IOWA STATE UNIVERSITY
Aerospace Engineering Department

2018 NSF CPS PI Meeting
Nov. 15-16, 2018

PI: Peng Wei

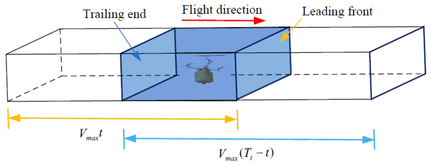
Award Number: 1565979

CRII: CPS: Towards an Intelligent Low-Altitude UAS Traffic Management System

Pre-Departure Flight Planning

Flight Plan Coordination and Demand Estimation

Main Idea: we use the concept called "dynamic geofence" instead of static geofence to dynamically reserve airspace. We also study the trade-off between ground delay and air delay



Formulation/Solution: computational geometry, flight plan, aircraft performance

Students supported: Guodong Zhu

Publications: 2 conference papers

Industry/Society Impact: our concept has been well accepted in both UTM and UAM communities

En Route Conflict Resolution

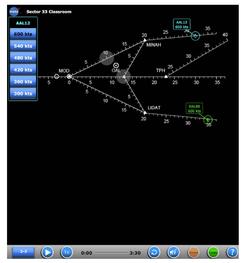
Autonomous Air Traffic Control (Auto-ATC)

Main Idea: can we design an autonomous agent to perform the ATC's daily routine, i.e., tactical sequence and separation tasks?

Formulation/Solution: hierarchical deep reinforcement learning

Students supported: Marc Brittain

Publications: 2 conference papers (including one best paper award at ICRAT18)



Air Traffic Flow Management

Multi-Resource/Multi-Routes Capacity/Demand Imbalance

Main Idea: we manage pairwise traffic demand given multiple limited capacities with multicommodity flow. We hedge capacity uncertainty with stochastic programming. We treat demand shift and demand uncertainty

Formulation/Solution: stochastic programming, multicommodity flow, mixed integer linear programming (MILP)

Students supported: Guodong Zhu

Publications: 5 conference papers

Industry/Society Impact: Our algorithm has been implemented in May 2018 at American Airlines. Everyday there are 20 to 40 flights benefiting from our algorithm

$$
\begin{aligned}
\min \quad & \underbrace{\sum_{r\in\mathrm{PCA}}\sum_{t=1}^{T} G_t^r}_{\text{ground delay costs}} + \underbrace{\sum_{r\in\mathrm{PCA}}\sum_{t=1}^{T}\sum_{q=1}^{Q} c_a p_q A_{t,q}^r}_{\text{air delay costs}} \quad \boxed{\text{if demand exceeds PAR, some flights will take ground delay}} \\
\text{s.t.} \quad & P_t^r = \mathrm{UpFCA}_t^r + \boxed{D_t^r} - (G_t^r - G_{t-1}^r) \quad \forall r \in \mathrm{FCA}, \forall t \\
& L_{t,q}^r = \mathrm{UpFCA}_t^r + \mathrm{UpPCA}_{t,q}^r - (A_{t,q}^r - A_{t-1,q}^r) \quad \forall r \in \mathrm{PCA}, q, t \\
& M_{t,q}^r \geq L_{t,q}^r \quad \forall r \in \mathrm{PCA}, \forall q, \forall t \quad \boxed{\text{if PAR exceeds real capacity, some flights will take air delay}} \\
& \sum_{(r,r')\in\mathrm{CONN}} f_t^{r'} = 1 \quad \boxed{\text{sum of flow fractions equals to 1}} \\
& G_t^r, P_t^r, L_{t,q}^r, A_{t,q}^r \geq 0 \quad \forall r, \forall q, \forall t \\
& \mathrm{UpFCA}_t^r = \sum_{r',r\in\mathrm{CONN}} f_{t-\Delta^{r',r}}^{r',r} \cdot P_{t-\Delta^{r',r}}^{r'} \\
& \mathrm{UpPCA}_{t,q}^r = \sum_{r',r\in\mathrm{CONN}} f_{t-\Delta^{r',r}}^{r',r} \cdot L_{t-\Delta^{r',r},q}^{r'} \quad \boxed{\text{travel time between PCAs are considered}}
\end{aligned}
$$

Autonomous On-Demand Free Flight

Computational Guidance and Collision Avoidance with MCTS

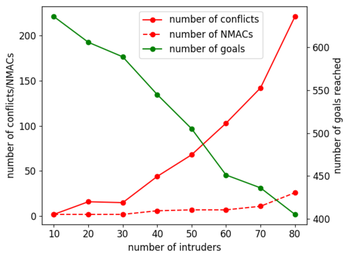
Main Idea: can we design a decentralized real-time onboard algorithm to guide aircraft fly from A to B, and avoid collision with other nearby aircraft?

Formulation/Solution: Markov decision process and Monte Carlo Tree Search

Students supported: Xuxi Yang

Publications: 1 conference paper + 1 journal paper

Industry/Society Impact: Airbus "Blueprint for the Sky – the roadmap for the safe integration of autonomous aircraft"



Efficient Urban Air Mobility Arrivals

Energy Aware Traj Optimization and Arrival Scheduling

Main Idea: our arrival scheduler will calculate RTAs for each aircraft to maximize the skyport throughput, then the optimal control algorithm with the given RTA will generate the most energy efficient arrival trajectory for individual aircraft

Formulation/Solution: rotorcraft mechanics, optimal control, battery prognostics, combinatorial optimization

Students supported: Priyank Pradeep

Publications: 5 conference papers (including one best paper award at GNCC18)

Industry/Society Impact: N/A

$$\frac{dV_x}{dt} = \frac{T\sin\theta - D\cos\gamma}{m}$$

$$\frac{dV_h}{dt} = \frac{T\cos\theta - D\sin\gamma - mg}{m}$$

$$T_{\text{rotor}} = \frac{P_{\text{rotor}}}{V\sin\alpha + v_i}$$

Autonomous Drone Racing

Online Learning/Decision Making in Dynamic Environments

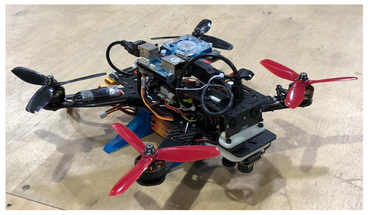
Main Idea: we are establishing both software and hardware basis to enable high speed autonomous drone racing with competitors in highly dynamic indoor environments

Formulation/Solution: reinforcement learning, optimal control, deep learning (computer vision), LIDAR sensing, FPGA computing.

Students supported: Anwar Manjanoor

Publications: 1 conference paper

Industry/Society Impact: N/A



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