Introduction

Much attention has been given to the verification and validation of simulation codes. While verification and validation still remain an integral part of the process of predictive science, a great deal of the focus has recently shifted to uncertainty quantification. UQ analysis requires the use of complex statistical computer codes that frequently are poorly understood by the physicists performing the simulations. In order to increase confidence in the results of the UQ analysis, at least a simple verification process should be performed on the statistical codes.

The goals of this project were:
- To exercise our entire UQ pipeline on a simplified test problem using analytic solution as a substitute for experimental data
- To make a first step at verifying the validity of our UQ methods and software

The verification process included:
- UQ analysis on a simplified problem with an analytic solution
- Comparison of results on the simplified problem using different UQ methodologies and codes
  - Gaussian process, MARS, Bayesian MARS, MART
  - Testing the ability of the UQ software to distinguish between active and inert input parameters
  - Blind calibration of an input parameter whose correct value is known

Simplified Problem

Shock tube
- Two gamma-law gases at rest separated by a diaphragm
- Density and pressure to right of diaphragm were held fixed at a value of 1
- Computed 62 cases varying three input parameters
  - $350 < \rho_0 < 650$
  - $70 < \gamma \rho_0 < 150$
  - $10 < c_s \gamma \rho_0 < 50$
- Orthogonal array Latin hypercube design
- Added five inert input parameters that had no effect on the output

Output quantities of interest

Four positions
- $x_{\text{shk}}$ - location of shock
- $x_{\text{cd}}$ - location of contact discontinuity
- $x_{\text{tail}}$ - location of tail of rarefaction
- $x_{\text{head}}$ - location of head of rarefaction

Four values of state variables
- $P_{\text{shk}}$ - pressure at left of shock
- $P_{\text{cd}}$ - density at left of contact
- $P_{\text{tail}}$ - density at left of tail
- $P_{\text{head}}$ - velocity at left of shock

Experiment Design

Output Correlations

Simulation vs. Analytic Solution

Conclusions

- We currently have four methods available to perform UQ analyses for our simulations and experiments
- All four methods worked well and provided consistent results for the simple test problem
- All four methods successfully recognized the inert inputs
- Calibration of $\gamma$ produced the expected answer
- We now have confidence that our UQ software is ready to analyze simulations of the CRASH experiments

Prediction Results

Emulation of the Simulator

Gaussian Process Results

For perfect agreement, the points should lie on the red line

Some output variables show a small systematic bias

This is probably due to inaccuracies in feature extraction

For perfect agreement, each point should lie on the red line

Each point is predicted from the remaining 61 simulations. For perfect agreement, each point should lie on the red line

Calibration of Input Parameters

Ten of the 62 analytic solutions were computed with $\gamma = 1.4$ and used as a substitute for experimental data. The statistical model was then used to calibrate the value of $\gamma$ using the 62 simulations.

Relative Importance of Input Parameters

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