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Robust Optimal Onboard Reentry Guidance of a Space Shuttle: Dynamic Game Approach and Guidance Synthesis via Neural Networks[1,2,3]

M. H. BREITNER[4]

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Abstract. Robust optimal control problems for dynamic systems must be solved if modeling inaccuracies cannot be avoided and/or unpredictable and unmeasurable influences are present. Here, the return of a future European space shuttle to Earth is considered. Four path constraints have to be obeyed to limit heating, dynamic pressure, load factor, and flight path angle at high velocities. For the air density associated with the aerodynamic forces and the constraints, only an altitude-dependent range can be predicted. The worst-case air density is analyzed via an antagonistic noncooperative two-person dynamic game. A closed-form solution of the game provides a robust optimal guidance scheme against all possible air density fluctuations. The value function solves the Isaacs nonlinear first-order partial differential equation with suitable interior and boundary conditions. The equation is solved with the method of characteristics in the relevant parts of the state space. A bundle of neighboring characteristic trajectories yields a large input/output data set and enables a guidance scheme synthesis with three-layer perceptrons. The difficult and computationally expensive perceptron training is done efficiently with the new SQP-training method

[1]This paper is dedicated to the memory of Professor Rufus Philip Isaacs on the occasion of the 20th anniversary of his death.

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[3]Dynamic games are multistage (multiact) games with a finite or an infinite number of stages (actions of the players). The latter are governed often by ordinary differential equations. Rufus Philip Isaacs, the acknowledged father of dynamic games, used the term "differential games."

[4]Associate Professor for Mathematics and Computer Science, Fachbereich Mathematik und Informatik, Technische Universität Clausthal, Clausthal-Zellerfeld, Germany.