Project 2: The Swinging Gripper

24-370 Engineering Design I, Spring 2011

Assigned 16 February, First prototype due 21 March, Second prototype and report due 4 April

Overview:

In this project, your team will design, fabricate, and test a robotic gripper comprised of custom and catalog components. Your team's gripper must hold a spherical object, contacting it only in specific regions. The gripper will be attached to a robot arm (provided) which will move rapidly through a circular arc. Near the attachment point on the arm, a motor-driven shaft (provided) will produce an open-loop torque when switched on. You must use this drive shaft to close your gripper on the object and hold it securely during arm motions. Don't drop the ball!

Your team must provide two fully-functional revisions of your gripper prototype for testing on the dates listed above. Both versions count! Both prototypes must meet all design and performance criteria. The only exception is dynamic performance; just one of your prototypes must successfully hold the object during rapid arm motions for full credit.

During the design process, you must use a combination of sketching and simple models, including free body diagrams and analyses in symbolic form; computer-aided design tools, including for modeling, static stress analysis and kinematic analysis of your assembly; catalog selection processes; material selection processes; and prototype manufacturing methods. You will have a small budget for purchasing catalog components. You will be required to use certain materials and manufacturing methods for some of your parts. Your team will need to fabricate and assemble your gripper on your own, unless you use funds from your budget to have parts made (within time limits). Documentation of all these steps will be required in your final report.

Diverse teams have been assigned so as to maximize the learning experience for all members. Your team will evenly divide project tasks, such that members participate in all parts of the design process evenly. Your final report will include documentation of the division of efforts. Your team will also provide anonymous self and peer evaluations.

In addition to your report and required gripper performance criteria, there are two optional challenges! The team with the lightest functional gripper assembly, including all parts, will win bonus points and a prize! Additionally, the team with the lowest-cost gripper assembly, including all costs other than team labor, will win bonus points and a prize! Teams that come close to the winning benchmarks will also win pro-rated bonus points. Prizes will be awarded based on the best of all entries from both revisions.

Please read each project description in full as they come out, so that you are not surprised by deliverables at the last moment. Please use the course email address, TA office hours, and/or Q&A sessions at the beginning of class if you have any questions about the project.

Sketched-in specifications and constraints:

This "sketch description" is intended to give you a qualitative understanding of the design challenge, without the distracting details of quantitative data. Use this opportunity to generate conceptual sketches and perform symbolic analyses related to the design.

Gripping geometry and kinematics:

Your team's gripper will need to start in an open position, then close in on the spherical object and hold it firmly. The sphere will be of medium size compared to the useful design envelope. The sphere will be of medium to low density compared to other materials used in your design. The gripper attachment point will be above the sphere. Attachment may occur only in two places: at a bolt pattern in the horizontal plane on the bottom of the robot "wrist", and on the drive shaft. The sphere cannot be supported from below by your gripper, i.e., there is an impermissible region extending downwards from just below the hemisphere line. The gripper must also not interfere with an initial impermissible region to one side of the sphere prior to closure. The gripper must use the drive shaft with an open-loop motor-driven torque to close and to hold the sphere. Finally, the gripper must not extend beyond the assembly envelope (permissible region) when closed. These ideas are qualitatively shown in the sketch in Figure 1.

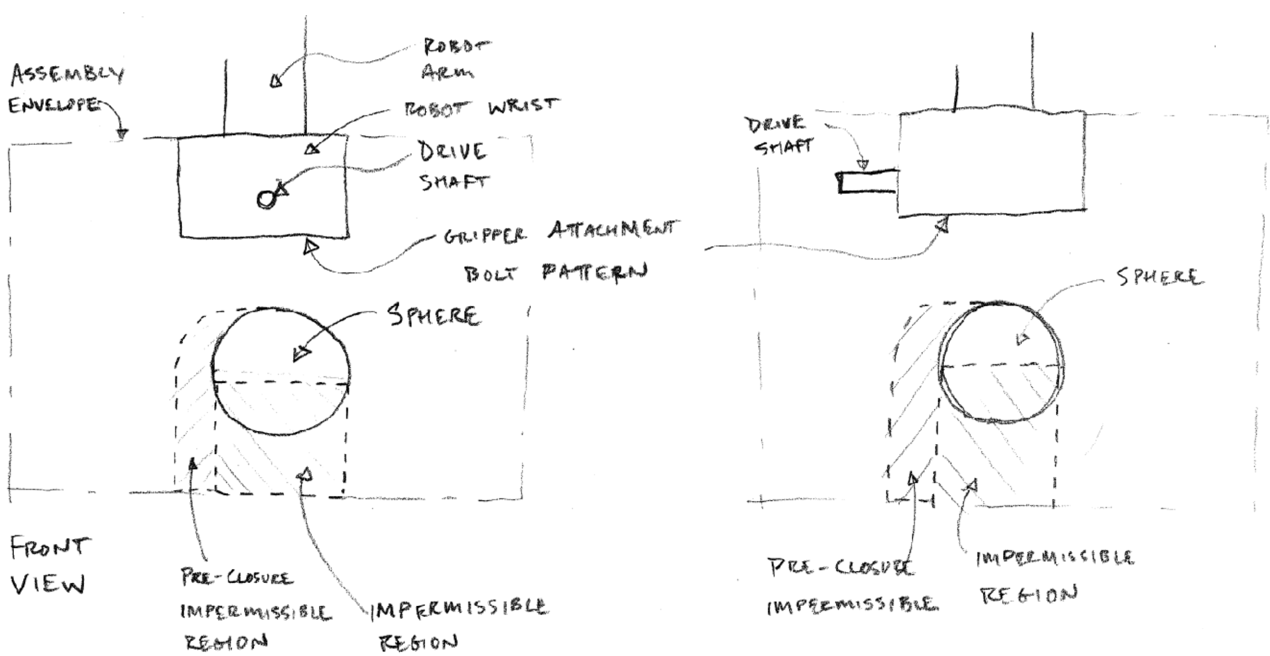

Figure 1. Gripping geometry, including possible attachment points, interference regions, and part envelope.

Dynamic arm motions:

The gripper will be mounted to the end of a robotic arm that will swing rapidly while the sphere is held. The robot arm will be relatively long compared to the size of the gripper envelope and sphere. The robotic "shoulder" joint will be a free-rotating one-degree-of-freedom pin hinge. This joint will allow rotation within the front plane, which is the same rotational direction as the drive shaft. The robot arm will hang loosely in gravity during gripper closure. After the sphere has been gripped, the robot arm will be manually rotated to a horizontal position, and then released. This will cause dynamic accelerations to be experienced by the gripper and sphere, as long as they are moving with the arm :D These ideas are qualitatively diagrammed in Figure 2.

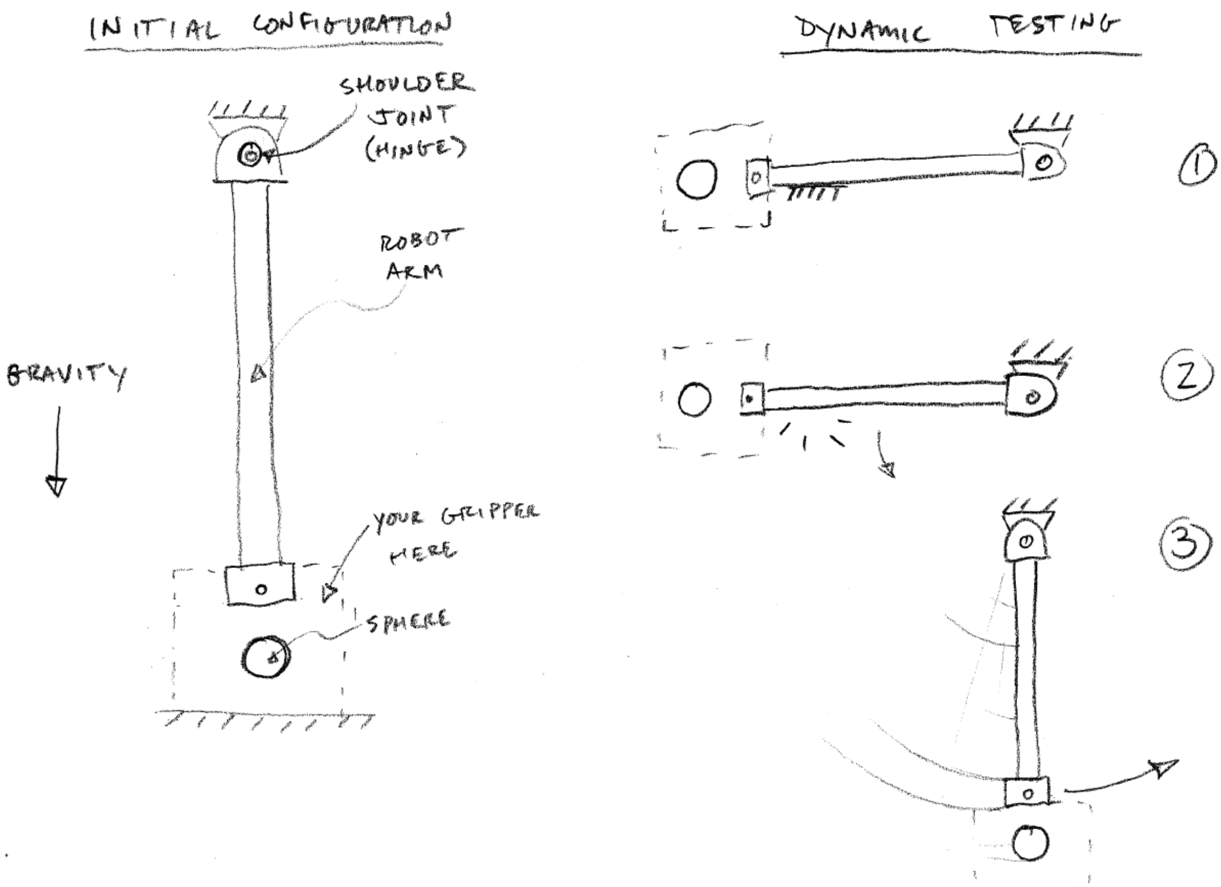

Figure 2. Dynamic robot arm motions with the gripper holding the sphere.

Final Report: You will submit a final report presenting your final design, as well as the conceptualization, simple modeling, detailed modeling and analysis, and manufacturing that went into its creation. The report should be divided into the following sections:

1. Cover page:
    a. details to be announced.
2. Conceptual Design Sketches
    a. Please include all your notes and sketches from your idea generation sessions. These will be evaluated on the basis of both apparent volume and apparent quality of design ideas. A typical set of sketches and notes might occupy 3 pages, front and back, with a medium density, for each component in your assembly.
    b. Your notes must include free-body diagrams, using force and moment balance to obtain reaction forces, with symbolic parameters. This will allow you to understand the implications of different design choices on the function of your components and assembly.
3. Simple Modeling of Candidate Designs
    a. Please evaluate at least 2 candidate designs for each component using simple analytical modeling approaches
    b. Include hand-drawn sketches of the simple models that allow analytical analyses of interest. Include the analysis you performed by hand. For example, you might model one aspect of the part as a beam in bending, and then relate peak stress, beam height, and part mass in a single function. You will probably need more than one simple model to analyze different aspects of each candidate model.
    c. Although “conceptual design sketches” and “simple modeling of candidate designs” are listed as separate items in this list, ideally these are intermingled in a logical way throughout your design sketches. There is a continuum between a crayon stick figure on the back of a napkin and a Matlab parameter sweep, which you may find yourself flowing along during your designing.
4. Materials Selection
    a. details to be announced
5. Component Selection
    a. details to be announced
6. Detailed Model and Analysis of Final Design
    a. details to be announced
7. Manufacturing Report
    a. details to be announced