Training Knowledge Bots for Physics Based Simulations Using Artificial Neural Networks

Jay Ming Wong
Department of Computer Science
University of Massachusetts Amherst
jayming@cs.umass.edu

Jamshid Samareh (Mentor)
Vechicle Analysis Branch
Systems Analysis and Concepts Directorate
jamshid.a.samareh@nasa.gov

NASA Langley Research Center

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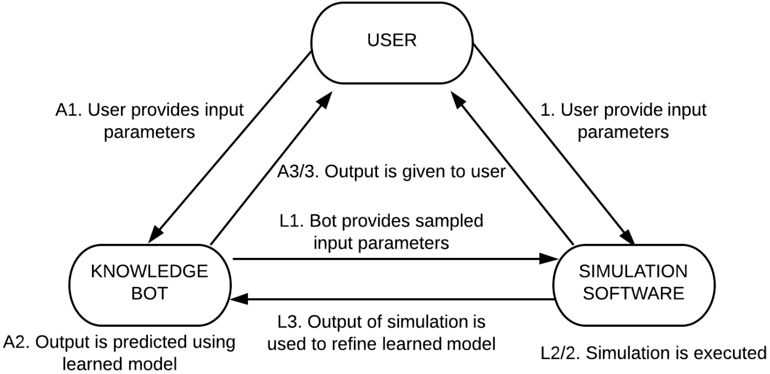
Overview

Purpose of the Knowledge Bot

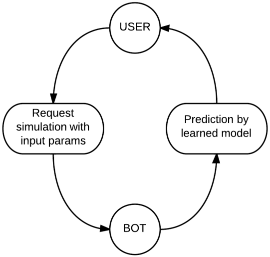


Role of the knowledge bot in system analysis and design process

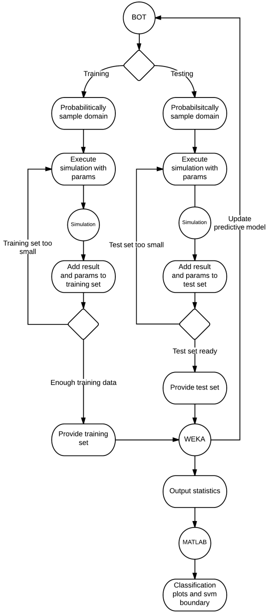
Purpose of the Knowledge Bot

- In system analysis the following physics base simulations are essential in the design and analysis process,
  1. Computational Fluid Dynamics (CFD)
  2. Trajectory Analysis (POST2)
  3. Finite Element Analysis (NASTRAN)

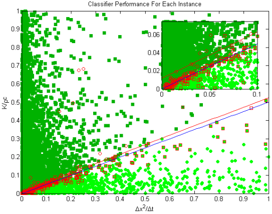
Approach



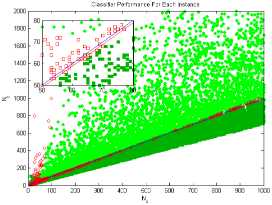
User-Bot relationship



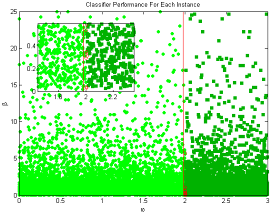
Classification Results



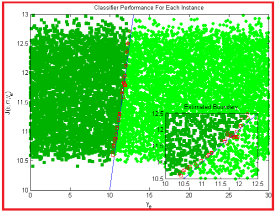
Parabolic 1D Heat Conduction



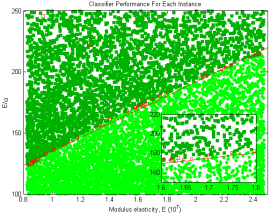
Hyperbolic Wave Equation



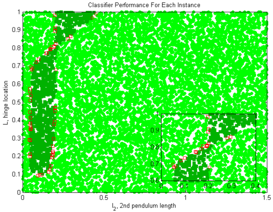
Elliptic Laplaces' Equation



Venus Direct Entry Trajectory

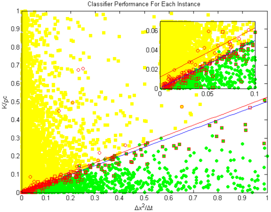


Pressure Vessel Design



Slosh Propellant Dynamics

Classification Results



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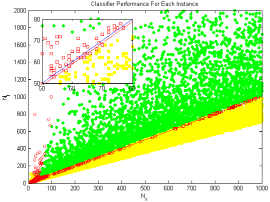

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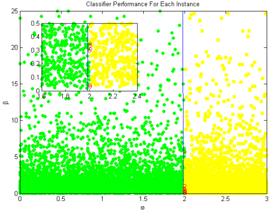

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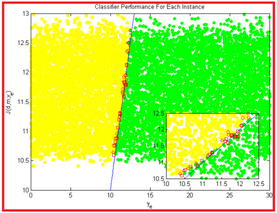

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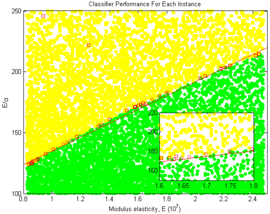

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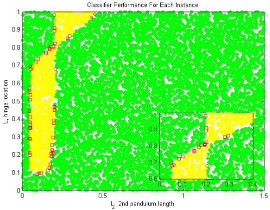


Slosh Propellant Dynamics

Direct Entry Problem

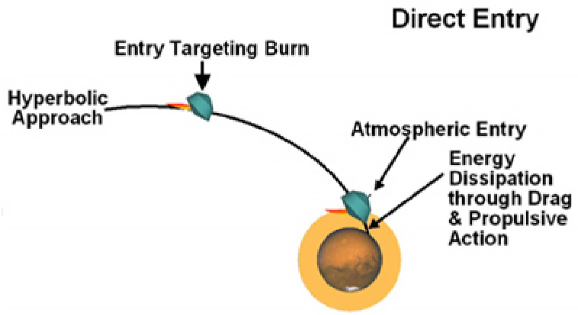


Illustration of direct entry concept[1]

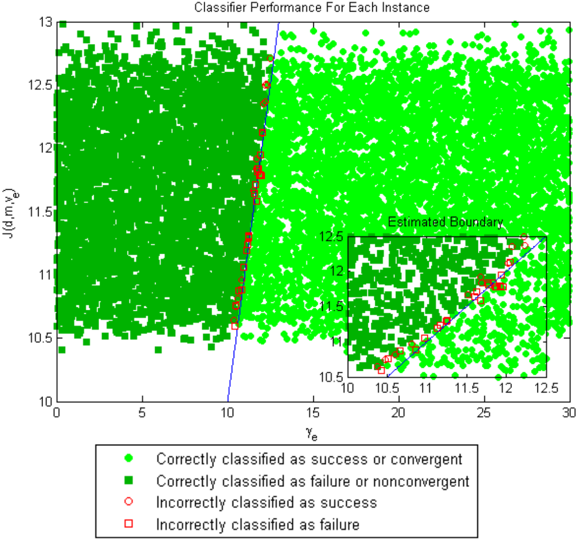
[1] http://cosmology.com/Mars128.html

Direct Entry Problem

- Purpose was to observe atmospheric-assisted direct entry of a 45-degree sphere-cone vechicle using d (diameter),m (mass), v_e (entry velocity), γ_e (entry flight path angle) on planet Venus
- Find region where successful entries and failed entries will occur at, some instances may be captured some may not
- Train neural network to classify when success or failure will occur based on input parameters
- Probabilistically sampled $0.5m \leq d \leq 4.0m$; $500kg \leq m \leq 5000kg$; $10km/s \leq v_e \leq 13km/s$; and $-30^o \leq \gamma_e \leq 0^o$
- Use SVM to discover clear bounday between success and failure
- Describe the boundary in a clear expression with least squares

Classification Results of Atmospheric-assisted Direct Entry

- Classification Plot demonstrates instances and their predictions
- $\gamma_e, J(d, m, v_e)$ boundary using SVM and least squares



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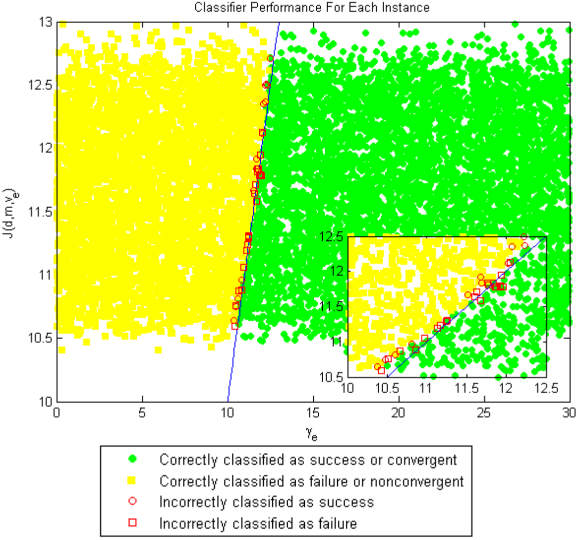


What is $J(d, m, v_e)$?

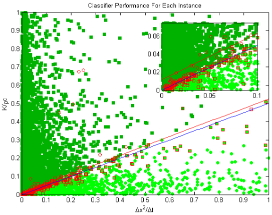
- $J(\cdot)$ is an expression relating d, m, v_e to γ_e along the classified border between success and failure in direct entry
- $J(d, m, v_e) = \gamma_e$ lies along the border

$$J(d, m, v_e) = 0.0219 m^{0.0096} v_e^{0.6646} d^{-0.0017} \tag{1}$$

1. if $\gamma_e < J(d, m, v_e)$, direct entry failure
2. if $\gamma_e > J(d, m, v_e)$, direct entry sucess

- Artificial neural network classification shown to be over 99.6% accurate

Recall... Classification Results



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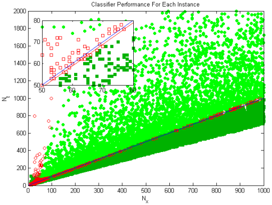

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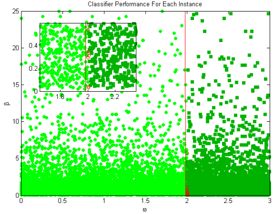

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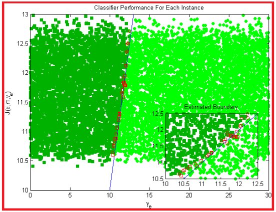

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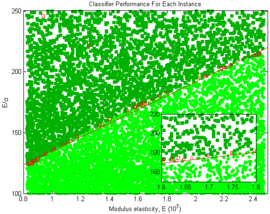

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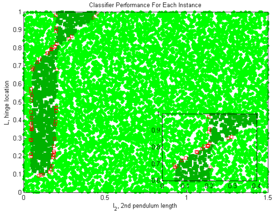

Slosh Propellant Dynamics

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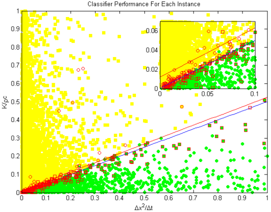

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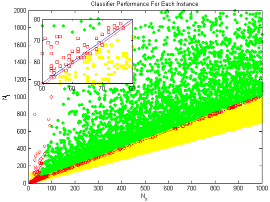

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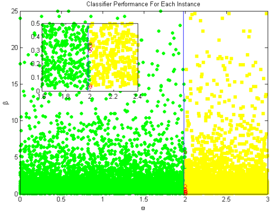

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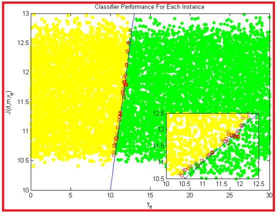

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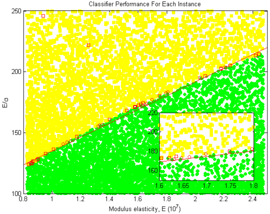

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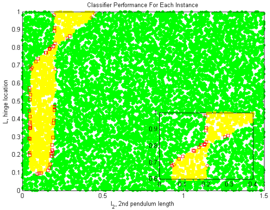
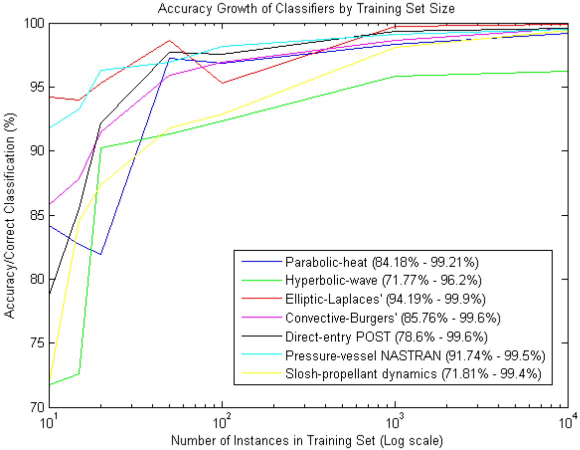


Slosh Propellant Dynamics

Classifiers Accuracy Growth



Conclusions and Insights

1. Underlying properties of physics-based simulations (CFD, POST2, NASTRAN, slosh) can be accurately learned using ANN
2. All ANN classifications were over 99% accurate (Hyperbolic wave 96%)
3. SVM is an effective tool to identify classification boundaries