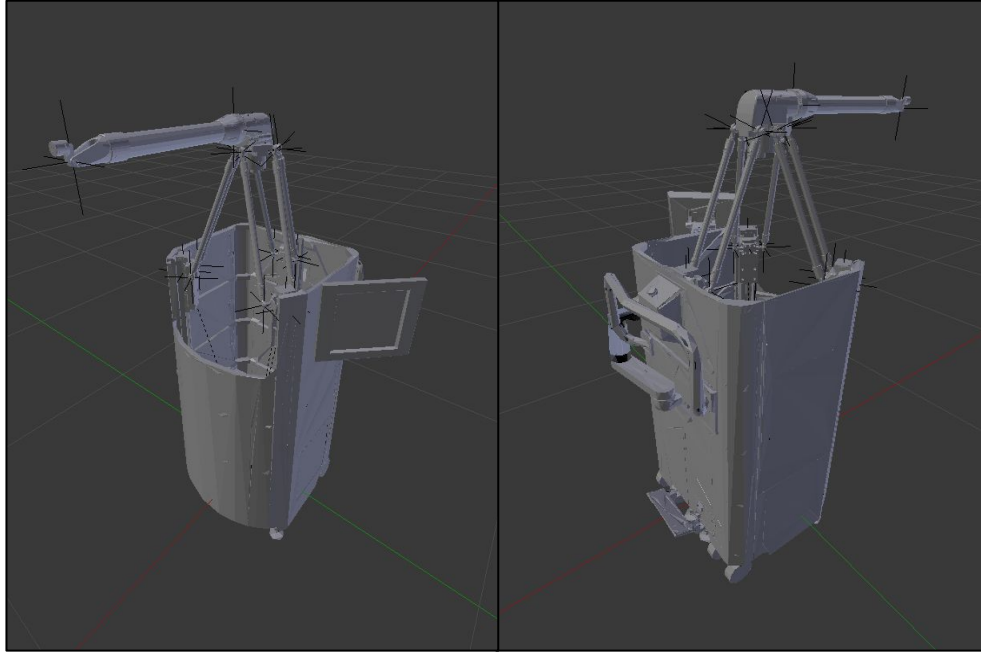
1. Galen simulation model
2. Simulation of the experiment (script to run the simulation)
3. Working and (virtually) tested XYZ+wrist calibration pipeline ready to be used with actual robot
4. Detailed calibration procedure for actual robot

**Maximum:** Expected + simulation tutorials

# Current Progress

Team 2: Can Kocabalkanli and Nico Lamaison

# Galen Model & Control Script



## Steps to Final Model/Simulation

### Galen Model:

- AMBF start-up issues (being addressed by Adnan)
- Add fiducial fixture
- Add inertial parameters

### Control Script:

- Finalize virtual calibration maneuver
- Adapt Python control script template for Galen Mk. 2

Figure 1 - Images of Galen Mk. 2 AMBF model in Blender modeling environment. Full assembly shown with visible joints.

# Calibration Pipeline

- Calibration code and all subfunctions complete (BUT untested)  
Potential Errors:
  1. Fitting Bernstein Polynomial between 5-dof and 6-dof vectors
  2. Galen forward kinematics calculation
- Completed script to unit test Steps S1-S4  
Started to write script to test integrated system (including hand-eye calibration)

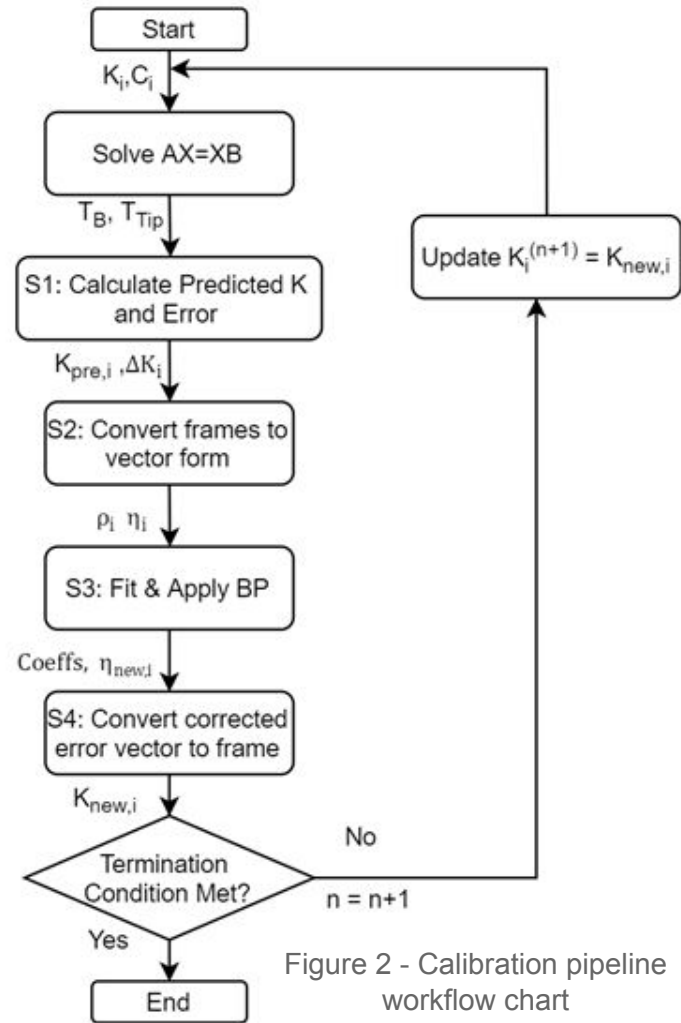


Figure 2 - Calibration pipeline workflow chart

# Virtual Procedure for Testing Calibration Pipeline

1. Place a frame in the simulation environment to represent optical tracker frame, and another to represent the reference frame. (One frame could suffice)
2. Record the transformation from the reference to the robot base and to the “tracker”
3. Add a pointer tool to the simulation, and add a point on the tip to track it's position
4. Move the simulated robot to N different configurations, record the poses of:
  - a. The end effector wrt robot base  $K$
  - b. The tool tip wrt optical tracker  $T_{TB}$  (or directly wrt reference,  $C$ )
  - c. Optical tracker wrt reference  $T_O$
5. Introduce Gaussian noise to  $K$  to “distort it”

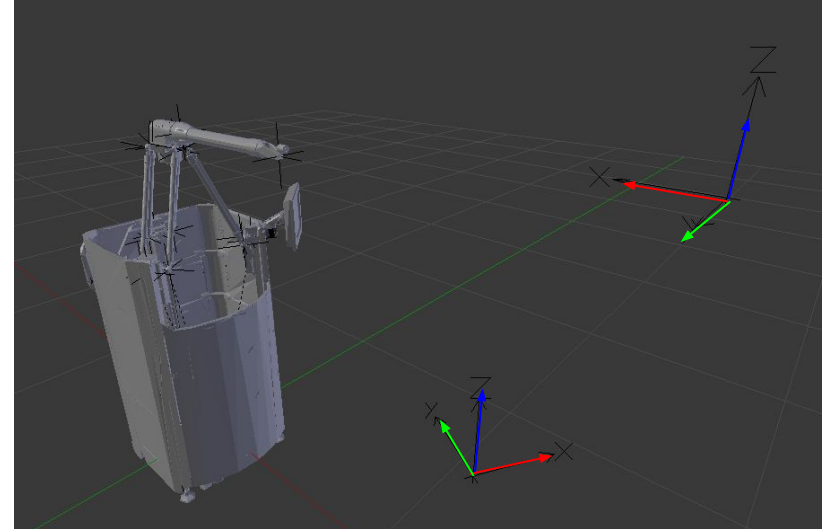


Figure 3 - Experimental setup for virtual calibration

To be discussed with Dr. Taylor:

1. Going over virtual (and real) procedure
2. Introducing distortion

# Checkpoint Summary

## Organization:

- **DONE:** Redefined final deliverables in worst-case scenario and adjusted tasks and dependencies accordingly
- **NEXT STEPS:** Continue working with Galen and mentors to provide best possible final deliverable

## Simulation:

- **DONE:** Construct kinematically-accurate Galen Mk. 2 in simulation environment
- **NEXT STEPS:** Adjust model to fit calibration procedure and finish control script, recreate experimental procedure in simulation environment

## Calibration Pipeline:

- **DONE:** Complete calibration software package, some unit testing
- **NEXT STEPS:** Testing and debugging integrated package, testing pipeline in simulation environment

Thanks! Questions?