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Optimal detection of changes in real-time data: Applications in satellites

Peter Johnson
University of Manchester, UK

Detecting changes in random processes as quickly and accurately as possible is important for many scenarios. Examples include: detecting a plane using radar; identifying nuclear material at ports; reacting to breakages in atomic clocks on satellites and; determining when is the best time to buy/sell stocks and shares. Using advanced applied probability, it is possible to provide an optimal time to stop and declare that a change has occurred (optimal in the sense of minimizing the delay after the change) with a fixed probability of error. This collaborative work looks at problems of this type applied to issues in detecting breakages in clocks on board satellites. The sophisticated solutions of these optimal stopping problems show that the first hitting time of a test statistic to a defined boundary is the quickest possible decision time for a given level of accuracy (see figure). This means that no other method can outperform the algorithms used, which is a valuable asset in high performance systems. This research has two high profile satellite applications: The New Horizons mission, and The Galileo Project. Most recently solutions of this type have been involved in helping engineers from NASA detect an unusual change in the two on-board quartz clocks (which are replied upon to beam accurate data back to earth) as its satellite passed Pluto. These methods are also helping resolve similar problems in detecting the breakages in the atomic clocks used in the Galileo project; the first global navigation system primarily for civilian use is being developed by the European Union. The accuracy of these clocks is critical to accurate positioning with a 100 nanosecond error meaning positioning could be out by up to 30 meters on the ground.

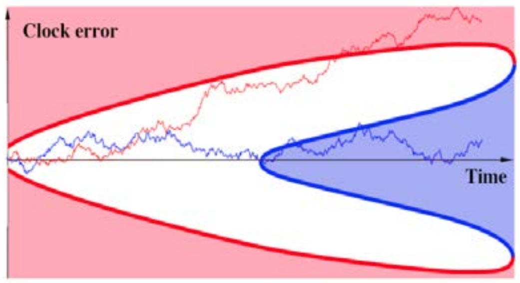

Figure. This boomerang shape is the optimal stopping boundary when the the possible clock error has a Gaussian distribution. If the clock error hits the red region then it is determined that a drift is present and the satellite temporarily stops transmissions until the clock can be recalibrated. If it hits the blue region, however, then it is determined that the clock is still working correctly and the satellite continues transmitting subject to further monitoring.

Biography

Peter Johnson is currently pursuing his Post-doctorate studies at University of Manchester, Manchester. He has mainly worked with optimal stopping and free boundary problems in the area of sequential analysis. However, he also has a keen interest in "HMM tracking algorithms, filtering theory and non-linear optimal stopping problems". His research area is Applied Probability.

peter.johnson-3@manchester.ac.uk

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