

Developing a Data Driven Prognostic System with Limited System Information

Laura Pullum, Marjorie Darrah, Spiro T. Skias
Institute for Scientific Research, Inc. (ISR)

Kam S. Tso, Ann T. Tai
IA Tech, Inc.

1 Introduction

The purpose of this research is to determine the feasibility of an automated, self-modifying prognostic system, along with a library of supporting algorithms that could be applied to the Airborne Laser (ABL) [1]. The library will consist of data mining and prognostic algorithms supporting an architecture capable of refining and implementing the algorithms that monitor a critical system without a human-in-the-loop. When the data mined indicates systemic changes, the self-modifying prognostic system refines the previously developed algorithm. The resulting library architecture will be portable to different platforms and extensible to accommodate advances in data-driven prediction and prognostics techniques. The ABL is part of a highly classified program within the DoD, and as such, detailed system information and data was not available outside the program. This extended abstract describes the approach we are taking to develop a data-driven prognostic system for the ABL, given the limited distribution of ABL information. Our approach can be outlined as follows: 1) Gather available unclassified information about the system, 2) Identify similar, but unclassified, systems, 3) Draw parallels, as appropriate, between the two systems, 4) Develop the solution architecture using the alternative system as a test case. Each step is described in more detail below.

2 Gather Available Information

Although a system is classified, there may be a substantial amount of unclassified information available in the public domain through the World Wide Web and other publications. Though much of this information is high-level system overviews, it often includes a good general understanding of how the system operates. In the case of the ABL, a surprising amount of information was found through the Web and published papers, for example [1, 2]. A high level overview of the ABL target acquisition process was found in [3] which yielded critical information for our analysis. It presents the ABL's six-phase approach to target acquisition: Phase I: Report of imminent TBM threat, Phase II: Activate acquisition sensors and plume trackers, Phase III: Activate track illuminators, Phase IV: Activate active beacon illuminator, Phase V: Activate high energy laser, and Phase VI: Contingency. Brief descriptions of each phase provided understanding of the operations the prognostic system would assist.

3 Identify Similar Systems

Once the available information was gathered, the next step was to identify a system with similar functionality. That system would be used to identify potential test cases for the proposed solution. In 2002, the ISR completed a research project on the Hubble Space Telescope (HST) under a grant from the NASA Goddard Space Flight Center (GSFC) [4]. The project was a proof of concept for using data mining algorithms and techniques to improve the operational efficiency of the Fixed Head Star Tracker (FHST) Pointing and Control System. The FHST operation is one of four phases in the science target acquisition (taking images of deep space) process for the HST. The four phases of the HST science target acquisition process include: Phase I: HST slew, Phase II: Initial pointing and control, Phase III: Fine guidance tracking, and Phase IV: Science target acquisition. The HST and ABL are similar in their respective acquisition processes.

4 Draw Parallels

With an alternative system identified, the next step is to draw parallels between the two systems. The HST and ABL target acquisition processes have very strong similarities. Although their missions are very different, their basic acquisition functionality is similar enough to make the HST a viable test case, as shown in Table 1. Aside from drawing the similarities between the target acquisition processes, we were also challenged with the task of identifying the potential failure modes of the ABL. Since there was no available information on ABL failure modes, we turned again to the HST. After an analysis of the HST failure modes, it was determined that they could also serve as potential failure modes for the ABL, as shown in Table 2. Note that these tables reflect suppositions of the authors.

5 Develop Solution Architecture

Now that parallels are made between the ABL and the HST, the HST may be used as a viable test case. ISR's previous project involving the Hubble Space Telescope provides much information about this system. Recent Hubble data was acquired from NASA GSFC and the work of developing the prognostic algorithms began. The Data Driven Prognostic System will be developed using a general approach making it more portable to other systems. In the early months of the

<i>Operation</i>	<i>Hubble Space Telescope</i>	<i>Airborne Laser</i>
Phase I - Slew	Command that directs the telescope to point in the general direction of the science target.	Intelligence report that indicates coordinates of ballistic missile threat within the ABL operating area.
Phase II - Initial Pointing and Control	FHST commanded to locate and track a designated star within a 1.5×1.5 degree FOV. Maintain lock on the designated star so that the HST can maintain bore-site on science target.	ABL Beam Control Laser activated to conduct the initial plume tracking of the target missile.
Phase III - Fine Guidance	FGS commanded to locate and track a designated star to fine tune the bore-site position on the science target.	TILL and BILL are activated to monitor and report atmospheric conditions and to illuminate the target missile for fine guidance.
Phase IV - Target Acquisition	HST takes an image of a potentially once in a lifetime phenomena in Deep Space.	The COIL (kill laser) on the ABL is activated to destroy the illuminated target missile.

Table 1: Similarities of HST and ABL System Operations

<i>Failure Mode</i>	<i>Hubble Space Telescope</i>	<i>Airborne Laser</i>
Near Neighbor	Two stars are within the 1.5×1.5 degree FOV of the FHST. The FHST gets confused and begins oscillating between the two stars and eventually begins tracking a point between the stars.	Multiple missiles could be launched from within the ABL's coverage area. Could cause confusion for the ABL in determining which missile to target.
Moving Target	The FHST has located the designated target star and an object passes between the line-of-sight of the FHST and the star causing the FHST to break track on the target star and follow the moving target.	The ABL has begun engaging the target missile and an object (decoy missile, enemy fighter, etc.) passes between the ABL and the missile target. This could cause the ABL to lose focus on the target missile and track the passing object.
Near the Edge	The designated star is near, or beyond, the tracking boundary of the FHST rendering the FHST unable to track the target star.	The ABL could get a late track on the missile which would cause a lag in tracking. The missile would be ahead or outside of the ABL's tracking FOV.

Table 2: Similarities of HST and ABL Potential Failure Modes

project, we are identifying the appropriate data mining algorithms to do the necessary analysis. Next we will use the Hubble data set and identify prognostic tasks that need to be accomplished. Then data mining techniques will be applied to the sample data set to diagnose and characterize possible failures. After this has been accomplished, an overall prognostic method will be developed along with an architecture for the library of data mining algorithms. The algorithm library will consist of data mining algorithms that are relevant to the prognostic tasks of the Hubble and will hopefully generalize to the ABL.

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