Policy Compression for Aircraft Collision Avoidance Systems

**Introduction**

ACAS Xu formulates UAV collision avoidance as a POMDP and generates an optimal offline policy. This policy is represented as a large, multi-dimensional lookup table requiring over 2GB of storage space, too large for certified UAV avionics systems. We seek to find a functional representation of the policy without degrading performance by training deep neural networks.

**ACAS Xu Table**

Table represents the value of every state-action pair. Five possible actions: turn each direction at two possible strengths and Clear-of-Conflict (COC). The state has 7 discretized dimensions, creating 600 million table values.

**State Dimensions**

- $\tau$: Time to vertical CPA
- $pRA$: Previous action
- $\rho$: Range
- $V_{own}$: Ownship speed
- $V_{int}$: Intruder speed
- $\theta$: Intruder bearing
- $\psi$: Intruder heading

**Network Architecture**

Size of network is driven by desired compression. With 600,000 parameters in the network, different network shapes and optimizers were investigated. As a result, the network has 6 hidden layers and uses AdaMax optimization, an adaptive gradient descent method.

**Simulation Results**

On 1.5 million simulated encounters, the neural network outperforms the original table on critical safety and performance metrics. However, due to the large amount of computation, the neural network greatly increases the runtime required.

**Loss Function**

**Challenge**: Regressing a policy table must give accurate values while maintaining the highest valued advisory for every state.

**Solution**: Use an asymmetric MSE loss function. As a result, the neural network policy is much more similar to the original table policy than with nominal MSE.

**Network Speedup**

To speed up neural network, train multiple small networks on subsets of the table. Only one small network is evaluated at runtime, decreasing runtime required. Using an array of 45 neural networks, network evaluation is faster than a table lookup.

**Policy Plots**

The policy plots show the comparison between the original table and the neural network. The neural network policy is much more similar to the original table policy than with nominal MSE.

**Policy Plots for Network Array**

Through neural network regression, a UAV collision avoidance policy was compressed by a factor of 1000 while improving performance. By training multiple small networks, the required runtime for policy evaluation was reduced. Future work will focus on fine-tuning the networks and network validation.

**Conclusions**

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