CALIFORNIA STATE SCIENCE FAIR
2011 PROJECT SUMMARY

Name(s)
Bolun Liu

Project Number
S0314

Project Title
An Innovative Predictive Model of Catapult Performance

Abstract

Objectives/Goals
We examine the consequences of using mathematical and statistical modeling to characterize the functional performance of a novel catapult design. Real-world projects are complex and runs are costly. Our project explores fractional factorial experimental design to characterize a mechanisms performance. The design allows for testing of multiple factors at an acceptable number of runs.

Methods/Materials
The novel mechanism is a catapult with a range of up to 4 m. We will: 1. build a novel catapult that produces reliable, predictive functional performance; 2. run a fractional factorial design of size 2^(5-1) (resolution IV); 3. create mathematical and statistical models to predict functional performance. We will compare the catapult performance of a theoretical model to the predictive capability of fitted statistical model. The catapult will be subjected to tests using a semi-randomized experimental design with 20 runs (2^(5-1) + 4 centerpoints), and five three-level factors. The response effects for factor settings will be assessed by comparing responses at high- and low-level settings. The most significant effects for given factor settings will be used to construct a multiple regression model. The predictive capacity of the fitted regression model will then be tested. The theoretical model will be compared to the statistical model.

Results
Projectile launched towards 1 m, 2 m, 3 m had average values of 1.09 m, 2.01 m, and 3.08 m, respectively. Shot distributions were approximately normal distributed in agreement with our models. We verified the goal of building a novel, precise, mechanical apparatus, since all factor effects were clearly distinguishable from random noise. Additional predictive tests of the fitted model exhibited performance at a 95% confidence level. The catapult was not equally capable at all targets; however, resulting impacts fell within the hypothesized 0.15 m range of the intended target. This is a remarkable level of predictive capability.

Conclusions/Discussion
The goals of the project were fully attained. More advanced studies of catapult performance could be done: 1. we could investigate quadratic effects in the experimental design; and 2. we could use advanced multiple regression analysis, such iterative multiple regression analysis (IMRA).

Summary Statement
Statistical experimental design complemented by multiple regression analysis allows for the characterization of functional performance of a complex mechanism.

Help Received
Dr. John C. Howe, Dr. Charles Barker, and Bowei Liu were mentors. Encouragement from my parents.