MIXTURE DOE ON VIDEO GAME PHYSICS

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In the 21st century, most youths are playing video games for too long (a duration of 13 hours/week according to some studies). Parents do not want their children to play video games as they think it has a negative effect on their children. Chosen based on its wide applications of physics, Hill Climb Racing is the video game used in this project. Technology is applied to increase the vehicle transportation safety. Based on the engineering failure mode analysis and return of investment, a systematic car upgrading system was developed through statistical modeling to optimize the car performance. Several physics applications such as kinematics, energy/power, momentum, friction, circular motion, and gravity were applied on the car racing mechanisms. The statistical Mixture DOE tool optimizes the upgrading strategy based on the limited playing duration budget while helping better understand the vehicle mechanics.

INTRODUCTION

The application of Mixture DOE on physics in this project is just an example of how statistics can be applied to education. This connection between video games and statistics can turn "non-value added" activities such as video games into something productive and fun at the same time. This paper will demonstrate how to use Mixture Design of Experiment Modeling to help student students learn to apply physics when controlling a continuous track tank on the desert stage. Vehicle mobility is important when driving in the desert as in sand dunes, mobility is reduced by 60% or more. With no firm and stable ground footing, it is easy to slide down or even get buried in the desert. One way to solve this is using the continuous track design which has tracks, that have a larger surface area than normal wheels. These tracks can "distribute the weight of the vehicle evenly, enabling the vehicle to traverse soft ground with a decreased risk of being stuck in the sand dunes" [1-4]. The tank is chosen for this project to demonstrate the benefit of the continuous track design on the desert stage. Figure 1 demonstrates the general physics which could be applied on playing this car racing video game. Several physics applications are applied on the car racing mechanisms:

- Kinematics: acceleration (uphill climbing), deceleration (downhill, breaking)
- Friction: statistic/dynamic friction
- Circular motion/vibration: bump size
- Potential energy: gravity, altitude

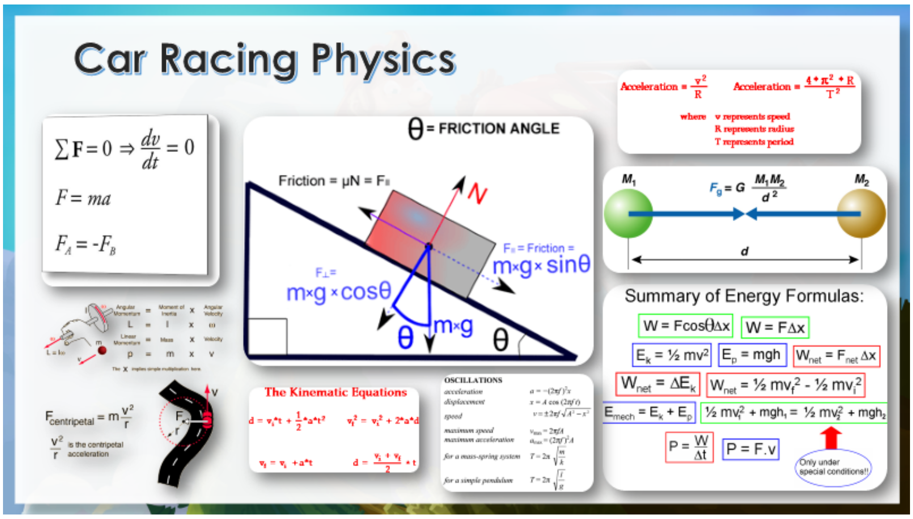

Figure 1: Car Racing Physics Diagram

The greatest challenge in the Desert Stage is when a tank is driving downhill while driving over a bump (causing it to lose speed and balance in the air). Then, the tank needs to climb up a steep hill (as shown in Figure 2). The vehicle needs to be equipped with a good continuous track for better

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downhill traction, suspension for balance control, and a powerful engine for climbing. The Hill Climb Racing Game is a game created by Fingersoft. In the game, players can upgrade four options per vehicle, the four for the tank being engine, suspension, traction, and fuel. The more you upgrade a vehicle, the more likely it will go farther. You receive coins when you play (the farther the distance, the more coins you receive), and you can use the coins to upgrade and improve your vehicle. The paper will use a Mixture DOE test that will optimize the upgrading technology to achieve the best Return (distance) of Investment (playing time), in other words, being able to travel the longest while minimizing the time spent in playing the game.

Figure 2: Car Racing Failure Mode

METHODS: MIXTURE DOE METHODOLOGY & SAMPLING

To maximize the Return of Investment (ROI) of tank technology upgrading on the desert stage, a special Mixture Design of Experiment (DOE) was designed. Mixture Design has the following two design characteristics: (1) properties of mixture DOE are a function of the relative proportions of the technologies rather than their absolute levels, and (2) because the proportions sum to one, mixture designs have an interesting simplex geometry. This enables the Mixture DOE to optimize all four variables at the same time. The total investment (playing time or upgrading budget) is fixed. The allocation of the upgrading portion among four technologies would be optimized based on Mixture DOE modeling. 21 Mixture DOE data points were collected in random sequence to avoid any noise factor. Each design had varied levels of the four technologies. The 21 data points had higher than 90% test power, and uniform Design space distribution, passing the Mixture DOE assumptions. Due to dependent relationship among the four technology input variables (sum up constraint), there is a significant interaction confounding and the square terms in the regression model which would be further addressed in next section.

RESULTS AND DISCUSSIONS: RESPONSE SURFACE MODEL

Response Surface Model was utilized to optimize the Tank's Vehicle Technologies based on the Mixture DOE data collected. Quadratic terms were missed due to their confounding with the interaction terms. The model is shown in Figure 3.

JMP Profiler and Sensitivity Analysis is conducted in Figure 4. Suspension and Engine are the top two parameters. The optimal design is to upgrade Engine the most (35% portion) and Fuel the least (15% portion). The optimal setting can achieve distance performance ~ 1,576. Suspension and Engine are top two factors (Tracks are third) deciding the car racing performance which is consistent with our previous failure mode analysis. Tank needs to maintain the balance control in air when hitting desert bumps while needs to super Engine to climb the steep hills immediately after slowing down on the down hills as shown in Figure 2 earlier.

Ternary plot platform in Figure 5 recognizes three mixture factors at a time and also provides the upper and lower operation range. Ternary plot uses shading to exclude the unfeasible areas excluded by the operation boundary. To set the goal of players to end playing this game, the performance judged by distance has set the lower limit at 1,560. In the Ternary Plot, the White Zone is the design space which could achieve the 1,560 targets while the red zone would fail to achieve the target. This ternary plot could help visualize players' upgrading risk.

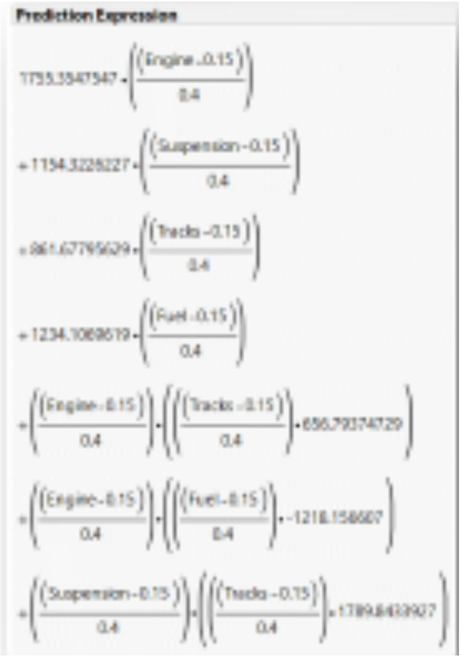

Figure 3: Mixture DOE Model

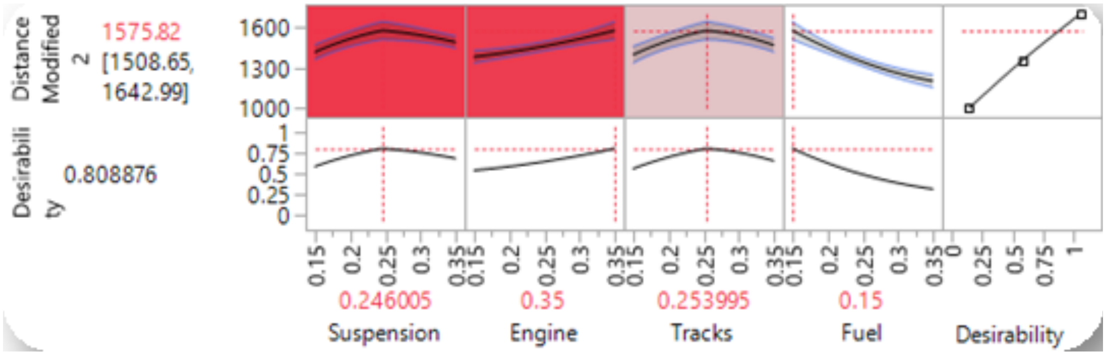

Figure 4: Profiler Sensitivity Analysis

Mixture DOE Interaction confounding has been briefly discussed. In Figure 6 Mixture DOE Effect Summary report, the interaction effect can be calculated between the Total Effect and the Main Effect. Among the top three terms, the interaction effect is more than its main effect. There are two scenarios: (1) interaction effects incudes both the interaction effects and quadratic main effects due to their confounding mixture nature (as the Mixture DOE incorporates all four variables at once), and (2) interactions may indicate two competing physics related to the failure mode (in other words, the interaction is due to some physics-related matter). The second situation would be related to our goal: understanding the physics science behind the interaction. We could look at the Interaction between the Suspension and Engine illustrated in Figure 2. When the tank was going downhill and over a desert bump, suspension and engine are both important, possibly indicating an interaction between the two (as suspension is needed to keep the vehicle from falling over when going downhill while engine is needed to go over the bump). The suspension upgrading level would decide how the tank controls the vibration balance after hitting a bump. A great suspension control may force down the tank's front orientation angle which would make it more difficult to speed up to immediately climb uphill after overcoming the bump. At the same time, a tank with a great engine may drive faster and provide less time for the tank to adjust the front orientation angle (so that it will not fall over). Players have observed such failure mode frequently when collecting the data.

Figure 5: Mixture DOE Ternary Plot

Summary Report

Column	Main Effect	Total Effect
Suspension	0.421	0.978
Engine	0.429	0.963
Tracks	0.15	0.405
Fuel	0	0

Figure 6 Mixture DOE Effect Summary Report

RESULTS AND CONCLUSIONS

This paper has demonstrated a powerful Mixture DOE methodology to maximize the ROI of playing the Car Racing Video Game. In this Car Racing Tank Desert paper, Engine and Suspension are identified as top two technologies to perform well on the Desert Stage. To climb a very steep hill, heavy tanks would need higher power. To pass many softer sand dunes (bumps), the tank would need to upgrade suspension to minimize vibration and improve in-air control. Mixture DOE also identified significant interaction effects which could further researched. This STEM (Science, Technology, Engineering, Mathematics) project can help students connect school science (physics) with statistical tools (Mixture DOE) on things they like to do (video games).

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