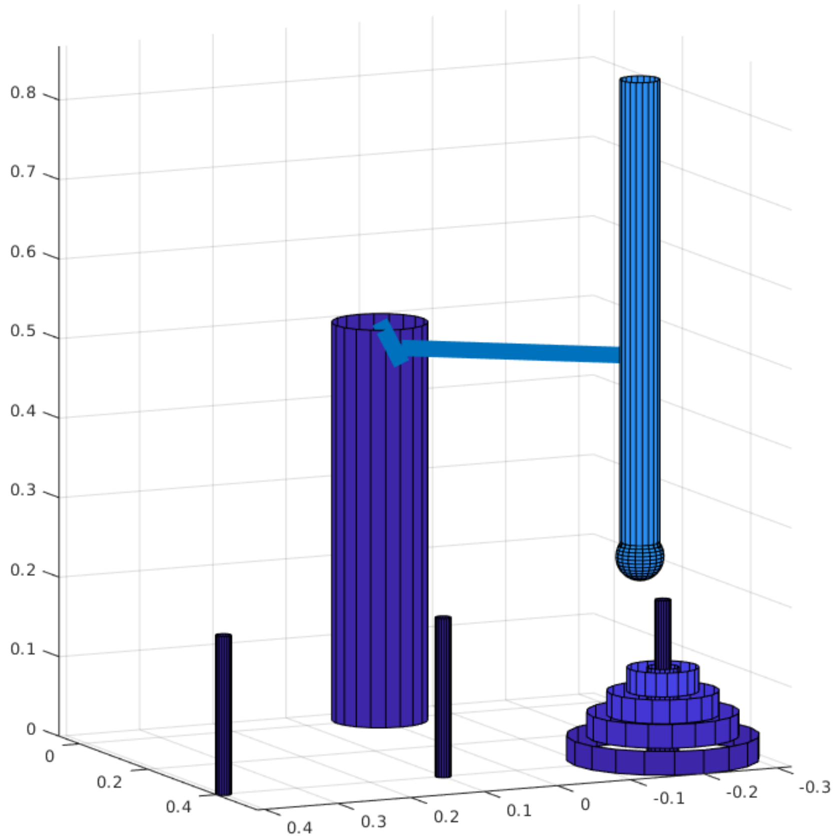
The Towers of Hanoi



Construct a simulation of the **Towers of Hanoi**, with a SCARA robot solving the puzzle in a virtual world. Plan a series of trajectories to move the disks from peg to peg. Enact joint level control, with simulated dynamics.

Use the **provided MATLAB simulation**. Your solution may be in any language you choose. Your program only needs to output a data file with the configuration parameters. To see a demonstration, run hanoi_sim("DEMO").

For an example of dynamic simulation using timestepping, see **pendsim.m**.

Robot Parameters

z0 offset	0.5 m
z1 offset	0.02 m
link 1 properties	0.3 m length, 0.05 m x 0.06 m rectangular prism, 6 kg
link 2 properties	0.3 m, length, 0.05 m x 0.06 m rectangular prism, 6 kg
link 3 length	0.6 m x 0.05 m cylinder, 5 kg (zero position at midpoint, +z downward)

Environment Parameters

Standard Earth gravity, no friction. Assume that gravity compensation on the mechanism is active. The pegs (0.02 m diameters and 0.2 m height) are at the following locations:

Peg 1	[-0.2, 0.4, 0.0] m
Peg 2	[0.1, 0.4, 0.0] m
Peg 3	[0.4, 0.4, 0.0] m

The gripper works by magic (magnets?) So a disk will snap to it if the state is 'on' and the end effector is within 1 cm of the disk. The robot phase shifts the disk or something, so it can pass through solid matter when gripped by the robot. Be nice and don't exploit this vagary too much.

Tasklist

As follows is a breakdown of the main, high level tasks that should be used in your solution:

- create a solution for the Towers of Hanoi puzzle, break it down into discrete moves. (e.g. move to peg 0, move down to disk at level 3, etc.)
- encode motion primitives, such as move to top of peg i, move down to level n and grasp, ungrasp.
- write a function that generates a parametric or spline-based trajectory given parameters from a motion primitive
- write a high level function that strings together motion primitives, creates trajectory segments, and then creates a complete trajectory for the entire puzzle solution.
- Optional checkpoint: create animation of manipulator without dynamics and controls to check path planning solution, and subsequent dynamics and controls components.
- Model manipulator dynamics, using Euler-Lagrange or other method.
- Create timestepping simulation, that calculates velocities and positions over time given generalized accelerations. (The positions are output to the data file, to be read by the hanoi_sim() program.)
- Create a function to calculate joint level control for the mechanism, given the desired trajectory calculated above; running through the inverse kinematics to calculate desired joint angles.
- Plot states, record the hanoi_sim() output in a video, write report

Requirements

- Standard Towers of Hanoi problem, four disks, three posts
- Robot manipulator must move all disks from start to finish configurations (Start with four disks on L peg, end with same four disks on R peg, without stacking a larger disk on top of a smaller disk.)
- **Solution must include trajectory planning (parametric path with velocity profiles, or splines)**
- **Solution must simulate the manipulator dynamics**
- **Solution must include joint level control**

Output File

Text file, space delimited, with the following fields: (all angles in radians, g is the grip state - 0/1)

$\boldsymbol{\theta_1}$ $\boldsymbol{\theta_2}$ $\boldsymbol{d_3}$ **g**

Note that the timestep is 0.01 seconds.

Deliverables

- full report, with source code, and all derivations for trajectories, dynamics and controls
- data file, with joint angles for simulator
- video showing full movements from start to finish

Include the following data plots in your report:

- joint states (configuration parameters, joint torques / forces)
- end effector position, velocity, and acceleration (desired and actual values)
- error plots for configuration parameters, trajectory (desired minus actual)

Programming Assignment 2 Rubric

Criteria	Ratings					Pts
Puzzle Solution Complete solution to the Towers of Hanoi problem.	**10.0 pts** **"That's a mighty fine hat"** Working solution, with correct starting and ending configurations. Minimum moves, with no larger disks placed on top of smaller disks, or disks off of pegs.	**7.0 pts** **Minor errors** Non-minimal solution, minor errors in placement or disk grasping.	**5.0 pts** **Major errors** Incomplete solution. Errors in placement, illegal moves, or disks not placed on pegs.	**0.0 pts** **A complete mess** Really? Just grab a solution from Wikipedia.		10.0 pts
Report Complete report, with introduction, solution methods, derivations of dynamics, controls, and trajectories, data plots of states and parameters.	**10.0 pts** **WITNESS ME** Oh what a day, what a lovely day. Report makes sense, is well organized, includes all sections. Even has that professional looking clear plastic binder.	**8.0 pts** **Minor errors and omissions** Minor problems in the report, needs improvement.	**5.0 pts** **Major problems** Major problems in the report, missing sections, incomplete derivations, missing plots.	**0.0 pts** **MEDIOCRE** Not your best work, but I guess you tried. (Actually you probably didn't try to turn in a report this bad.)		10.0 pts
Trajectory Generation Create motion primitives and trajectory generation components.	**20.0 pts** **Complete, smooth trajectory** Trajectory with proper continuity, implemented motion primitives chained together to produce an overall trajectory.	**17.0 pts** **Minor errors** Minor errors in the trajectory, with continuity, or end effector placement. Still gets the job done.	**12.0 pts** **Errors** Errors in the trajectory, or incomplete components. Major discontinuities between segments.	**6.0 pts** **Big mess** Trajectory has major errors, or is mostly incomplete. Still some development of the parametric or spline trajectory model.	**0.0 pts** **Missing** Completely missing trajectory generation component.	20.0 pts
Manipulator Dynamics Model the manipulator dynamics, derive the equations of motion, and encode them into functions. Implement a timestepping simulation.	**20.0 pts** **Complete and correct** Complete dynamics for all members, correct equations of motion. Applied to timestepping simulation, and fed into joint controller.	**17.0 pts** **Minor Errors** Math errors or minor omission in development of equations of motion. Still implemented correctly for joint level control.	**15.0 pts** **Errors** Errors in the derivation of the equations of motion. Dynamics not correctly utilized, or timestepping simulation lacking.	**7.0 pts** **Major Omissions** Incomplete solution for the dynamics. Missing simulation component. Dynamics not utilized for the joint level controller.	**0.0 pts** **Completely missing** Dynamics solution not attempted in any way.	20.0 pts

Criteria	Ratings						Pts
Joint Level Control Implement joint level control to enact the puzzle solution and feed torques/forces into the dynamics.	**20.0 pts** **Working Controller** Working joint level control, with minimal tracking errors.	**17.0 pts** **Minor Errors** Appreciable tracking error, minor problems in controller development. Moderate instability.	**15.0 pts** **Errors** Tracking errors, or significant errors in controller development. Sometimes fails to track desired trajectory.	**10.0 pts** **Major errors** Missing components, or significant flaws or omissions in controller development. Completely fails to track desired trajectory. But it tries, in its own special way.	**5.0 pts** **A complete mess** Who knows what it's trying to do, but it's doing something. At least there was an attempt to implement a controller.	**0.0 pts** **Completely missing** Joint level controller completely omitted from assignment.	20.0 pts
Data plots Create plots of state data, controller torques/forces, and trajectory parameters. Also produce a video running the entire solution.	**20.0 pts** **All plots** All plots included, as specified in the deliverables section. Clear, clean, and easy to read and interpret. And the video was cool.	**17.0 pts** **Minor issues** Some minor organizational issues or slight omissions in the plots. Read the assignment carefully, and ask questions if you're stuck.	**12.0 pts** **Missing plots** Many plots are there, but still many are missing. Things are a mess, and hard to understand.	**5.0 pts** **A feeble effort** A couple blurry plots of the low hanging fruit, like end effector position. You should have tried harder.	**0.0 pts** **Missing plots** Where did they go?		20.0 pts
							Total Points: 100.0