MANE 4280/6710: Numerical Design Optimization

Fall 2024

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Project #3 — **Analysis-model write-up: due Oct 25, 2024**
Report: due Nov 12, 2024

Background

You work for Walt Disney Imagineering and your team is designing a new Tilt-A-Whirl. See Figure 1 for an example. One of the distinctive features of the Tilt-A-Whirl is that its motion is difficult for riders to anticipate, which is also why it is so much fun.

Figure 1: Example Tilt-A-Whirl (left) and a planview (right).

Your objective is to maximize the standard deviation of the anglular velocity of each car on the platform, $f = \sigma\left(\frac{d\phi}{dt}\right)$, which is hypothesized to correlate with uncertainty in the motion and, hence, rider enjoyment. Referring to Figure 2, the following list describes the design parameters and their bound constraints for the problem.

- The first design variable is the angular velocity of overall ride, $\omega = \dot{\theta}$, in radians per second. This variable must satisfy $3\ \mathsf{rpm} \leq \omega \frac{60}{2\pi} \mathsf{rpm} \leq 8\ \mathsf{rpm}$.
- The second design variable is the radial arm from the center of each car platform to the (approximate) center of gravity of the car. This variable is denoted r_2 and must satisfy $0.1\ \mathsf{m} \leq r_2 \leq 1.5\ \mathsf{m}$.
- The final variable is α_1, which defines the maximum/minimum incline angle (in radians) of the beam from the center of the ride to the car platform, i.e. along r_1. This variable determines how big the "hills" are, and it is restricted to $0\ \mathsf{rad} \leq \alpha_1 \leq 0.3\ \mathsf{rad}$.

In addition, the following parameters of the ride are fixed, and cannot be adjusted.

- The beam length from the center of the ride to the center of each platform is fixed at $r_1 = 4.3\ \mathsf{m}$.
- The incline offset is fixed at $\alpha_0 = 0.036\ \mathsf{rad}$; this parameter indirectly controls the incline at $\theta = 0$.
- The parameter $Q_0 = (m/\rho)\sqrt{g r_2^3} = 20$, where m is the mass of the car, ρ is a damping coefficient to account for friction, and g is the acceleration due to gravity.

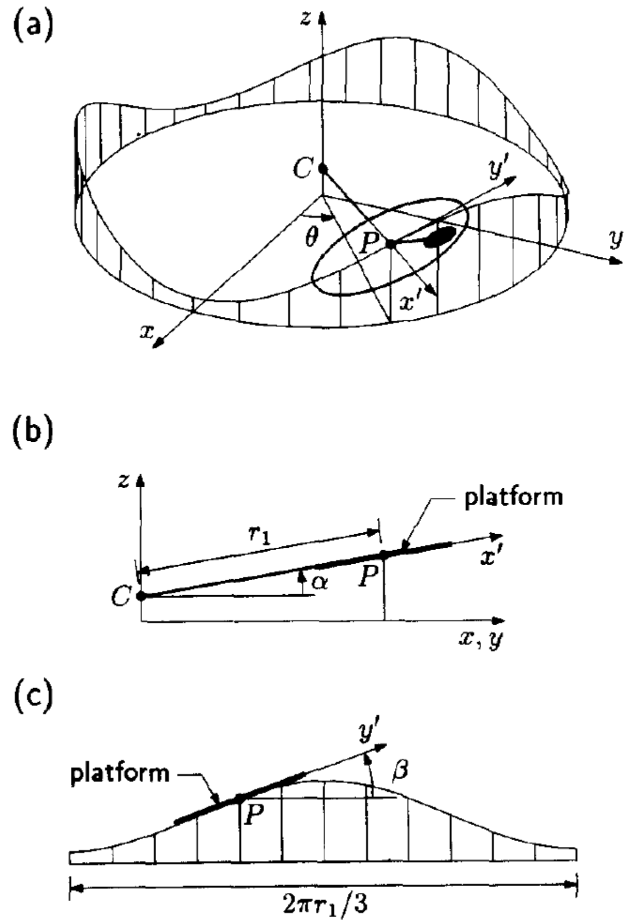

Figure 2: Perspective view (a) showing a single platform, vertical cross section taken through points C and P (b), and vertical cross section taken through point P and tangent to the track.

Analysis Model

Write a concise (less than one page) description of how you will analyze the Tilt-A-Whirl. Specifically, discuss how you will estimate the angular velocity $d\phi/dt$ of the car as a function of time.

Optimization Method

We will use a surrogate model to approximate the objective function and then apply a gradient-based or gradient-free optimization to the surrogate.

Project Report

Write a report that **concisely** describes your approach and results. At a minimum, the report should contain

- an executive summary;
- a description of the analysis method, including any assumptions and limitations inherent in the method;
- the optimization problem statement and optimization method(s), including the objective and any constraints;

- results, including the final parameter values;
- conclusions and/or discussion of the results, and;
- an appendix with the source code.

The length of the report is not to exceed 10 pages (excluding the code appendix). Please refer to the corresponding rubric for how the report will be assessed.

Very Important: For the project, please provide figures and results that verify that your analysis model is working as expected.

Collaboration

You are permitted and encouraged to discuss the project with each other, provided each of you writes your own code and report. A good policy to follow in order to avoid academic misconduct is to not take project notes or exchange project files with one another; i.e. exchange information verbally and you should be fine.