OBTAINING MEASUREMENT DATA USING COCKPIT VIDEO CAMERAS

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ABSTRACT

Rather than classic data bus-based acquisition and extraction, we can use cockpit video cameras to extract measurements. These technologies can reduce installation costs and complexity and minimize aircraft modification to obtain parameter data and may be sufficient for some quick-turn, limited-scope flight test operations. This paper explores the challenges and possible approaches for extracting measurements from video imagery of cockpit displays and provides an in-depth case study of a portable cockpit display video measurement system that reads digital measurements from aircraft instrument panels.

KEYWORDS

Video, Data extraction, Cockpit

INTRODUCTION

Typically, flight test measurements are acquired through a combination of adding discrete aeromechanical sensors to the structure and tapping into the communication busses between flight control computers. The amount and type of measurement sources depends on a combination of the maturity of the aircraft design under test and what specific test objectives need to be achieved. Historically, smaller test programs (such as testing a modification to an aircraft design that has already been certified in a prior large test program) have simply used a subset of the same instrumentation used for the most involved large test programs. While this minimizes purchasing multiple types of instrumentation equipment, it means that installation effort cannot drop below the minimum required by a subset of that instrumentation technology. Recent industry efforts have focused on leveraging wireless sensing components to remove the cost (install time, cost, and weight) of cabling, but the results have been hampered by practical considerations of power management and batteries.

FLIGHT TEST VIDEO USE CASES

The growth of storage capacity for flight test data combined with falling costs of video cameras driven by other industries has led to a significant increase in the amount of video acquired from cockpit displays, control surfaces, and actuators. While many other industries have leveraged video cameras with machine vision techniques to monitor and control processes, the flight test industry has largely used the various video sources either as a secondary data source that is only inspected manually when measurements from other sensors conflict, or by manually acquiring measurements from the video through human inspection.

Seeing this landscape, we have begun to socialize a different strategy to help achieve the goal of reduced time and cost of flight test. Specifically, we feel that if measurement information can be reliably automatically processed from flight test cameras observing cockpit displays, then this instrumentation could potentially reduce or eliminate the need for more traditional instrumentation systems in certain low-instrumentation flight test programs such as supplemental type certificate (STC) or production test.

COCKPIT VIDEO DATA ACQUISITION

We have developed a prototype concept demonstration that detects a limited set of numeric display information and graphical gauge information from cockpit video and begun a dialog with various flight test programs to uncover use cases and requirements which will influence our further research and development. While these demos are far from complete implementations, the results achieved so far and the feedback we have received make us hopeful that a finalized system can provide an effective capability to flight test users.

We have compensated for the constraints of the flight test use case by augmenting traditional machine vision techniques with test-setup specific calibration and additional image processing approaches not typically needed in more controlled machine vision environments. This idea, while a natural fit for the flight test domain, is not common in other industries. Flight test, on the other hand, is comfortable with detailed calibration procedures. We expect that requiring a calibration procedure per install would require less overall setup time than using traditional instrumentation such that the goal of reduced time and cost required for a test is still achieved.

Using the machine vision techniques we have developed, data has been successfully extracted from flight test video of a helicopter's avionics display. These test case videos were from typical flight test operations with a combination of impairments from vibration, lighting, and momentary blockage by pilot movement. The software requires a video stream that captures the avionics system display, but it is forgiving of camera positioning up to 30 degrees off normal. This video can be either acquired and processed in real-time on a test aircraft or lab bench avionics display, or post-processed from a recorded video file.

The setup calibration approach requires the user to point the camera at the gauge from a distance equivalent to the back of the cockpit and then mark several features and regions of interest in the image of the gauge. The ability for the algorithms to continually extract measurements without intervention after calibration provides validation of the techniques. Results from the helicopter flight test video extracted using this system have shown >99% fidelity when compared to truth data acquired from available data busses. The results can be seen in Figure 1.

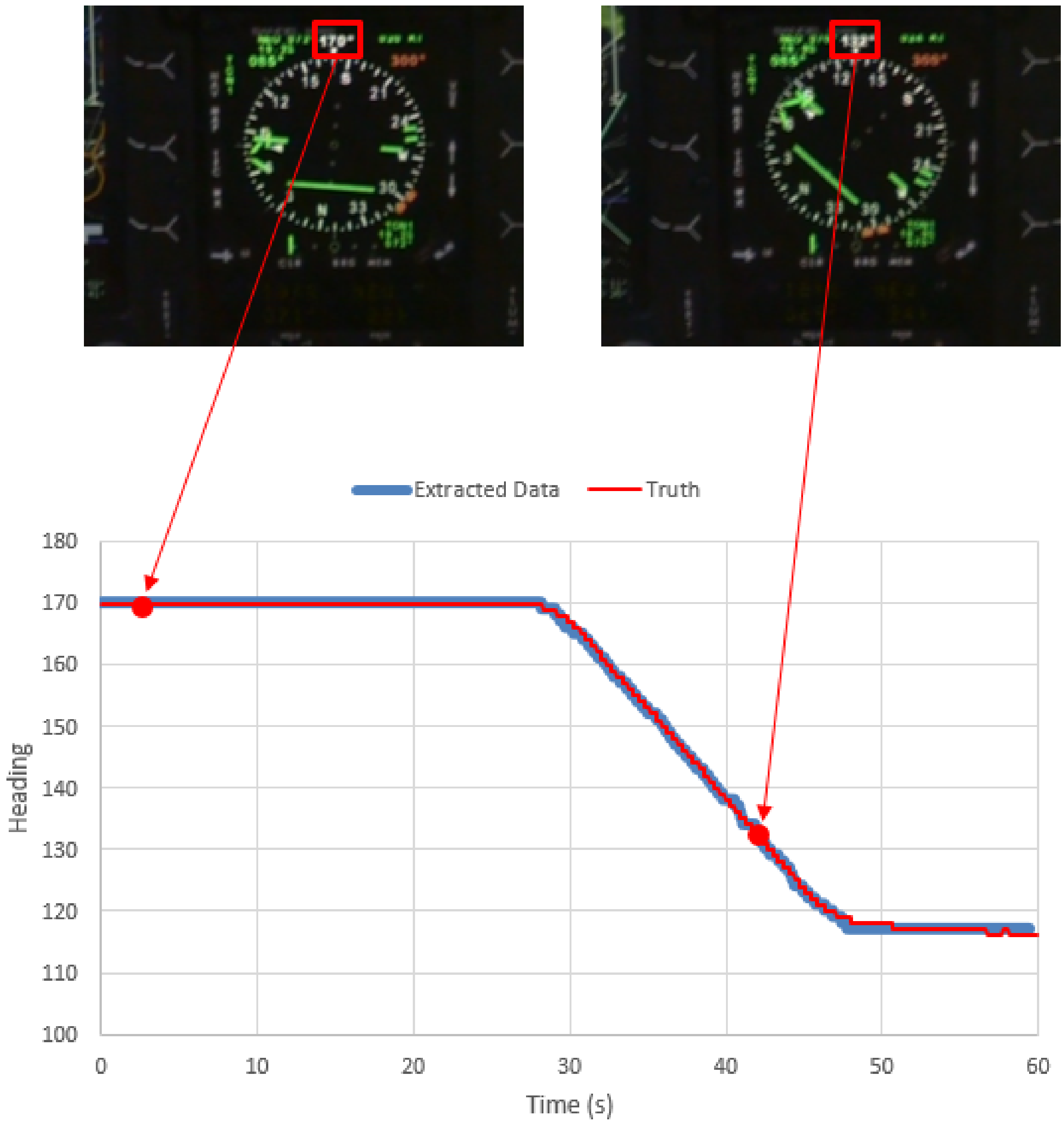

Figure 1. Measurements extracted from video processing compared to truth data (video courtesy Airbus Helicopters).

Besides acquiring numerical data, we have developed initial graphical gauge interpretation to extract measurements from the attitude indicator or artificial horizon display. Figure 2 shows roll and pitch extracted from video of the flight simulator gauges in SwRI labs. The setup calibration approach involves the user marking the region of the video that contains the attitude indicator and then double-clicking on the top vertex of the wing indicator which indicates the "nose" of the aircraft. This allows the algorithm to determine the center of the attitude indicator for zero compensation. Once this is specified, the algorithm is able to extract roll and pitch angles through detecting the relation of the lines in the image relative to this reference point.

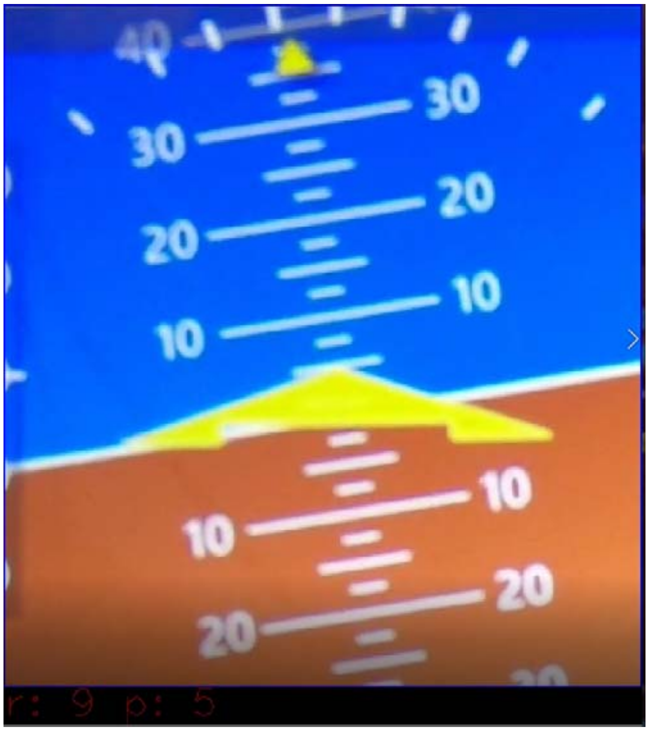

Figure 2. Attitude indicator region of interest with roll and pitch extracted from video image shown at bottom of region.

The machine vision techniques described here provide a less expensive alternative for gathering and extracting data during a flight test. Traditional methods involve tapping an avionics bus for existing instrumentation, adding the weight and complexity of a bus monitor that must have physical access to the test article's internals.

Machine vision techniques, used to extract data from cockpit displays, provide a bridge between these techniques. The avionics bus data can be reproduced, based on observations of the displays, without requiring the invasive installation of a bus monitor. Detailed knowledge of the bus catalog of the test article, what messages correspond to what values, and in what units, is no longer needed, as engineers can intuitively extract the values of note by associating measurements with the corresponding instrument. The flexibility of the camera is still preserved, as multiple passes can be made post-flight to extract data that had no prior use, but suddenly was relevant in post-processing.

FUTURE DIRECTIONS

Building on the initial prototype capabilities, we envision the system will ultimately have the capabilities to extract data from a variety of cockpit display types including:

- Alphanumeric text
- Attitude Indicator (i.e. artificial horizon for roll/pitch indication)
- Needle/dial gauges
- Horizontal and vertical bar gauges
- Boolean dashboard indicators

This set of displays covers the set of traditional aircraft instrumentation, including both the instruments for visual flight rules and instrument flight rules. It is also capable of monitoring status of many more advanced, specific instruments presenting data matching these categories and can be customized to specific flight program needs.

Like all measurement systems, consistent time marking is essential. IEEE 1588 PTP time of each acquired video frame is tracked and timestamps are applied to each measurement instance. The system supports adjusting the timestamps by an offset to compensate for video display and camera delays if needed. This provides the data with the timing accuracy necessary for comparative processing with other measurement sources.

Additionally, by utilizing portable and modular software techniques rather than hardware-specific processing, we are able to adapt to a wide variety of platforms from small embedded systems to general purpose PCs. Both the optical and platform components are independent from the software since the calibration process normalizes variations.

In addition to data extraction from avionics displays we see potential in measuring a variety of physical phenomena using similar specialized applications of machine vision. Possibilities include measuring wing deflection, flutter and vibration analysis, ice accumulation measurement, and engine analysis. Expensive and time-consuming installation of sensors could be replaced by the simple installation of a camera, where the nature of the physical event to be measured and the resolution of the camera allow.

CONCLUSION

This paper has described an approach to obtaining measurements from video of cockpit displays. We believe a system like this could be useful for reducing the installation complexity of small, short-term flight test programs such as STC and production test. The techniques explored here also open doors to using video from other flight test cameras as a sensor input in place of traditional discrete sensors. The initial results presented here can form the basis of a system that has the potential to provide flight test users a rapid-deployment data acquisition capability.