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Serving the data needs of multiple applications with one data source —*an industry application case study*

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Abstract: Automation of a technical process involves the feedback of sensor data for the automated control of particular aspects of the process itself. The same feedback data can be used for other applications such as health monitoring of systems or to update a graphical user interface or to analyze process performance. In order for this data to be utilized effectively, a system architecture must be designed to provide such functionality. This architecture must accommodate the dependencies of the system and sustain the required data transmission speed to ensure stability and data integrity. Such an architecture is presented in this paper, which shows how the data needs of multiple applications are satisfied from a single source of data. Also it will show that the flexibility of this architecture enables the integration of additional data sources that can be used to protect the performance of applications that consume the data as the order of data dependencies grows. This research is based on the development of an integrated automation system to test fuel controls for civil transport aircraft engines.

Keywords: data reuse, process control automation, data acquisition, test automation, aircraft fuel control systems

I. NTRODUCTION

Automation of technical processes is becoming prevalent across most industries. Whether the goal is to maximize process throughput, reduce waste or modernize tools used for business operations, automation opens up opportunities that improve a business's bottom line [1].

One such opportunity is the reusability of process data for technical or non-technical applications, e.g. to determine the overall health of systems through analysis of process data that contain information about the operating condition of different components. This could be the basis for a preventive maintenance strategy involving fixing faults with minimal cost implications before they become failures that could cost substantial amounts of money [2].

When a technical process has to be automated it is essential to feedback well-conditioned data from the process's sensors [3][4][5]. This requires either new or existing data acquisition (DAQ) system(s) to be employed in the collection of this data. The specification of the DAQ system must meet the needs of the process and the automation systems. Although this is extremely important, it is crucial that the data from existing systems is suitable to be reused for automation. In such cases modifications can be made to the data to ensure it is in an appropriate format or the automation systems can be designed to accommodate mismatches with the existing systems e.g. different update rates.

In an industry like the Maintenance Repair and Overhaul (MRO) sector of civil aviation, traditional DAQ (or t-DAQ as it will be called) systems are used in the delivery of data for test procedures [6]. Within this context the main purpose of such systems is to acquire data from specific sensors, process such data using hardware instruments and make it available for retrieval by Remote Terminal Units (RTUs) through a digital communication interface while simultaneously displaying the data on a monitor [7].

In order to reuse data for other applications besides automated process control, a t-DAQ and sensor systems should be evaluated on their capability to meet the requirements of two types of data consumer applications: time critical and non-time critical. Then the mechanism of managing the process of extraction and reuse of data should be implemented in a software centric environment.

The non-triviality of reusing data from t-DAQs for applications of automation comes from accommodating the limitations of the data extraction interface. The main causes of these limitations are: the supported rate(s) of data extraction, the rate at which the internal "holding" memory is updated and the format of data extracted. Consequently, it is vital to have an architecture for a data network that minimizes the impact of these constraints and ensures the accessibility and reusability of such data by other applications. This is essential for the automation of processes that are traditionally controlled manually.

Our definition of a time critical application is one that needs to know about its dependent process at least > 50 times/second. A non-time critical application is an application that requires information about its dependent process < 20 times/second.

In this paper, we present a software centric architecture that enables the reuse of data from one data source; and is scalable for the integration of additional data sources. The concept is based on having a live

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table whose content is the process data collected through the DAQ system and merged with additional features like an instrument name tag, data type tag & a description—to make it identifiable, extractable and reusable.

The context of our discussion is based on the automation of the test of fuel control systems used on civil transport aircraft engines [8]. Process control automation is the core application that reuses the process data from a t-DAQ system that will be introduced later.

In Section 2 the requirements of applications that will reuse process data from our t-DAQ system is reviewed. Next is an outline of the automated process control application structure in Section 3, which leads to a review of the limitations of a raw numeric data-only reuse architecture based on the t-DAQ: with results. In order to reduce these limitations, a "featurized" data reuse architecture is proposed in Section 4. And its implementation is treated in Section 5 with results and analysis of its impact. Finally a conclusion is given in Section 6.

II. REQUIREMENTS & SPECIFICATIONS OF DEPENDENT DATA REUSE APPLICATIONS

The role of each application designed to reuse the test data is to fulfill different tangible business benefits. For example, a Fault Detection & Diagnosis (FDD) application reuses measured process data to detect faulty operation of systems; learning *signature patterns* and their eventual failure modes [2]. This function could then be used to automatically manage moderate faults or activate an alarm before a failure occurs. As a result the number of unplanned downtime is reduced because there is a mechanism to establish the "ball park" of likely root cause(s) and thus increase the availability of test systems for the test process.

The Automated Process Control application: It is required to set different processes at specified set conditions accurately, using process data from the t-DAQ. The business benefit of this application is one of improved machine utilization, reduced total test time and associated variable overhead costs, e.g. electricity bills.

The FDD application: A requirement for the function of the FDD application is to have it online for active prevention rather than as a corrective advisory tool. Therefore, if the process data is first stored and retrieved for FDD, this will cause a delay which is unsuitable for our application. Our goal is to have the FDD application "advising" the APC application on strategies to manage faults and prevent failures from occurring [2][9][10].

The VR application: This uses real-time process data in a format that gives a visual representation of the process, known popularly as Virtual Reality (VR). For our application, this is a 'live schematic' of the test process with real time colour variations that depict whether respective test systems and test piece are operating within designed/specified ranges.

A VR application lends itself well to the cognitive faculties of operators. Where traditional display of process states as numbers requires an operator to mentally augment what is happening, a VR tool reduces the burden of generating such mental models and only needs an operator to observe which systems are operating as expected (*normal*: green), about-to-fail (*warning*: amber) or have crossed a maximum threshold (red). For this application the VR is a not time critical.

The D-board application: This implements analytical concepts to extract intelligent business information from available test process data. It would serve managers' needs to know process quality, operating capacity, anticipate unplanned maintenance and systems health in real-time. The D-board application is not time critical.

The Automated Data Entry & Recording application: This function is undertaken by operators who would read screens displaying numeric values of the states of different test process media and type these into a processing application for onward logging into a business database. In our application, the function of data recording requires that test data from the t-DAQ be extracted and transmitted to another application which *parses* the data on to the business database [11].

The ADER application has a time requirement that all recorded data should be extracted simultaneously, when the set process conditions are in *steady state* [11].

Table 1 shows a summary of the requirements of all the applications that would reuse test data from the t-DAQ as part of the automation of the test process. It covers crucial functional aspects such as the minimum frequency at which an application needs its data; the volume of test data each needs to execute its function correctly and the variety/types of data—whether numeric, textual or logical. These are summarized in Table 1. From this table it is clear that the frequencies of data speed required range from less than 1 Hz for the D-board, up to 50 Hz for the APC application which has the least variety of data.

Table 1: Requirements of consumer applications

	Time criticality (max. delay)	Data size	Data variety
ADER	1 sec	20	3
VR	1 sec	20	3
APC	< 0.020 sec	3	2
FDD	0.5 sec	52	6
D-board	300 sec	32	4

Nonetheless, it is obvious that physically connecting wires to the analog input terminals of the t-DAQ system, in order to connect multiple DAQ devices for each application is impractical. The risk of loose connections and electrical loading issues could cause inaccuracy of measurements; excluding other non-functional costs.

A software based design is seen as a practical way to extract the data from the t-DAQ through its digital