APPLICATIONS OF A HARDWARE SPECIFICATION FOR INSTRUMENTATION METADATA

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ABSTRACT

In this paper, we discuss the benefits of maintaining a neutral-format hardware specification along with the telemetry metadata specification. We present several reasons and methods for maintaining the hardware specifications, as well as several potential uses of hardware specification. These uses include cross-validation with the telemetry metadata and automatic generation of both metadata and instrumentation networks.

KEYWORDS

Instrumentation, Metadata, Hardware Abstraction Language, IHAL, XML

INTRODUCTION

In current practice, telemetry metadata is stored in the Telemetry Attributes Standard (TMATS) format. The design of TMATS includes a section H for describing the hardware used in the telemetry system. While the presence of this section indicates recognition by the T&E community of the need for hardware descriptions, section H has never been fully implemented and is virtually unused in practice.

At the 2006 International Telemetering Conference, we presented the Instrumentation Hardware Abstraction Language (IHAL), a neutral, eXtensible Markup Language (XML) based language for specifying instrumentation hardware and instrumentation hardware networks. IHAL provides a means to describe not only the specific hardware components, but also the usage of those components in a specific network configuration. The language has been designed to serve three roles: (1) as a specification language for describing the hardware and hardware networks, (2) as a command language for configuring each hardware component, and (3) as a query language for polling the hardware components for their current configuration [1].

While IHAL does not currently support full telemetry metadata specifications, the hardware information contained in an IHAL instrumentation network specification can be used to supplement and validate the information contained in the network's metadata specification.

This paper will explore various uses of a hardware specification in conjunction with a telemetry metadata specification. We will describe a way in which hardware specification constructs can be merged into an instrumentation metadata specification. We will also discuss various applications of hardware specifications including forensic analysis, mutual validation of the specifications, metadata generation, and identification of hardware alternatives.

INSTRUMENTATION SPECIFICATION AS METADATA

One potential approach to utilizing an instrumentation specification is to view the instrumentation specification as metadata itself. Since every measurement is obtained from a specific combination of hardware, and the value of that measurement is dependent on the specific hardware settings, it is reasonable to view a pool-level description of the hardware capabilities and a use-level description of the hardware configuration as metadata describing the acquired data.

A telemetry metadata specification language could make use of a pool-level hardware description language to define a global list of the instrumentation hardware used in the system. Further, use-level network configuration specifications could be included to define the specific configuration of the hardware used to acquire the data. Finally, each measurement in the metadata specification could refer back to the specific hardware configuration used to acquire it via a simple reference to a unique identifier.

The physical storage of the hardware-enhanced metadata specification could take different forms. In one case, the instrumentation specifications could be stored in the same file as the traditional metadata, with the cross-references occurring between IDs in the same file. This approach is advantageous in that it keeps all of the metadata about a specific test together in one file, eliminating the possibility of one part of the metadata becoming separated from the other. The disadvantage of this approach is that it will increase the size of the file that must be transmitted and parsed by the various tools involved in the test process (instrumentation support systems, vendor software, hardware control units, etc).

A second approach to metadata storage is to keep the instrumentation specifications in a separate file from the traditional metadata. In this situation, the cross references between the measurements and the instruments would include a reference to the IHAL file as well as the specific ID within that file. This approach addresses the goal of minimizing the size of the file that must be managed by the various tools. However, it introduces the potential problem of the files becoming separated, or the cross-links becoming broken.

Finally, the two approaches to metadata storage could be combined. In this combined approach, the instrumentation and traditional metadata would be stored in the same file for the permanent record. However, various pieces of this combined file (e.g., just the instrumentation data or just the measurement data) could be extracted and fed to the tools on an as-needed basis. With this approach, the full metadata specification can be stored together for historical purposes. However, each tool (software or hardware) can be fed only the portion of the file relevant to its task, maintaining efficiency.

In any instrumentation metadata storage scenario, it would be useful to separately maintain a large collection of pool-level hardware specifications. This collection would include specifications of all of the hardware available to the range, regardless of in which tests it is used. This library of instrumentation hardware descriptions could be used in the construction and design of future instrumentation networks, and could also be used for replacement hardware searches, which is described in more detail in a later section.

FORENSIC APPLICATIONS OF INSTRUMENTATION METADATA

If the instrumentation specification is maintained along with the measurement metadata, the test engineers will have all of the information related to each measurement in a single location. This is especially useful for forensic applications, or when a test needs to be reimplemented or reexamined many years after the initial execution of the test.

For instance, imagine the situation where a particular measurement is observed to be outside of the expected range of values. With this hardware-enhanced metadata specification, the engineer can quickly find the exact hardware component(s) that may be malfunctioning or miss-calibrated. In another situation, a subtle inconsistency in the acquired data may only be discovered years after the data was initially acquired. The enhanced metadata specification will contain all of the information necessary to reproduce the original test, either physically or in simulation.

The presence of a hardware specification that is linked to the metadata specification would also aid in locating data. Software tools could be implemented that allow searching across the hardware specification and returning the data associated with the hardware search results. For example, the user could search for the usage of a data acquisition unit (DAU) that meets certain requirements, and then be able to immediately see the data acquired by that DAU.

Finally, when data are missing or appear to be missing, the hardware specification can be used to determine the cause. From the hardware specification, it would be easy to determine whether the hardware necessary to capture the data were present and, if so, whether it was correctly configured to capture that data. Thus, the hardware specification linked to the metadata makes it possible to determine if the source of missing data is a hardware configuration problem, or a lost data problem.

INSTRUMENTATION AND METADATA VALIDATION

Regardless of whether or not the instrumentation specification is viewed as metadata, an instrumentation specification and a measurement metadata specification can be used to validate each other. As mentioned previously, the values and availability of the recorded measurements are heavily dependent on the hardware used to acquire them. With this relationship in mind, a set of validation rules could be developed to determine whether a specific hardware configuration is compatible with a specific metadata specification, and vice versa. These rules could then be used by a simple rule-based “expert system” to automate the validation process. Over time, the rule set could be extended and refined, resulting in an increasingly better automatic validator. A number of implementations of expert systems are already available, including CLIPS for C/C++ [2] and JESS for JAVA [3].

Some initial validation rule ideas follow:

- Does the instrumentation system contain the necessary number and type of instruments and sensors to acquire the data? (a temperature measurement needs a thermocouple, a strain measurement needs a strain gauge and an input card that has bridged input, etc.)
- Are the instruments configured to acquire the data at the desired sample rate and desired units?
- Are the instruments configured to acquire the data at the desired resolution?
- Are the instruments configured to acquire the data within the desired range of values?
- Is the DAU configured to output the data in the appropriate format (PAM, PCM, NRZ-L, etc)?

INSTRUMENTATION AND METADATA GENERATION

Just as an instrumentation specification and a metadata specification can be used to validate each other, so can one be used to generate the other. A fully specified instrumentation configuration can be used to infer a partial, “first-cut” telemetry metadata specification. Conversely, a full telemetry metadata specification can be used to generate a valid instrumentation configuration. Similarly, a specification of one can be used to help “fill in the blanks” of a partial specification of the other.

Given a complete instrumentation specification, one can infer a certain amount of telemetry metadata. The types of metadata that can be inferred from the hardware include:

- **Number and types of measurands**: Based on the number and types of transducers and signal conditioning cards, it is a trivial matter to infer the number and types (temperature, strain, etc) of measurands in the input stream.
- **Basic format of the output stream:** From the DAU’s configuration, one can obtain the type of output stream (PCM, PAM, etc.) and the format (NRZ-L, etc.).
- **Sample rate of the measurands:** Similarly, the sample rate of each measurand can be extracted from the configuration of the data acquisition hardware components.
- **Resolution of the measurands:** The bit depth of each measurand can be obtained by examining the type and configuration of the instrumentation hardware.

From this inferred information, a first-cut telemetry metadata file could be automatically generated that specifies the measurands, and their output format. More detailed information about the output format (assignment of measurands to PCM frames, for example) could be guessed by the automated system. The job of the engineer would then be to simply rearrange the output format as desired and fill in the information that could not be inferred.

Similarly, given a complete metadata specification and some knowledge of available hardware, an instrumentation network can be constructed. The knowledge of available hardware could be stored in a library of pool-level instrumentation hardware descriptions. Then, software could be written to automatically construct a valid instrumentation network for the metadata specification.

Using the same rules used to validate a hardware configuration against a metadata specification, the software could infer the correct number and types of transducers, signal conditioning cards, and DAUs. The same rules could also be used to infer the correct hardware settings in many cases. Further, if there is a neutral specification of available hardware available from various vendors (e.g. in the IHAL instrument pool), the software system could suggest specific hardware models to use in the instrumentation network. Such suggestions would make it easy for engineers to compare similar hardware made by different vendors.

While a complete generation will rarely, if ever, be possible, a partial generation could still save the test engineer much time and effort. In this same manner, if a partial specification is given of the metadata/hardware, the presence of a hardware/metadata specification can be used to automatically generate the missing information, using the same approaches discussed.

IDENTIFICATION OF REPLACEMENT HARDWARE

Since a hardware specification language such as IHAL can describe both the pool-level capabilities of instrumentation hardware as well as the use-level configuration of a specific instrument, such a specification could be used to find replacements for instrumentation hardware. If a particular instrument is configured and used in a network, the available pool-level specifications could be searched to find other hardware that is capable of being configured and used in the same way. An automated tool could be used at design-time to identify several instruments capable of meeting a given requirement, and then choose the least costly or most readily-available one. Similarly, this capability could be used to automatically find replacements for faulty instruments among those available in the range’s inventory.

The ability to automatically find replacement hardware could be especially useful in the situation where a test must be reexecuted at a later date. This retest could occur many years later, when the original hardware is no longer available. By comparing the original hardware configuration with a formal specification of currently available hardware, an automated system could suggest modern replacements for the instruments that are no longer available.

FUTURE ARCHITECTURE

The integrated Network Enhanced Telemetry (iNET) community is currently developing the next-generation standard for describing instrumentation metadata. Designed to eventually replace TMATS, the new XML-based standard will have a broader scope and be used for describing the instrumentation system, the telemetry data, and the constraints placed on the data. However, it is not currently planned for the new metadata specification language to include constructs for specifying the hardware used in the instrumentation system [4]. Regardless of the form taken by future T&E metadata specifications, the hardware specification can still support this information in the ways described in this paper. It will simply be a matter of adapting the software tools that use the metadata and hardware specifications to make use of the syntactic and semantic changes. In fact, an XML-based metadata specification would be more compatible with an XML-based hardware specification such as IHAL.

In the future iNet architecture, instrumentation metadata could be used to perform the functions described in this paper in real-time. When the data appears to be invalid, the instrumentation and metadata specifications could be validated immediately, and the hardware could be automatically reconfigured in real-time based on a change in the metadata. Or, a change in the hardware configuration could initiate the automatic generation of a new metadata specification.

CONCLUSIONS

The presence of the H section in TMATS indicates recognition in the T&E community that a formal hardware specification language would be valuable to test engineers. After presenting our design of an instrumentation hardware abstraction language, we now propose several uses of a detailed hardware specification, either alongside or embedded in the existing metadata specification. Such uses include test re-creation and forensic applications, metadata and network validation, metadata and network generation, and automated instrument replacement. Further, we suggest that a hardware specification will be even more useful in future T&E architectures.

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