RBE-550 Motion Planning

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Transmission

DUE: 2023-12-04 @ 12:00 UTC

Abstract

The previous two assignments were hard on our trucks, most likely attributable to jerky motion control implementation. So now it's time for a transmission rebuild. Create an RRT-based motion planner to remove the mainshaft from the transmission case without scratching up everything on the way out.

1 Introduction

This is going to be an arduous rebuild process. Thankfully, all you need to do is implement a motion plan for the initial steps of removing the mainshaft. See Figure 1 for an illustration of the transmission with the top cover and shift forks removed.

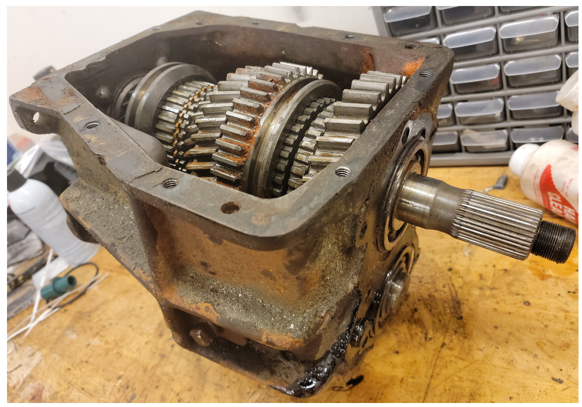

Figure 1: SM-465 transmission, worse for wear

Given an idealized representation of the transmission, in a state with the bearings and input shaft removed, but the mainshaft still inside the case, implement a motion planner to create a full 6 DOF path or trajectory that moves the mainshaft from its initial configuration to a configuration outside the transmission. A detailed view of the mainshaft is shown in Figure 2. Note that the input shaft and drive gear are still installed in this depiction.

Start with the mainshaft centered in line with the two bearing bores in the case. Implement an RRT type motion planner to plan a collision-free path from the starting position to a position sitting at rest on the workbench outside the case.

2 Transmission Model

A simplified model of the SM-465 is shown in Figure 3. Included in this model is the case, with PTO ports and bearing bores, plus mainshaft and countershaft assemblies. Refer to the OpenSCAD files attached to this assignment for the exact models of the constituent parts.

Refer to the file transmission.scad for the details on the model. The files main_transmission.scad and apart_transmission.scad are used to generate the model for viewing in both the initial and intermediate states.

A top view of the transmission model is shown in Figure 4. This illustrates the alignment of the mainshaft in the case. Note that the large white gear on the left side is actually the input gear on the countershaft. Whereas, in this view, the input (from the engine) is on the left side, and output to the driveshaft and wheels is on the right.

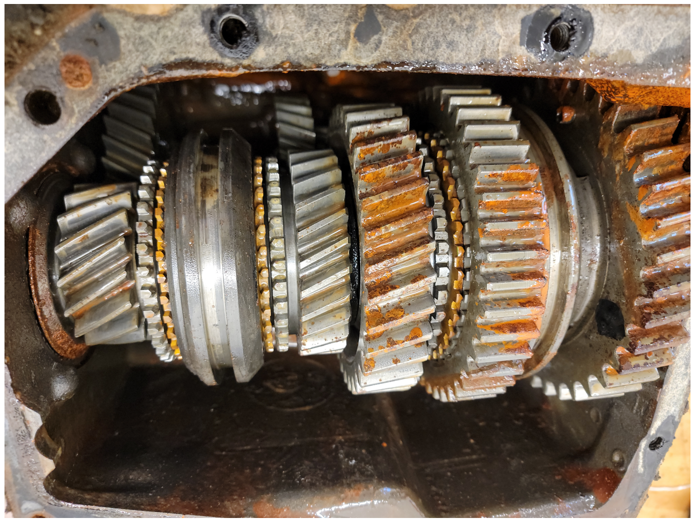

Figure 2: SM-465 transmission, detail of mainshaft gearing

Figure 5 depicts a side view of the transmission. As in Figure 4, the input is on the left and output is on the right. This view illustrates the placement of both the mainshaft (top), and countershaft (bottom) assemblies. Note the large windows on either side of the case, these are for PTO (Power Take Off) drive mounting. Good luck removing the mainshaft through either one of these ports, though your RRT planner might try.

2.1 Dimensions

Select dimensions of the mainshaft and countershaft are given in Figure 6 and Figure 7. Use these values in your collision checker model. You may simplify the collision checking by using a bounding volume, or combining adjacent gears, synchronizers, and collars into single volumes.

The front and rear plates for the transmission case are identical in the simplified model, with dimensions shown in Figure 8. The thickness for all plates in the case is 25 mm. And the length, width, and height of the case is $\{280, 210, 300\}$ mm.

3 Task

The goal at this step in the rebuild process is to remove the mainshaft from the case. With the bearings uninstalled, it can be carefully lifted out. Refer to Figure 9 for an example.

During removal, the mainshaft must not make contact with the countershaft, or the case. The simulation should start with the transmission in the initial assembled state, and end with the mainshaft completely clear of the case. For example, design the final state to contain the mainshaft

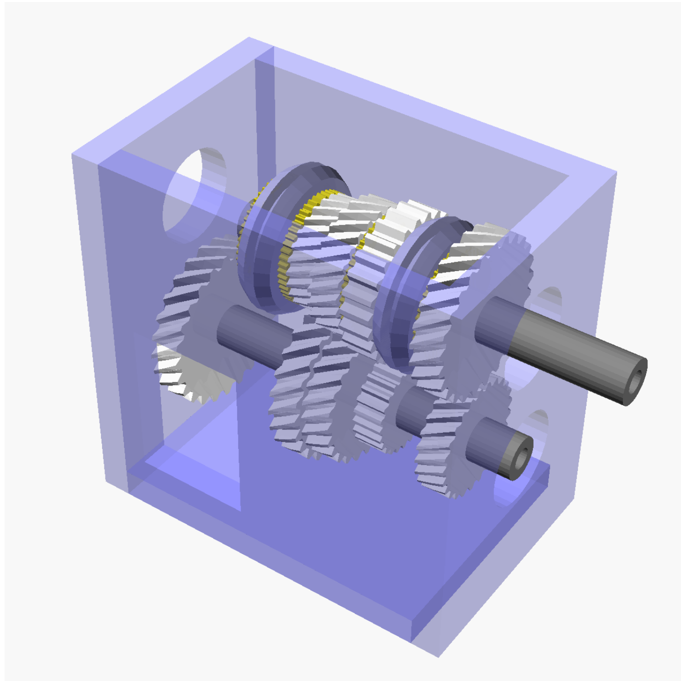

Figure 3: Simplified model of SM-465 transmission

at rest on an adjacent surface such as a workbench.

4 Methods

Use an RRT algorithm, or a variant, to design a motion planner to transport the mainshaft assembly in three dimensional space. The single rigid body has a full six degrees of freedom, and no constraints aside from those imposed by collision. Carefully choose the level of fidelity for a collision model. The most straightforward method is to model the gears as cylinders. You could also import the provided OpenSCAD files into your simulation system for a full collision check against every detail.

Use any software or programming language in your implementation, which should include the following components as detailed in Sections 4.1 through 4.3. Python, C++, MATLAB, ROS, or any other tools are acceptable. Third party libraries such as CGAL, OMPL, or others may be used for any component, including the planner implementation. Be clear in your report and delineate what you wrote and what you integrated from external sources.

Refer to Chapter 5 in LaValle [2006], and the course lectures for details on RRT implementation.

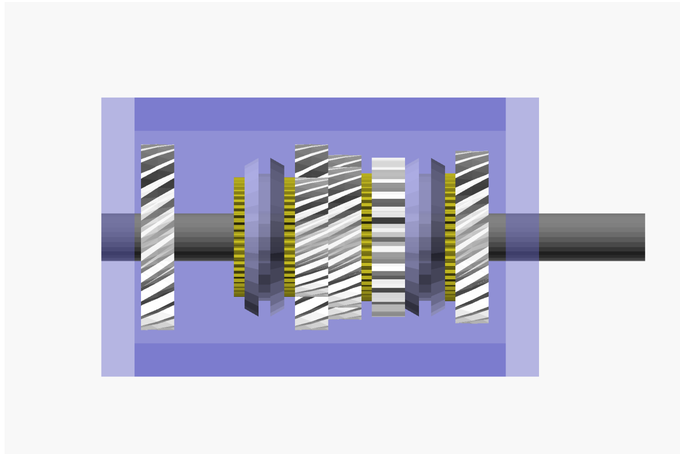

Figure 4: Top view of SM-465 transmission model

4.1 Planner

Implement or integrate an RRT-based planner that takes the initial and goal states as input. It should create a tree in full configuration space, and find a solution path. Note that a bidirectional RRT might be needed for this problem. The following components are suggested for a complete and successful planner implementation:

- graph data structure (store vertices and edges)
- nearest neighbor search
- collision checker
- local controller (move the mainshaft assembly in 3D space) – dynamics optional
- sampling method

4.2 Collision Checker

The collision checker should check the current configuration of the mainshaft assembly against the walls of the case, and other objects in the environment. Generally check for cylinder-cylinder collision, and cylinder overlap with a bounded plane. The OpenSCAD files could be imported into a collision checker library for a more high fidelity approach. Or use more efficient implementations utilizing a bounding volume hierarchy, or simplified cylindrical elements. Take careful consideration in modeling collisions in the environment. It's acceptable to use bounding volumes instead of exact geometry in the collision checker. But collision checking must be rigid body based, with no interpenetration allowed. Consider that damaging the assembly or housing through deformation destroys the entire transmission and relegates it to the scrap heap.

4.3 Visualization

Visualization for this assignment is straightforward. Only basic 3D shapes need to be represented, plus lines to illustrate graph edges and path segments. Use tools like MATLAB figures, or plotting with Matplotlib in Python to produce figures and graphics. If you want to include fancy stuff like textures, shading, and lighting, more power to you. Writing this entire thing in a GLSL would be time consuming, yet awesome.

5 Results

Produce at minimum two plots of the resulting path. Create one figure of the resulting path (position component only) as a 3D line. Choose any view orientation that clearly illustrates the characteristics of the path. Additionally, create an animation of the mainshaft traveling along the path (which should include the orientation component). A static plot showing the mainshaft at multiple interesting configurations along the path is acceptable in lieu of a full animation. Note that for this and the following plots, showing both shafts and the case is helpful to add context.

In addition to the solved path, produce a figure depicting the RRT graph structure projected into 3D (and projected into a 2D figure). Choose a view orientation that makes sense to illustrate the structure of the tree. Include multiple figures if necessary.

Include full source code with your submission, along with a brief writeup about the development, implementation, and experimentation. Also include a photo of the ugliest vehicle you can find that has a SM-465 transmission.

6 Grading and Submission

This assignment is due 2023-12-04 @ 12:00 UTC. *Late submissions are not accepted.* Upload completed assignment components (as individual files, not a single ZIP or TAR file) to the course site on Canvas.

Weight	Type	Component
10%	PDF	path figure
10%	video,PDF	path animation
20%	source code	complete source code
30%	source code	RRT planner implementation
20%	source code	collision checker implementation
10%	PDF	RRT figure

7 References

Steven M. LaValle. *Planning Algorithms*. Cambridge University Press, May 2006. ISBN 9780521862059. URL `http://lavalle.pl/planning/`.

8 List of URLs

Last update: August 12, 2023

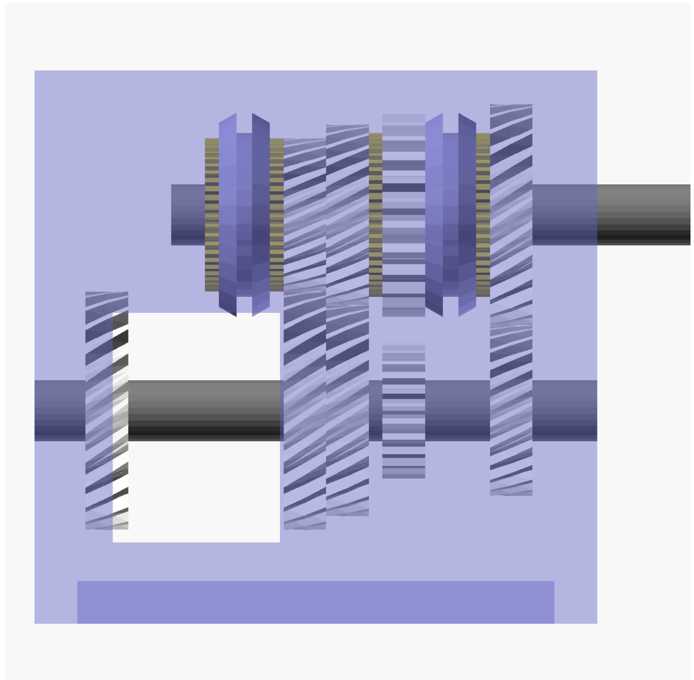

Figure 5: Side view of SM-465 transmission model

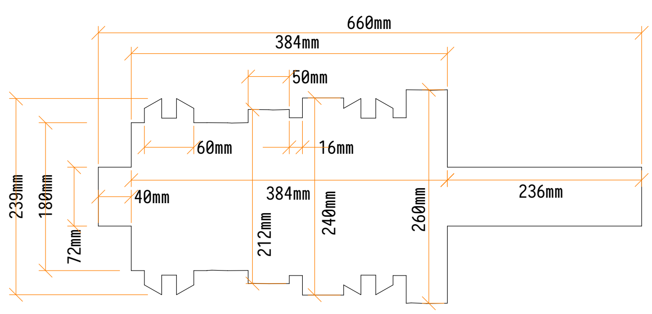

Figure 6: Mainshaft of SM-465 transmission model

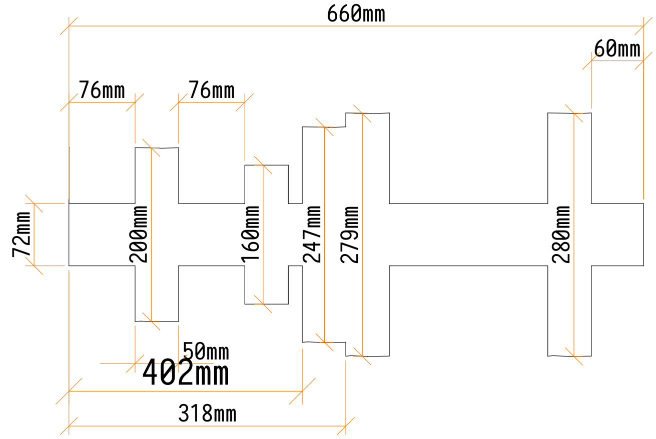

Figure 7: Countershaft of SM-465 transmission model

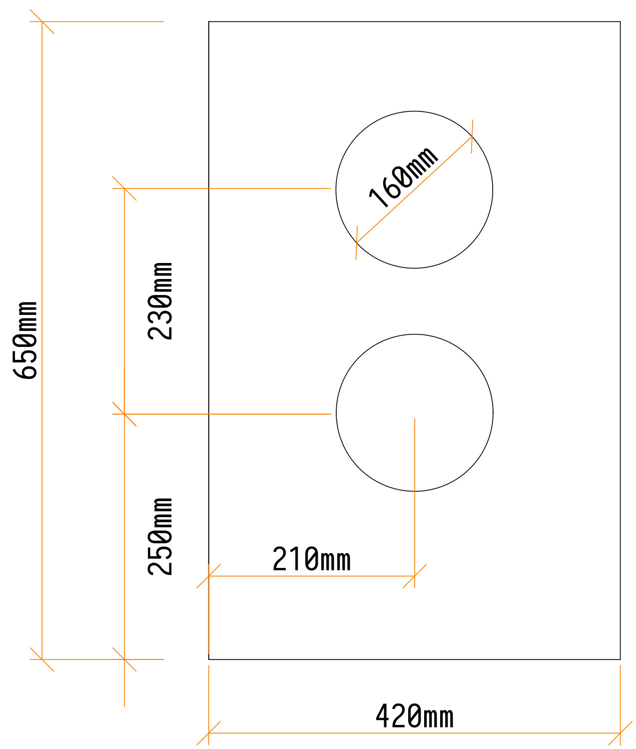

Figure 8: Front and rear case walls of SM-465 transmission model

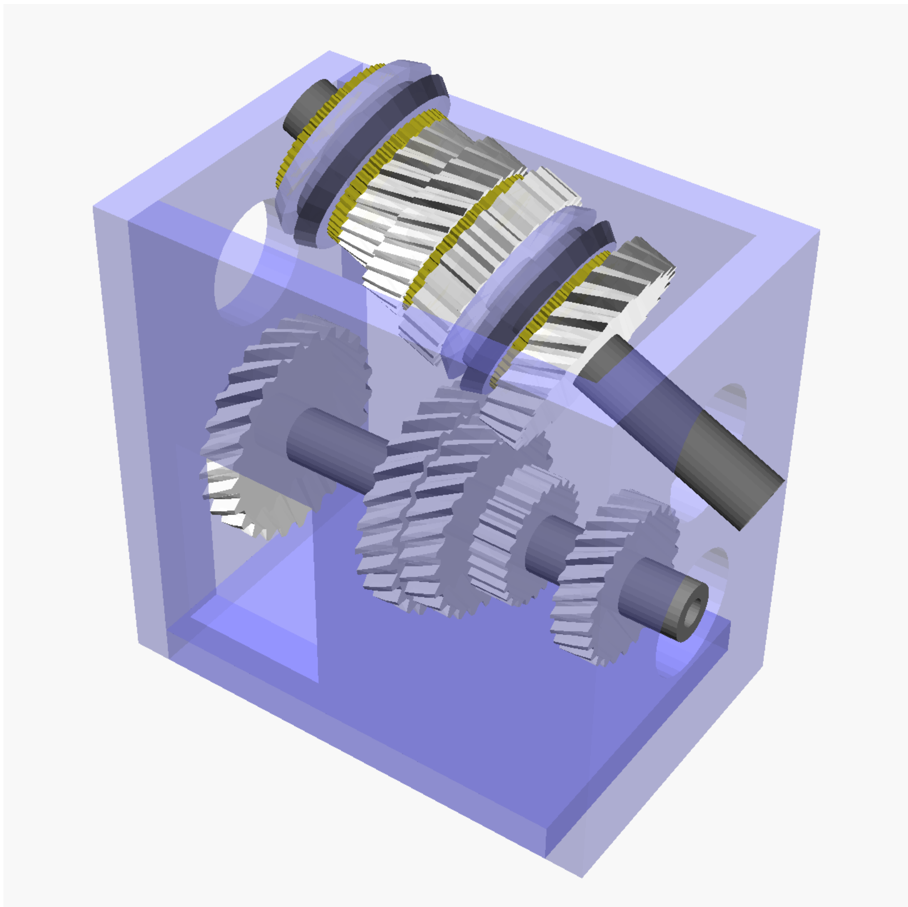

Figure 9: SM-465 during mainshaft removal