Genetic algorithm for investigating flight MH370 in Indian Ocean using remotely sensed data

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Abstract. This study utilized Genetic algorithm (GA) for automatic detection and simulation trajectory movements of flight MH370 debris. In doing so, the Ocean Surface Topography Mission(OSTM) on the Jason- 2 satellite have been used within 1 and half year covers data to simulate the pattern of Flight MH370 debris movements across the southern Indian Ocean. Further, multi-objectives evolutionary algorithm also used to discriminate uncertainty of flight MH370 imagined and detection. The study shows that the ocean surface current speed is 0.5 m/s. This current patterns have developed a large anticlockwise gyre over a water depth of 8,000 m. The multi-objectives evolutionary algorithm suggested that objects are existed on satellite data are not flight MH370 debris. In addition, multi-objectives evolutionary algorithm suggested that the difficulties to acquire the exact location of flight MH370 due to complicated hydrodynamic movements across the southern Indian Ocean.

1. Introduction

Since March 8 2014 and despite, twelve countries have joined in for the search-and rescue efforts of missing flight of MH370, it is so durable to find a plane like MH370 [1]. By the way, China deployed 10 high-resolution satellites to scurry the South China Sea, Digital Globe opened its crowdsourcing platform Tomnod and Airbus Defence and Space mobilized its five satellites to find some leads [2]. We live in an age and era where technology tracks our every little movement. Why then it is so difficult to find a plane like MH370? The Malaysian Airlines flight went missing on March 8 2014 and every new piece of information seems to shroud the flight's disappearance in more mystery. Theories ranged from hijacking to disruption to a conceivable suicide by one of the pilots. Finally, citing satellite-data analysis by British firm Inmarsat, has concluded that the flight, which vanished while flying to Beijing from Kuala Lumpur, had crashed thousands of miles away in the southern Indian Ocean (Figure 1) and none of the passengers or crew on board survived [2].

According to Grady [3], leveraging a combination of satellite and terrestrial assets, news networks continue to dig-deep into their portfolio of communications options. Among those options are their pre-existing full time, loss of satellite capacity, or contribution feeds. Nearly all major news networks leverage these contribution feeds to help deliver studio-to the studio feeds, move content from one corner of the globe to another, or supplement other terrestrial-based pathways.

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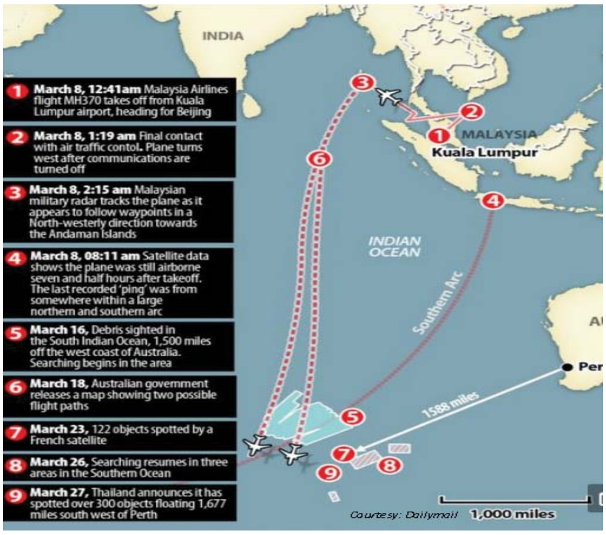

Figure 1. MH370 suspected location in the southern Indian Ocean.

Aireon will enable airlines and ANSPs to more accurately track the location of aircraft, something that, as evidenced by the recent MH370 disappearance, is very much needed. By providing near real-time data transmission via satellite, aircraft can be tracked within a few miles of its location at any time, no matter where it is on earth. In light of the disappearance of flight MH370, technological advancements in flight tracking have come under some serious scrutiny. How will Aireon play a role in flight tracking of commercial aircraft? How does it differ from the available current tracking technologies. The rummage for the flight MH370 has been a sobering reminder of the vastness and uncharted mystery of our planet's oceans. Conversely, the race against the clock to find the airliner's black box has also provided something of a showcase for the technologies that are enhancing our ability to operate in an environment often considered to be every bit as challenging as outer space [4].

The main question can be raised up what appropriate sensors can be used to monitor and detect flight MH370 debris? The high-resolution sensors either on board of satellite or airborne can detect and identify the flight MH370 debris. Even HF ground radar can detect any foreign objects moving in the coastal zone. This also is required the standard methods of object automatic detection by using high resolution microwave satellite data with 1 m as in the spot mode of both RADARSAT-2 SAR, TerraSAR-X satellite data. The RADARSAT-2 SAR satellite has a synthetic aperture Radar (SAR) with multiple polarization modes, including a fully polarimetric mode in which HH, HV, VV and VH polarized data are acquired. Its highest resolution is 1 m in Spotlight mode (3 m in Ultra-Fine mode) with 100 m positional accuracy requirement. In addition, RADARDSAT-2 SAR Scan Narrow SCNB beam is its and a high revisit period of 7 days. Further, has nominal near and far resolutions of 7 m. If the length of the flight is 24 m, means it could clearly be detected in RADARDSAT-2 SAR Scan Narrow. This suggests that, as high cloud covers are dominated in the southern Indian Ocean, it is suggested to use airborne SAR sensors like uninhabited aerial vehicle Synthetic aperture radar (UAVSAR, by JPL, L-band) with a 22-km-wide ground swath at 22° to 65°.

Clearly, the lack of remote sensing and in situ data made the hunt of flight MH370 even more convoluted. Satellite altimeter measurements could provide accurate data of bathymetry, sea level, and ocean wave and ocean current movements. In this regard, the main objective of this work is to utilize the capability of Ocean Surface Topography Mission (OSTM) on the Jason-2 satellite with genetic algorithm (GA) to investigate the existing of the flight MH370 debris in the southern Indian Ocean under the impact of Indian Ocean circulation.

2. Study Area

Figure 2 shows seafloor topography in the Malaysia Airlines flight MH370 search area. Dashed lines approximate the search zone for sonar pings emitted by the flight data recorder and cockpit voice recorder popularly called black boxes. The first sonar contact (black circle) was reportedly made by a Chinese vessel on the east flank of Batavia Plateau (B), where the shallowest point in the area (S) is at an estimated depth of 1637 meters. The next reported sonar contact (red circle) was made by an Australian vessel on the north flank of Zenith Plateau (Z) (Figure 2). The deepest point in the area (D) lies in the Wallaby- Zenith Fracture Zone at an estimated depth of 7883 meters. The Wallaby Plateau (W) lies to the east of the Zenith Plateau. The shallowest point in the entire area shown here is on Broken Ridge (BR). Deep Sea Drilling Project (DSDP) site 256 is marked by a grey dot. The inset in the top left shows the area's location to the west of Australia. Seafloor depths are from the general bathymetric chart of the oceans [5].

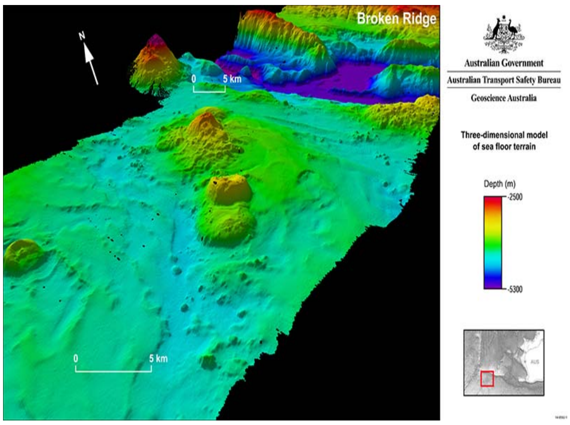

Figure 2. Bathymetry of Indian Ocean.

3. The publicly available data

According to Zweck [6], the only publicly available reliable data are: (i) the location of the INMARSAT 3-F1 satellite in a geostationary orbit at an elevation of 35,800 km over the point on the earth at 1.5°N, 64.5° E; (ii) the data released by the AAIB on March 25th which includes the times at which the satellite pinged the aircraft, together with the measured burst frequency offsets (i.e., the Doppler-shift frequencies) at those times; and (iii) a map released by the Malaysian government which shows that the angle between the 8:11 am arc and the satellite position was about 40°. The initial search area is accurately shown on a March 17th map on the web site of the Washington Post newspaper. This map also includes the approximate location of the satellite and four red arcs marked with the times 5:11am, 6:11am, 7:11am, and 8:11am. Although this map is qualitatively correct, the data it seeks to represent does not agree quantitatively with the three reliable data sets described above [6]. Since the methodology the Inmarsat team is used to deduce possible flight paths depends on accurate knowledge of the locations of the arcs, it is not currently possible for their calculations.

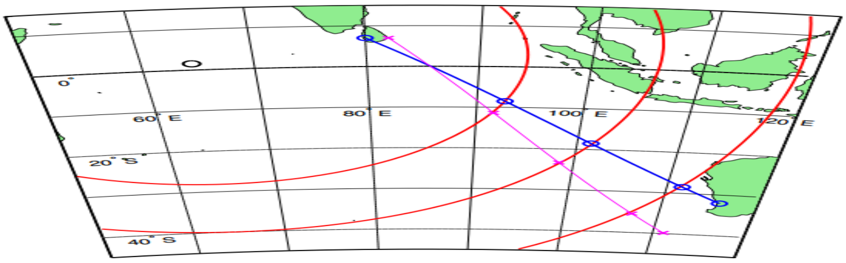

Figure 3. Map of path of a fictitious flight, XX123, from Colombo, Sri Lanka towards Perth Australia, departing at 12 noon and arriving in Perth at 7:48 pm [7].

In addition, in Figure 3, the three red arcs show the location of the plane at 3 pm, 5 pm, and 7 pm. Using only this information, the blue curve shows the 400-knot flight path. The magenta curve shows how the flight path that is deduced would change if the starting location were assumed to be 220 km due east of Colombo. A plane traveling along the magenta path would have a speed of 416 knots and be 970 km from Perth at 7:48 pm [7].

4. Genetic algorithm and debris of MH370

The genetic algorithm (GA) can work in two ways: (i) if a piece of debris is located in the southern Indian ocean, GA can predict, or backtrack, to the original location, or the possible crash site; and (ii) if a piece of debris is located by satellite, GA can decide either the debris belong to flight MH370 or not. The simulation of flight MH370 debris is done using GA. Following Anderson [8], GA encodes the parameter values associated with each candidate solution as a string, which usually in binary format. For each parameter, the number of bits provided must be sufficient to encode the full range of possible values associated with that parameter.

The string representing a solution is simply the concatenation of the sub-strings corresponding to the individual parameters; by analogy with biology, this string is referred to as a chromosome. Starting with an initial population of candidate solutions (i.e., chromosomes) constructed by means of a random number generator, a genetic algorithm iteratively applies three basic steps: (i) rank the members of the current population according to fitness, (ii) select superior members which will be used to breed the next generation, and (iii) apply operators on randomly-selected pairs of these members to mimic the transfer of genetic material to offspring that occurs during biological reproduction, thereby producing a new generation with statistically superior characteristics [8].

4.1 Multi-objective optimization based Pareto dominance

Following Anderson [9], the definition of the problem given above is in one sense incomplete – it does not specify the choice of norm for the space $\boldsymbol{Y}$. In a single objective optimization problem, the objective space is usually a subset of the real numbers and a solution $\boldsymbol{x}_1 \in \boldsymbol{P}$ is better than another solution $\boldsymbol{x}_2 \in \boldsymbol{P}$ if $\boldsymbol{y}_1 < \boldsymbol{y}_2$ where $\boldsymbol{y}_1 = \boldsymbol{\mu}(\boldsymbol{x}_1)$ and $\boldsymbol{y}_2 = \boldsymbol{\mu}(\boldsymbol{x}_2)$. In the case of a vector-valued objective function mapping, comparing solutions is more complex and one must endeavour to capture the essential priorities of the problem in the choice of norm. Herein lays the crucial distinction between single objective and multi-objective problems - whereas the former afford simple scalar measures of fitness that can be used to rank individual members of the design space, the latter are characterised by conflicts of interest among the competing objectives as measured by μ_i, $i=1,m$ [9-11]. There are several ways to deal with this complication. Perhaps the simplest is to create a scalar figure of merit as a weighted sum of the separate objective measures,

$$\text{(i) minimise} \quad \mu_{\boldsymbol{i}} = \sum_{i=1}^{m} \alpha_i \mu_i \qquad (1)$$

Another approach is to convert all but one of the objectives into constraints,

$$\text{(ii) minimise } \mu_j \text{ subject to } \mu_i \le z_i \ \forall i = 1, m; i \ne j \qquad (2)$$

While convenient, these methods shed little light on the nature of the trade-offs made. As there may be subtle, non-quantifiable considerations involved in site selection, such as risks to personnel or to equipment, a better approach is to map the trade-off surface so that the decision maker can execute judgment in making a final selection. To perform this mapping, it is not necessary to run (i) or (ii) above for a large number of parameter selections α_i, z_i and to inspect the outcomes. Instead, we can use an evolutionary stochastic optimisation algorithm to reveal the Pareto front, as described below.

Pareto optimality is based on the binary relation of dominance. A solution $\boldsymbol{x}_1 \in \boldsymbol{X}$ is said to be dominated by another solution $\boldsymbol{x}_2 \in \boldsymbol{X}$, written $\boldsymbol{x}_2 \prec \boldsymbol{x}_1$, if $\boldsymbol{x}_2$ is at least as good on all counts (objectives) and better on at least one, that is,

$$\boldsymbol{\mu}_i(\boldsymbol{x}_2) \le \boldsymbol{\mu}_i(\boldsymbol{x}_1) \ \forall i = 1, m \text{ and } \boldsymbol{\mu}_j(\boldsymbol{x}_2) < \boldsymbol{\mu}_j(\boldsymbol{x}_1) \text{ for some } j. \qquad (3)$$

With this relation, the Pareto set of optimal (non-dominated) solutions $\boldsymbol{P}^*$ will usually have multiple entries, associated with different trade-offs between the objectives. The image $\boldsymbol{Y}^* \subset \boldsymbol{Y}$ of the Pareto set $\boldsymbol{P}^* \subset \boldsymbol{P}$ is referred to as the Pareto front and knowledge of its shape greatly assists in choosing the best compromise solution [9]. The Genetic algorithm has implemented on the data of the Jason-2/Ocean Surface Topography Mission (OSTM), and QuikSCAT [12].

5. Results and discussion

Figure 4 shows the possible MH370 debris which acquired by Chinese satellite in 44° 57'S 90° 13'E in the southern Indian ocean with the length of 24 m. Further, Figure 5b, shows the corrected image generated by using a Genetic Algorithm. Figure 5b shows the segmented image generated by Genetic Algorithm which indicates that the bright object which claimed by Chinese satellite as MH370 debris is belong to aircraft carrier. The correlation between real aircraft carrier and one produced by genetic algorithm is 0.87 with standard errors of 0.002. This means that the optical remote sensing data either THEOS satellite or a China satellite are not able to determine precisely any debris belong to MH370 which considered as unusual uncertainty.

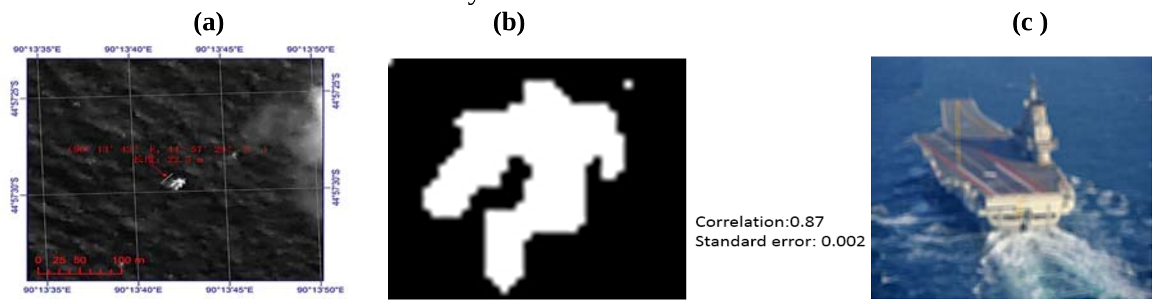

Figure 4. Flight MH370 debris in (a) China satellite , (b) GA segmentation results correlated to (c) aircraft carrier as example.

Figure 5 shows the simulated debris trajectory movements based on clues were given by Inmarsat-4 satellites. The debris moved from Australia across the Southern Indian Ocean since March 2014 to February 2016. This simulation took 7 hours to be completed using GA. Figure 6e shows that debris flow in anti-clockwise direction with root mean square error of current velocity of 10 cm/sec which is coincided with the Southern Indian current movement.

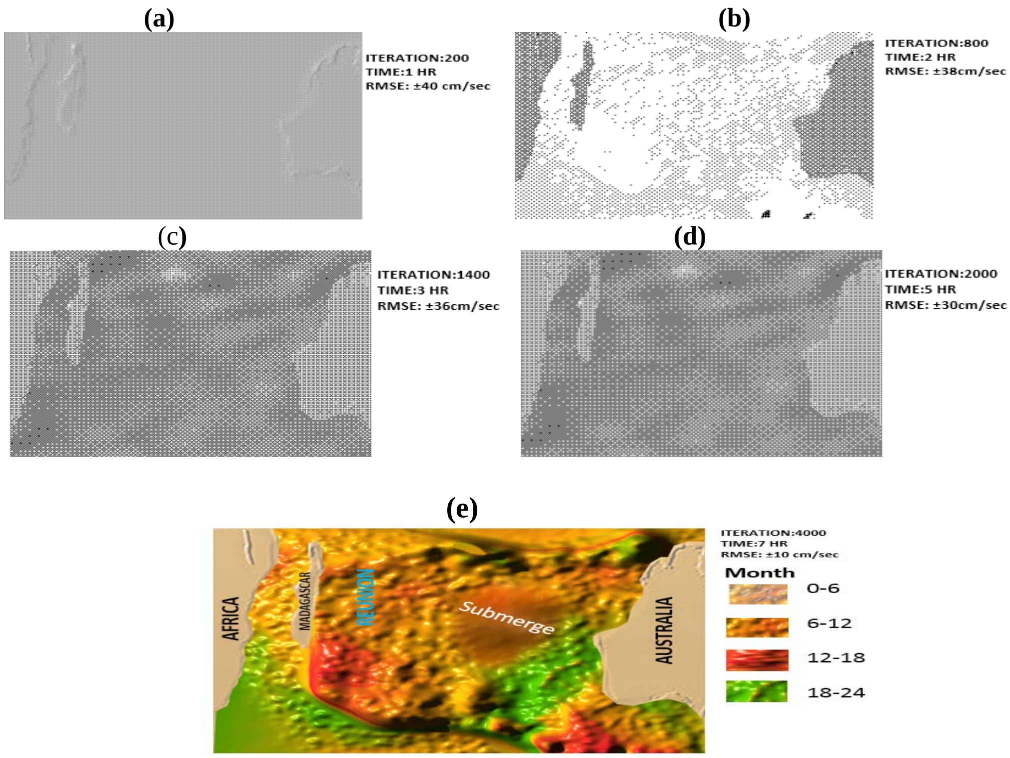

Figure 5. Genetic algorithm iterations of current movement and possible flight MH370 debris (a) 200,(b)800,(c)1,400, (d)2,000 and 4,000.

However, the element of the debris would not have floated for several months at the water's surface but would have drifted underwater a few meters deep. In fact, the Antarctic Circumpolar Current (ACC) will cause instabilities for the debris trajectory movements. In this regard, the MH370 debris could transport westward and spin in a large scale counter-clockwise eddies rotation and drifted westward to the African east i.e. Mozambique and Madagascar coastal waters. During this dynamic instability, either debris are more buoyant than water, in which case they float, or they are less buoyant, in which case they sink. Therefore, the turbulent movements with 50 km/ day of the large southern Indian gyre with width of 100 km would cause the debris to submerged in depth of 3,000 m to 8,000 m across the Southern Indian Ocean [12]. The debris has been found in Reunion Island are not belong to MH370. In fact, the debris would sink under sea surface of 3000 water depth within less than few months as explained above. If there is no clue confirms the existence of debris either from remote sensing data or ground search across the Southern Indian Ocean, this means the MH370 have landed vertically through the ocean surface and broke down to several pieces through the water column due to huge hydrostatic pressure of more than 2,000 m water depth. This confirms the theory of Marghany [12].

6. Conclusions

This study has used optimization techniques of Genetic algorithm to investigate the impact of ocean surface current on flight MH370 debris. The southern Indian Ocean during the months of March-April has dominated by anticlockwise large gyre moving with maximum velocity of 0.5 m/s and slowly drifts westward. It means that flight MH370 debris can potentially travel up to 50 km/day with large eddies of a width of 100 km wide. The study shows that flight MH370 debris could not move to Africa within 24 months and with less than 2 months it would sink before washed up on Réunion Island. However, it can be said that the turbulent flow due to large Southern Indian gyre would make the debris submerged in deep water more than 3000 m across the Southern Indian Ocean. In conclusion, intelligent system based on multi-objectives Genetic algorithm can be used to investigate uncertainties in data and information. In conclusion, it is difficult to determine the MH370 debris in the Southern Indian Ocean because of sophisticated and turbulent current, which could drift the debris away to westward that required large-scale search areas.

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