Modeling the Disappearance of MH370

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AM207: Advanced Scientific Computing: Stochastic Optimization Methods. Monte Carlo Methods for Inference and Data Analysis. *Spring 2014.*

What Happened?

Malaysia Airlines Flight 370 disappeared on March 8, 2014 en route from Kuala Lumpur to Beijing. Neither wreckage nor the final location of the airplane have been found, despite the most expensive and extensive search in aviation history.

What Do We Know?

- MH370 deviated from the flight plan at the Igari Waypoint and was last detected by Indonesian military radar near Pulau Perak.
- MH370 sent pings to an Inmarsat geostationary satellite which can reveal plane's radial distance from the satellite.
- There were 6 pings after disappearance from radar, every hour. MH370 was flying for >6 hrs after its last known position (but < 7).
- Possible ping distance errors were 2.5% or 5%, putting bounds on where MH370 is most likely located every hour after disappearance, along an arc from the satellite.
- We know a Boeing 777's cruising speed.
- We also got all 777-landable runways in the world and the top 10 Asian cities by population, to use in our HMM.

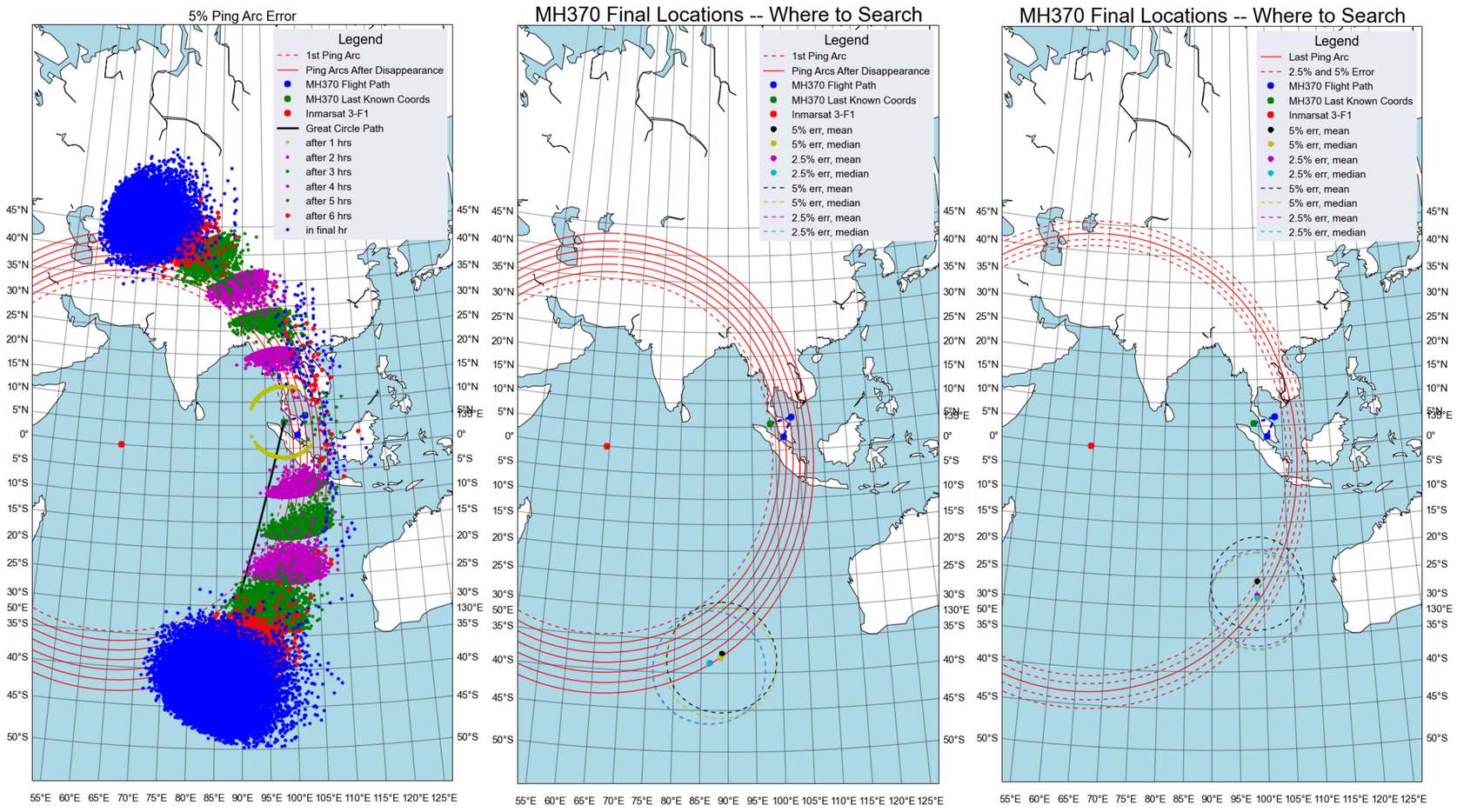
Monte Carlo Model

Our first task was to identify MH370's likely locations given the above available information. Our MCMC model incorporated ping arc error by creating a lat/lon probability grid over the area in which MH370 could fly (based on 6.5+ hrs in the air). This was done for each time step of the simulation, when the Inmarsat satellite pings occurred. Thus we use the data to inform our model.

Ping arc error was modeled as a Gaussian over the probability grid, w/ a mean of 0 (along the arc) and a standard deviation equivalent to 2.5% and 5% of the last ping arc. We also draw from a normal (Gaussian) distribution, Von Mises, or Wrapped Cauchy relative to MH370's current heading.

We assume MH370 tends to fly in more or less the same direction relative to the last heading, as most planes do. Ping and heading probabilities are multiplied and renormalized to create weighted likelihoods of new possible locations. The final heading selection (and thus next location) is randomly drawn using these weights.

We use a Bayesian approach to set up a Markov Chain Monte Carlo model to identify MH370's most likely location. We also apply a Hidden Markov Model (HMM), using abstracted scenarios of how a plane can move (and using MH370's last location), to demonstrate how to construct a testable plane scenario likelihood framework.



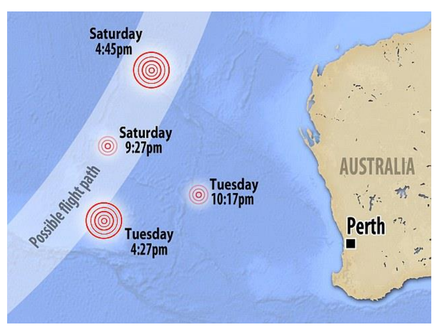
Results, Version 3 MC Model. Extensive simulations lead to a consistent conclusion: off Australia's west coast. In the middle and right, we plot the average MH370 location at final ping arc.

Where Is It?

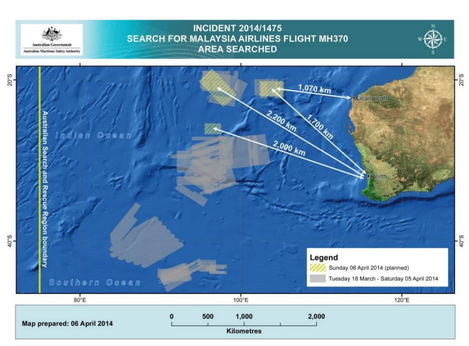
Across our simulations, MH370 went to the southern corridor 80+% of the time. Given satellite ping arc constraints on MH370's position, none of the routes are in a Great Circle from the plane's last known location. Since Boeing 777 autopilot's default settings fly a Great Circle route, we conclude the plane was intentionally routed or manually flown to its final destination.

Search Areas vs. Model Performance

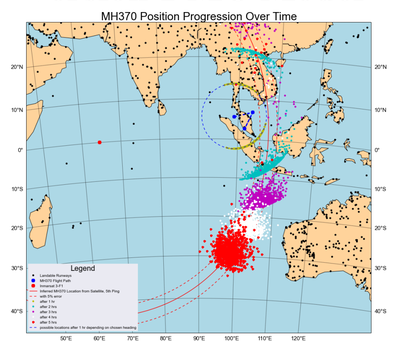
Possible Black Box Pings



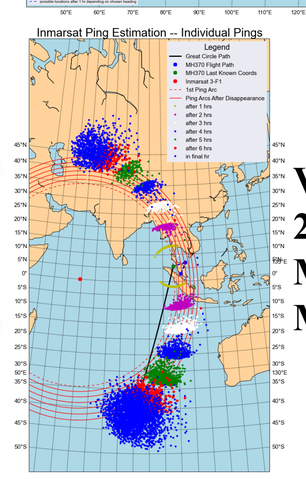
Search Areas



Version 1 MC Model

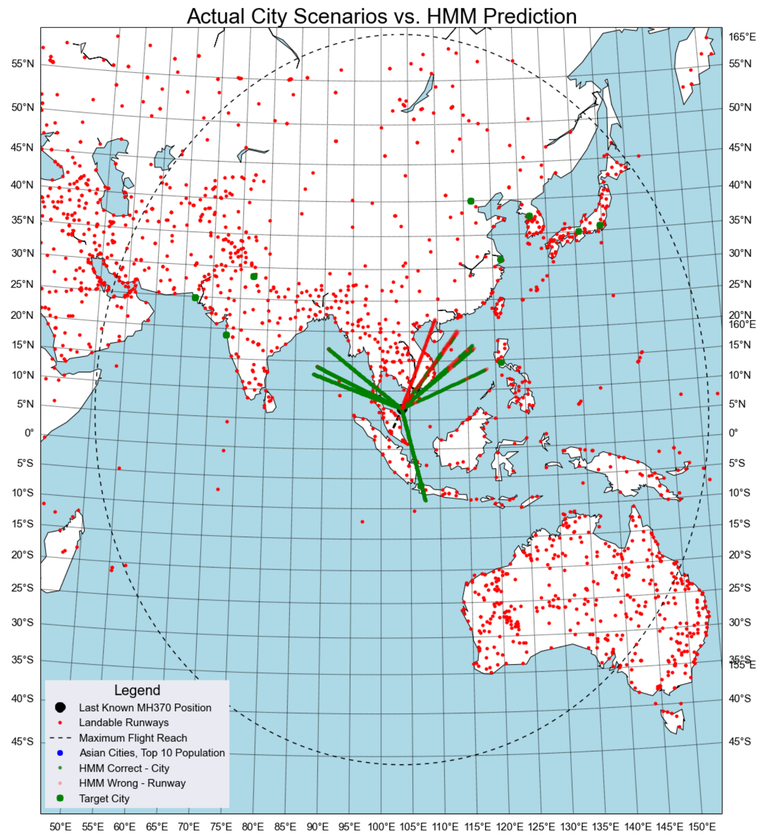


Version 2 MC Model



Hidden Markov Model

We next compared scenarios for where a plane could move (to a runway 90% of time, to a city 10%), using an HMM to detect the rare scenario from the common one.



HMM. Cities detected ~82% of the time, albeit with ~52% success rate overall (false alarms.)

More Info

Pavlos Protopapas. AM207 Lectures 3,5,7,18.

Fast Company Labs article series by Conor Myhrvold, late March through mid April 2014.