Warren J. Baker Endowment
for Excellence in Project-Based Learning
Robert D. Koob Endowment *for Student Success*

FINAL REPORT

Final reports will be published on the Cal Poly Digital Commons website (http://digitalcommons.calpoly.edu).

I. A "Big Data" approach to measurement for real-world, real-time automotive aerodynamics

II. Project Completion Date

5/25/17

III. Student(s), Department(s), and Major(s)

(1) Daniel Stalters, Aerospace Engineering

(2) Andrew Furmidge, Mechanical Engineering

(3) Jacob Rickman, Computer Science

IV. Faculty Advisor and Department

Dr. Graham Doig, Aerospace Engineering

V. Cooperating Industry, Agency, Non-Profit, or University Organization(s)

(1) Cal Poly Prototype Vehicles Lab (PROVE Lab) - non-profit IRA at Cal Poly, loaned a VectorNav GPS/Sensor unit and other tools/equipment
(2) Allan Hancock College - provided free use of their Lompoc test track, and volunteer time from a faculty member.

VI. Executive Summary

A "typical" sedan vehicle was instrumented with pressure, inertial (IMU), video, and GPS sensors to fully categorize the on-road conditions during an extended, multi-hour tests at the Allan Hancock EVOC track. The static pressure data sampled over the trunk lid of the test vehicle was processed along with all other pressure and IMU data gathered at the front and center of the test vehicle to build categorical and continuous models of the data using techniques borrowed from computer science and machine learning. These techniques highlighted both expected and unexpected trends in the aerodynamic data as well as

indicating it is notionally possible to build a continuous model of rear-vehicle aerodynamic response to on-road conditions. Front-vehicle aerodynamic data showed to be the most important dataset in the categorical models (Bayesian-Gaussian Mixture Model and Random Forest Classifiers), predicting 74% of the variation in rear-vehicle aerodynamics with only modest improvements in predictive capability coming from IMU data (2%) for a maximum prediction rate of 76%. When the models were trained only on discerning between direction of corner (IMU data indicated the occurrence of a cornering event), model performance improved to 81%. Continuous models (multivariate linear regression) showed significant predictive capability over the categorical models with an averaged R^2 values on the order of 0.95 (95% of variance in rear-vehicle aerodynamics captured by model). However, these models fall short in predicting asymmetric flow over the trunk lid (R^2 = 0.40 for this feature). Overall, categorical models predict a more complete breadth of the aerodynamic variation over the trunk lid but suffer from generalized conclusions resultant from data categorization. Continuous models numerically capture more of variation of the rear-vehicle aerodynamics but with a key blind spot relating to asymmetric flow patterns.

VII. Major Accomplishments

(1) Established that both categorical and continuous machine learning techniques can be used on aerodynamic data for a vehicle in real-world conditions – a full technical paper is being prepared on the development of the tests and the post-processing/algorithms.
(2) Identified areas of interest for further research into cross wind and cornering situations, and established "minimum amounts" of resolution and data required for such testing.
(3) Provided a unique opportunity for students from Cal Poly and Allan Hancock College to work together on an industry-relevant research project.

The student and faculty team made a video of the initial testing day at Allan Hancock College's test track facility:
https://www.youtube.com/watch?v=rJThjSrlYC0&

VIII. Expenditure of Funds

Funds provided by the Baker-Koob grant were used - very closely within the original budget - to purchase testing materials including pressure tubing, metal for front vehicle A-frame and rear pressure plate, cabling for power connections to vehicle battery to power instrumentation, and wood for rear frame, as well as fund the driving (mileage reimbursements) that took place to gather the data. A GoPro Session 4 was purchased to obtain vital on-car footage, and a field-grade Duracell battery unit was bought to power onboard sensor equipment for the vehicle after it was discovered that it could not run off the car 9V.

Some re-imbursement for food was also made as incentive for the students and faculty member from Allan Hancock College to give up two Saturdays to help complete the track testing.

The remainder of the funds were used to pay for travel to the SAE World Congress in Detroit Michigan where three students attended technical sessions and talked with industry and academic leaders about this research at Cal Poly - the third student was funded by a grant made by the Aerospace Engineering Department's Student Fee Committee.

IX. Impact on Student Learning

4 Cal Poly students (and 4 Allan Hancock College students) ended up working directly on the project. The students designed and executed the tests from start to finish – this included risk assessments and safe working procedures, preparation of test equipment and design and manufacture of apparatus, and development of the instrumentation itself for an on-vehicle test. All Cal Poly students gained valuable experience in each of these aspects, and left an excellent level of documentation for how both decisions and parts were made.

In terms of being able to gain knowledge in both aerodynamics and machine learning, the project was an outstanding experience for the students – the typical level of aerodynamic experience from a junior, even one who has participated in clubs like Formula, Is very limited due to minimal physical testing and real-world telemetry/data gathering. And being able to develop a customized, original machine learning procedure to handle types of data for which there doesn't exist any public precedent, was a challenging project that was achieved successfully due to the determination of the students to research and experiment. It will be a valuable project to have on the resume – it was also a worthwhile experience for the students to attend the industry-leading SAE World Congress and realize that their work has a place and relevance in the automotive sector.

High impact was also achieved in mentoring the Allan Hancock students, and working across disciplines to communicate concepts and goals effectively. The team really grew considerably in their professionalism and dedication throughout the project.

One of the students (Daniel Stalters) was sufficiently energized by the project that he has decided to pursue a Master's degree at Cal Poly to continue the work, while a junior volunteer (Kevin Joseph) that joined the project is preparing to continue the project in fall.