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OPTIMAL GUIDANCE USING TEMPORAL CONVOLUTIONAL NETWORKS FOR AUTONOMOUS MARS LANDING

Abstract

The future of space systems leans towards disruptive technologies such as Machine Learning, specifically Deep Learning. In this paper, we propose a deep learning approach to solve the problem of autonomous spacecraft landing. We consider the problem of Mars landing, where we propose a solution using temporal convolutional networks (TCN). TCNs is a recently developed tool in the field of deep learning, which replaces the need for two separate models, e.g., a combination of convolution neural network (CNN) and recurrent neural network (RNN) and provides a unified model which performs both low level spatial-temporal feature extraction and high level temporal feature extraction. The use of dilated convolutions makes TCN a better candidate while dealing with problems that require a large receptive field, which is the size of the input region used to extract features.

The aim of this paper is to model the mapping from images to the corresponding control actions while maintaining fuel optimality. This eliminates the need for state estimations, and optimal guidance is achieved using only image input from the onboard cameras. This solution involves supervised learning, for which a dataset of multiple trajectories was generated. Optimal trajectories were generated using an approach based on calculus of variations, using which 100 trajectories were generated, each having different initial conditions. This approach was chosen because it provides a closed form expression for the optimal acceleration, which is in turn used to extract the optimal thrust. Additionally, this technique allows for easier computation of trajectories, as the requirement of niche optimization software for optimal control approaches is eliminated. A total of 4600 corresponding images were generated using the computer graphics software toolset Blender and a digital terrain model from the University of Arizona's HiRISE website. The TCN is used to extract features from these images, which are further used to solve a regression problem estimate the thrust vector.

The results support the use of TCN, in terms of the root mean squared errors for both training and validation, which reduce over the number of passes of the entire training dataset. The training loss is observed to have a mean of 0.226 and standard deviation of 0.112, while the validation loss is observed to have a mean of 0.207 and standard deviation of 0.050.