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1 Problem Restatement

Pursuit of a lost plane:

The disappearance of flight MH370 kindled a long debate and serious introspection. The methods used for hunting the plane came into serious questioning when even after months, the searchers were no closer to discovering the plane or its debris. The problem asks to Build a generic mathematical model that could assist "searchers" in planning a useful search for a lost plane feared to have crashed in open water such as the Atlantic, Pacific, Indian, Southern, or Arctic Ocean while flying from Point A to Point B. Like in the case of MH370, we arent receiving any signal from the plane that is feared to have crashed.

The challenge in building a search model is the variation in Plane sizes and the different search techniques used. The problem requires to account for both.

2 Terminologies and Conventions

- **SAR**. Search-And-Rescue.
- **MTOW**. Maximum Take Off Weight.
- $\tilde{r}$. Distance between point of last contact and point of incident.

3 Assumptions and their Justifications

About the Search Domain and the Missing Aircraft

- **The search domain is a** 500**km by** 300**km rectangle of unobstructed ocean.** This rectangle would cover the whole uncertainty range based on the last known state of the lost aircraft for an interval of 15 minutes to 1 hour based on INMARSAT's "Log-on Interrogation" old and newly recommended standards in light of the MH370 accident[**citation**].

- **The missing aircraft is assumed to be still in this domain at $t = 0$.** Although escaping the domain at a later time is allowed.

- **The SAR targets remain clustered.** This means that the targets always stay in the same 20km by 15km cell on the coarse grid. This assumption is valid as long as the search plan is initiated close to the incident and no serve weather condition causes disturbances.

- **There are buoyant indicator of target location at all time.** Since no underwater search is performed, we assume that either our SAR objective (e.g. survivors, life rafts, parts of crashed debris) remain buoyant throughout our search planning, or our sensor can detect signs of the objectives

- **The local trajectory of concern is straight**. In addition to the obvious smoothness arguments, it is always possible to apply a conformal transform on the entire search domain to obtain a solution based on a curved trajectory.

- **No banking maneuver was made from incident to crash.** This is reasonable for that even in the worse case of gliding due to single engine failure, the average time from initial to of roughly 11 minutes[**Citation or see derivation later**]. And this time is not long enough to cause trajectory deviations across different search cells.

- **Hijacking or on-board navigation system only problems are not the cause of the incident**. Although hijacking incidents account for nearly 20% of all accidents in past 50 years **Citation!**, SAR plane (or vessel) detectors are largely useless in finding a cruising rouge plane. Also see problem restatement.

- **The missing aircraft can be accurately modeled as either G280, Boeing 737-900ER, or Airbus 380.** These three types of aircraft are well-known representatives of small private/business jets, medium range commercial flights, and large international flights. Cruise speed and other aircraft form factors (e.g. Lift to Drag ratio) are derived based on this assumption.

- **The crash radius of the aircraft is only a function of the cause of the incident and the type of the aircraft.** In addition, we assume that the historical distribution of the cause of the accidents is a reasonable prior for the current incident at hand, and it is it is invariant with respect to the type of the aircraft[1].

- **Aircraft is operating at MTOW**. Assuming they have cargo and passengers

- **Cruise altitude of all types of aircraft is assumed to be the same**. Describe/Justify.

About Debris Drifting

- **The local drift direction and speed can be accurately modeled as constant within each cell.** Operationally, the resolution of the cells can be adapted to actual drift data.

- **Nothing outside the search domain drifts back into it.** seems nice.

About the Search Agents

- **All agents are commanded and controlled by the central planner at each update interval.** No command and control overhead is assumed for the sake of simplicity.

- **Agents arrive at the boundary of the search domain at $t = 0$.** Search agents are assumed to have arrived on the edge of the search domain at $t = 0$.

[1] We do not have an aircraft aficionado at hand to sift through and separate the accident records based on size

- **Unlimited bandwidth between search agent communications**. This is necessary from a planning perspective as to ignore the less than pertinent issues with sensor fusion and coordination. Moreover, this factor is more than likely fixed by the hardware.

- **Types of search agents considered are helicopter, fixed wing UAVs, and surface vessels.** Although the problem only mentions "search planes," it is very common to have sur

- **Search agents use either magnetometer or camera as their main detector.**

- **Search agents all have a lateral range function of a bivariate Gaussian as a function of their type, altitude, and speed.** Detection follows Koopman's Random search formula.

- **The probability of false alarm is assumed to be 0%.** Lack of exact literature references, industry standard assumption [2013 book].

- **The search agents have no knowledge of local drift direction.** Although modern planning softwares used by professional SAR entities (e.g. SARPOS by U.S. Coastal Guards) all have existing database to accommodate real-time ocean drifting, these data are often not precise, not to mention useless on a fictitious geography.

- **Ignore refueling problems.** In operation, search agents can request refueling vehicles etc. and the time is not quite relevant.

- **Agents move either horizontally or vertically.** In operation, search agents can request refueling vehicles etc. and the time is not quite relevant.

4 Literature Review

1983 paper

2013 probablitic search book

5 Criteria for Optimal Solution

In real life the only success criterion is whether we can find the target and how long it takes to do so.

6 Describe Your Method

6.1 Description

6.2 Mathematical Interpretation

Probability of Escape

$$P[target\,in\,\partial\Omega|t=n] =: q_n$$

$$P[escaped|t=0] =: Q_0 = q_0 = 0$$

$$P[escaped|t=n, not\,escaped|t=n-1] = q_n$$

$$P[escaped|t=n] = q_0 + q_1 \cdot (1-Q_0) + \cdots + q_n \cdot (1-Q_{n-1})$$

6.3 Comparison to Most Interesting Literature Paper

UAV paper

Current SARPOS system (particle filter)

7 Comparison to a "Steepest Decent" Search Plan

also multiple agent/single agent etc.

8 Experimental Setup

grid cell size

9 Results

10 Sensitivity to Parameters

11 Strengths and Weaknesses

Strengths:

- **simple effective**. Description.
- **Short bullet point**. Description.
- **Short bullet point**. Description.
- **Short bullet point**. Description.
- **Short bullet point**. Description.

Weaknesses:

- **resolution/grid size**. Description.
- **renomalization/discretization error**. Description.
- **very simplified drift modeling**. Description.
- **Short bullet point**. Description.
- **Short bullet point**. Description.

12 Conclusion

- **Recommendation 1**. Why the data says so.
- **Recommendation 2**. Why the data says so.
- **Recommendation 3**. Why the data says so.
- **Recommendation 4**. Why the data says so.

References