Aircraft Collision Avoidance Controller

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CS6376: Hybrid and Embedded Systems

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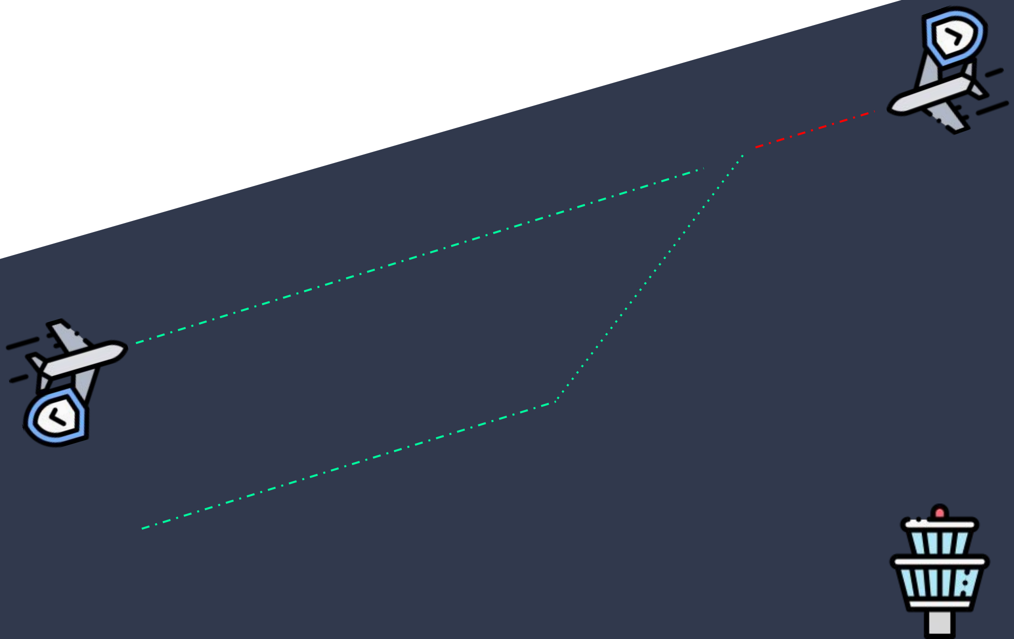
Vanderbilt University, Fall 2023



Introduction

The **traffic collision avoidance system (TCAS)** has been a vital safety feature in large transport aircraft since the 1990s.

It has **proven** highly **effective** in preventing midair collisions.

However, as we look to the **future** of air traffic control and management, **challenges** arise.

High-density airspace and the integration of **unmanned aerial vehicles (UAVs)** pose new complexities.

Related Work

The **Aircraft Collision Avoidance System X (ACAS X)** introduces a partially observed Markov decision process for future collision avoidance.

ACAS X focuses on reducing collision risk and false alarms, primarily issuing **vertical avoidance** actions due to computation and storage constraints.

Traditional radar-based systems face limitations in coverage, restricting implementation to close encounter scenarios and increasing pilot workload.

ACAS Xp, a future version, relies solely on **autonomous dependent surveillance-broadcast (ADS-B)** for broader application in general aviation aircraft.

Autonomous Dependent Surveillance Broadcast (ADS-B)

ADS-B is a **vital component of the U.S. Federal Aviation Administration's** NextGen air transportation system.

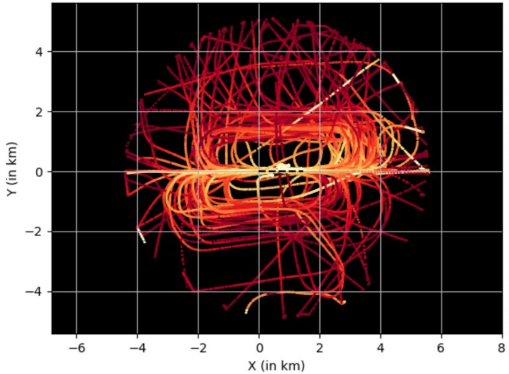
It broadcasts state and trajectory intent information from navigation satellites to other aircraft and ground stations.

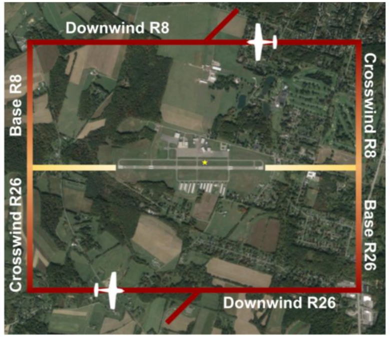
ADS-B's **broader surveillance coverage** compared to radar facilitates early conflict detection and resolution.

Challenges arise in adapting the current TCAS for ADS-B data, leading researchers to explore new approaches.

- *Holdsworth et al.* suggest collision avoidance planning with ADS-B and dynamic programming.
- *Kochenderfer et al.* propose using a partially observable Markov decision process to validate ADS-B reports in the collision avoidance system.
- *Lin et al.* present a sampling-based path planning method using ADS-B to avoid collisions with commercial aircraft.

Dataset





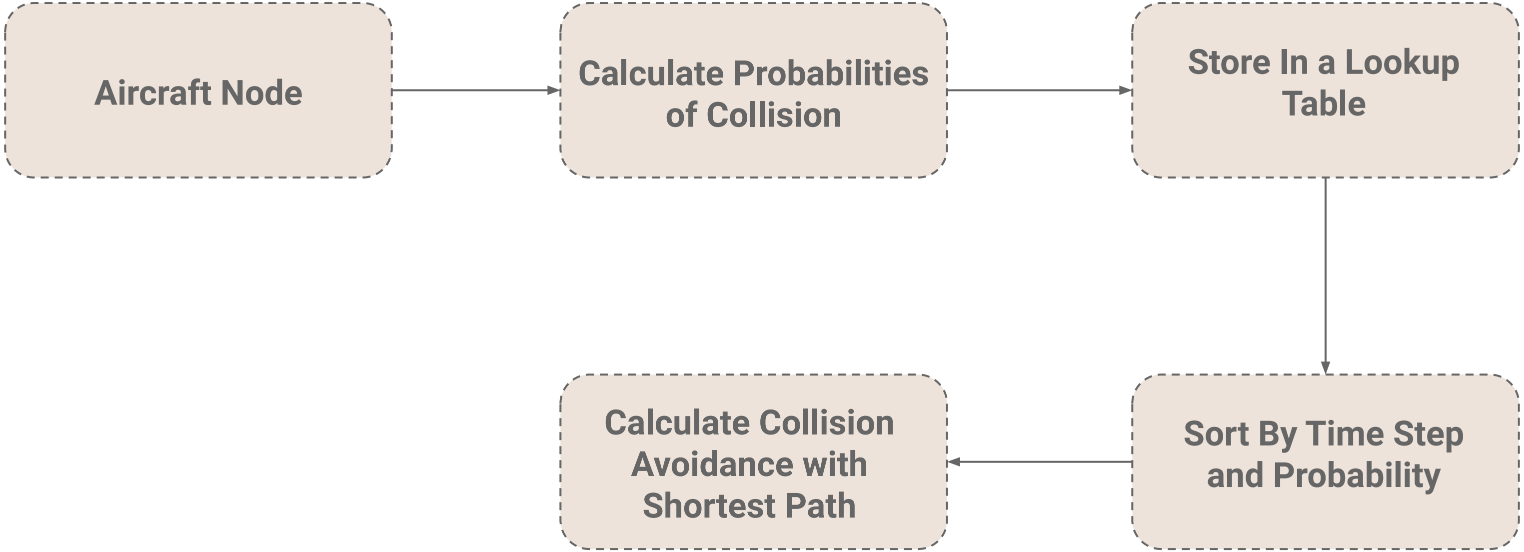
Example of data collected by ADS-B Receiver

Frame #	Aircraft ID	x (km)	y (km)	z (km)	$wind_x$ (m/s)	$wind_y$ (m/s)
0	10620674	1.3407	0.0026	0.3353	0.0	0.0
1	10620674	1.3135	0.0021	0.3353	0.0	0.0
2	10620674	1.2863	0.0017	0.3353	0.0	0.0
⋮	⋮	⋮	⋮	⋮	⋮	⋮
405	10620674	-3.8946	1.5872	0.9751	0.0	0.0

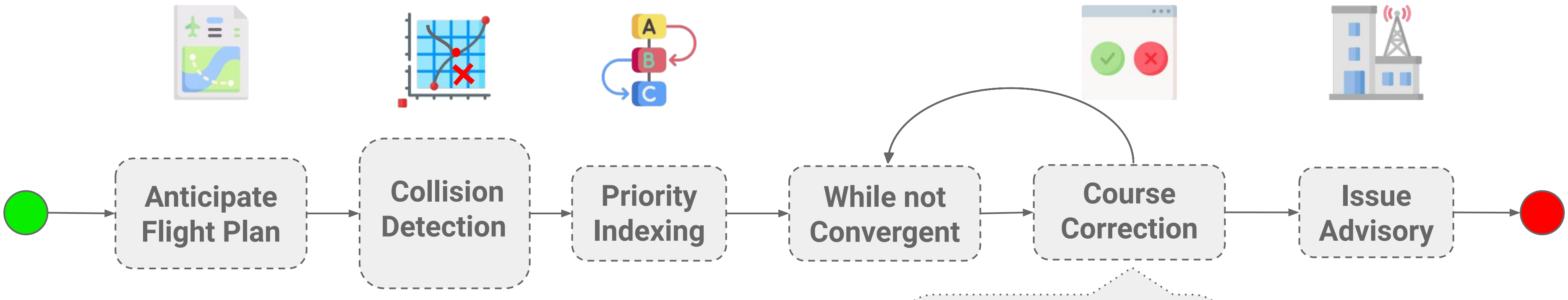
Carnegie Mellon University
The Robotics Institute

https://theairlab.org/trajair/

Collision Detection



Algorithm Flowchart



Example Action Space

Action Space	Vertical rate, ft/min
CL1500	+1500
CL2500	+2500
DES1500	+1500
DES2500	-2500

Output Walkthrough

1

```
# Running controller
------------------------------------------------------------------------------
# ADS-B Controller Receiver Data Info:
------------------------------------------------------------------------------
Dataset rows: 360722
Unique aircrafts: 164
------------------------------------------------------------------------------
# Controller Data Area Info:
------------------------------------------------------------------------------
Plane data range: Along the runway: -4.131442787589634 to 5.863296403919421 km
Plane data range: Perpendicular to the runway: -4.881616372506984 to 5.095150653901[illegible]7 km
System height data range: 0.0 to 1.82118 km
------------------------------------------------------------------------------
```

2

```
------------------------------------------------------------------------------
# Controller Iteration: 1
------------------------------------------------------------------------------
------------------------------------------------------------------------------
# Monitoring Collisions
------------------------------------------------------------------------------
Collision # 1
          Frame   AircraftID         x         y       z      windx      windy
86216   17138.0  11217673.0  1.762349  -0.00078  0.3048  -3.341066  -1.343522
103469  17138.0  11080625.0  1.757077   0.00211  0.3048   0.000000   0.000000
------------------------------------------------------------------------------
Collision # 2
          Frame   AircraftID         x          y        z      windx      win[illegible]y
104676  24113.0  10628960.0  1.119112  -0.001655  0.33528  1.914331  1.7180[illegible]7
159338  24113.0  10520887.0  1.124637   0.004383  0.33528  0.798856  2.4450[illegible]3
------------------------------------------------------------------------------
Collision # 3
```

3

```
------------------------------------------------------------------------------
# Collision Monitor Summary
------------------------------------------------------------------------------
Total number of collisions: 10
10 occurances of 2 aircrafts collisions.
------------------------------------------------------------------------------


------------------------------------------------------------------------------
# Setting priority order...
------------------------------------------------------------------------------
# Trajectory correction...
------------------------------------------------------------------------------
# Updating trajectory data...
------------------------------------------------------------------------------
```

4

```
------------------------------------------------------------------------------
# Controller Iteration: 2
------------------------------------------------------------------------------
------------------------------------------------------------------------------
# Monitoring Collisions
------------------------------------------------------------------------------
Collision # 1
          Frame   AircraftID         x          y        z     windx     wi[illegible]y
225749  24113.0  10628960.0  1.119112  -0.001655  0.94488  1.914331  1.718[illegible]7
351707  24113.0  10520887.0  1.124637   0.004383  0.94488  0.798856  2.445[illegible]3
------------------------------------------------------------------------------
```

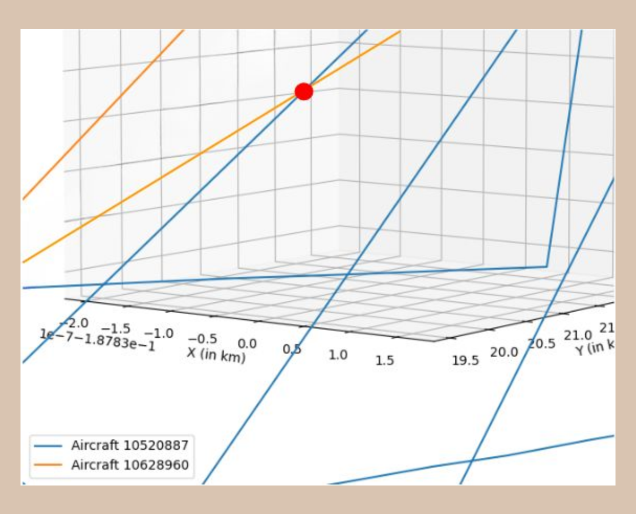
5

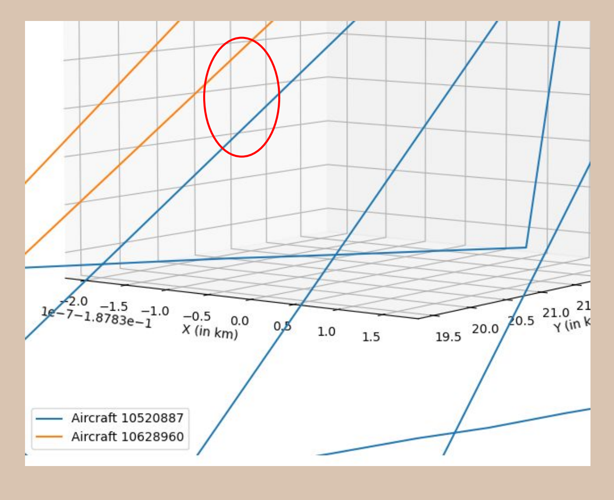
```
------------------------------------------------------------------------------
# Collision Monitor Summary
------------------------------------------------------------------------------
Total number of collisions: 1
1 occurances of 2 aircrafts collisions.
------------------------------------------------------------------------------
# Setting priority order...
------------------------------------------------------------------------------
# Trajectory correction...
------------------------------------------------------------------------------
# Updating trajectory data...
------------------------------------------------------------------------------
```

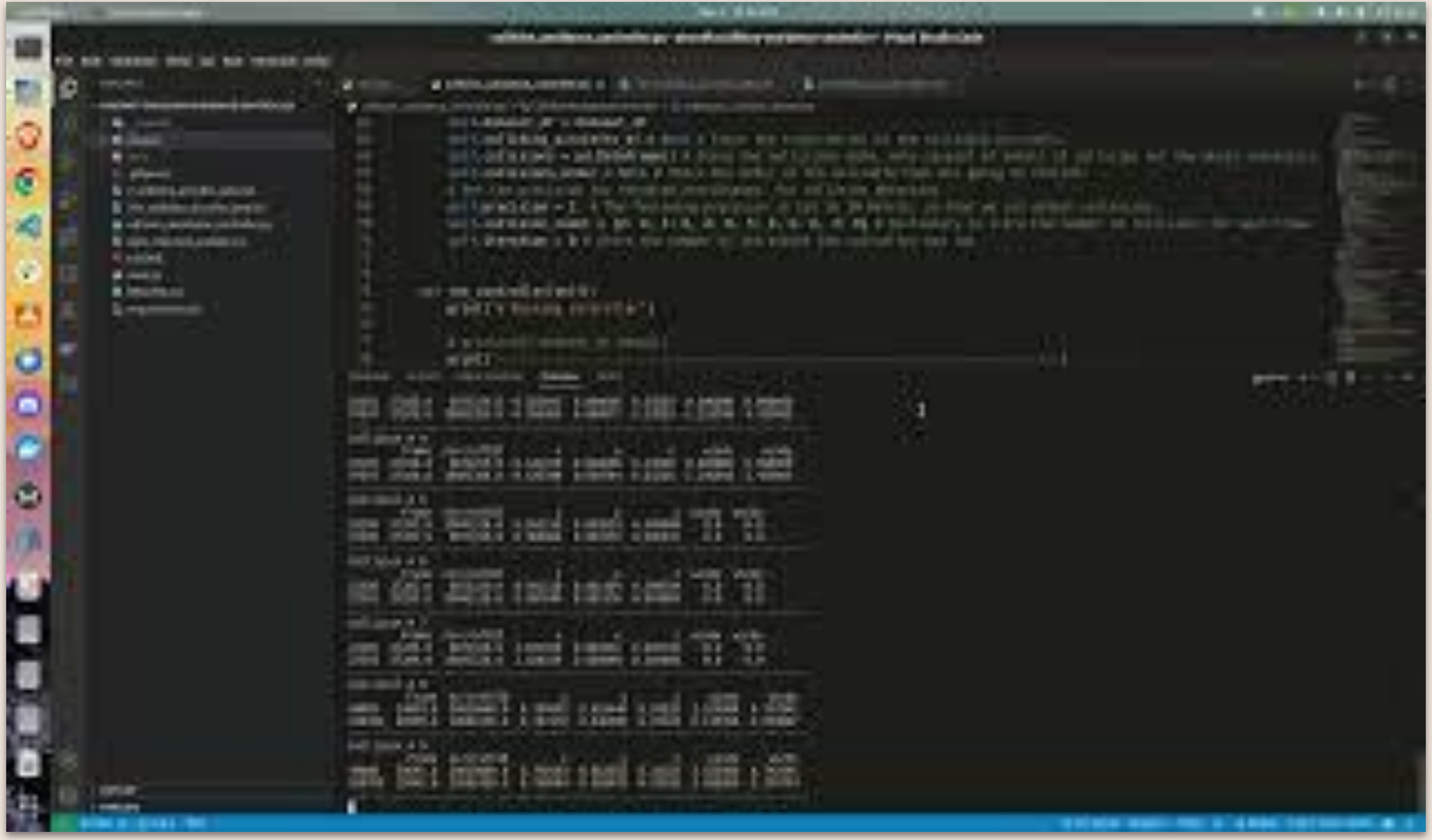
6

```
------------------------------------------------------------------------------
# Controller Iteration: 3
------------------------------------------------------------------------------
------------------------------------------------------------------------------
# Monitoring Collisions
------------------------------------------------------------------------------
------------------------------------------------------------------------------
# No more collisions found: Course correction completed
------------------------------------------------------------------------------
# Controller finished running
```

Visualization







Demo Link: https://youtu.be/RvGEqUJp-sI

Thank You