THE APS CABLE DATABASE *

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ABSTRACT

The IRMIS toolkit has been used to create a relational model of the cabling system at the Advanced Photon Source. The component concept in the existing hardware relational model has been extended to include component 'ports', each containing a variable number of signal-carrying 'pins'. In the relational schema each conductor (copper or fiber) in a multistrand cable bundle or ribbon is associated with the signal connection between two unique component pins. This close tie between conductor and signal is part of the IRMIS approach of integrating the accelerator software, hardware, and cable relational database coverage. The direct connection between each cable conductor and the component pin that it is attached to provides the user with end-to-end signal tracing capability.

The signal concept has been generalized to include energy as well as information flow, such as the current flow between a power supply and a magnet. Wiring list information, usually documented in some form of interface control document between the control system and external equipment, is now captured as part of the cable database schema. This paper will discuss the integration of the cable database with the existing control system software and hardware component databases.

INTRODUCTION

In spite of the importance of accurate and complete documentation of a facility's cabling system, many accelerator facilities today still have incomplete and perhaps even worse, incorrect cable documentation. Historically, cable installation often begins during the early construction phase of the project, long before standards for cable documentation have been put in place. Temporary, unlabelled cables all too often become permanent fixtures, usually without formal documentation. The traditional 'flat file' approach provided by text and spreadsheet files does not provide the multiple-view, global search capabilities required by the many eventual users of the cable plant. The 'free text' nature of data entry into these files often results in inconsistent data entry, making querying and searching difficult if not impossible. The diverse choice in cable and media types compounds the documentation problem

The cable database model presented here attempts to address these issues. Proposed is a single, centralized, relational model for cable documentation, capable of handling all known cable types. Its coverage includes documentation of field equipment wiring lists. The cable application along with its underlying relational model provides features directed at providing exhaustive coverage and assisting in validation of the data. The model is the logical extension to the IRMIS component database [1], and represents a pivotal element in the ultimate goal of relating accelerator hardware and control system software [2].

THE IRMIS COMPONENT MODEL AND INFRASTRUCTURE

The Integrated Relational Model of Installed Systems (IRMIS) is a pragmatic global approach to data modeling a complex facility such as an accelerator. By successively partitioning the facility into functional subsystems, one eventually arrives at the component level--the point at which the subsystem is replaceable as a single unit. The fundamental goal in IRMIS is to document the dynamical relationships (i.e., the control, housing, and power connections) that exist among these accelerator components. These connections are captured in a multihierarchical model capable of handling any component of the accelerator, from the macro scale (magnets, power supplies, racks, etc.) to the embedded scale (circuit-board components). The component instances stored in the IRMIS database along with their hierarchical intercomponent relationships form the infrastructure within which the cable database is constructed.

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COMPONENT PORTS AND THE BASIC CABLE MODEL

The IRMIS component model has been extended to include the concept of 'ports'. Component ports represent the visible, physical mechanism by which data is exchanged between collaborating components. Port templates extend the component type definition, drawing from a palette of standard port types. When a component of a given type is added to the database, the cable application uses the port template definition to instantiate the ports associated with the component type. Port-to-port connections physically implemented by means of a cable are documented by storing references to the connected ports, along with optional user-entered cable color and label attributes. The Entity Relation Diagram for the basic cable model is shown in Figure 1.

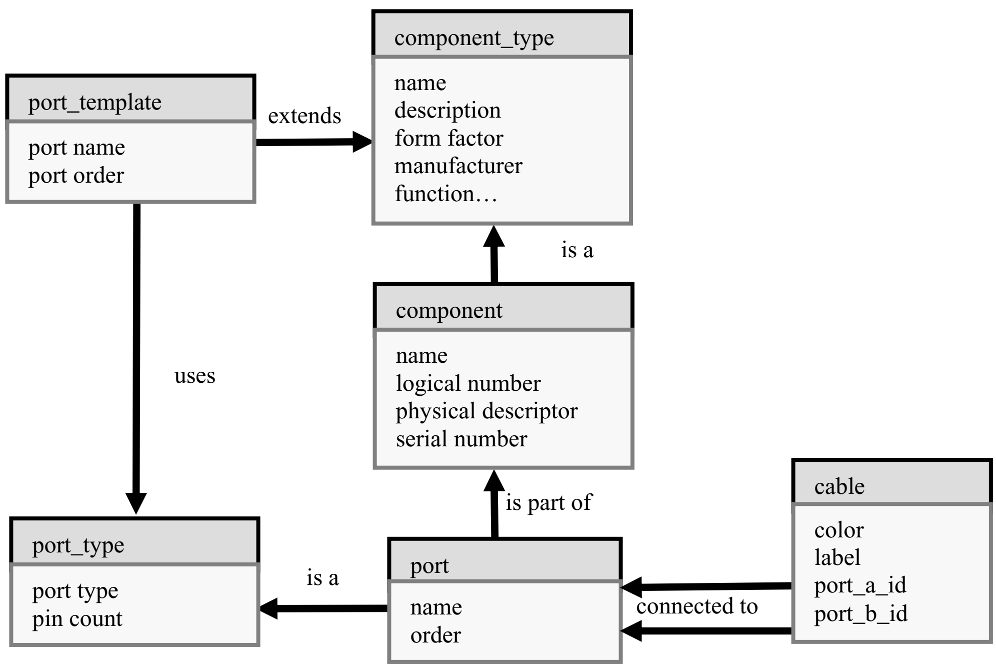

Figure 1. Component/Port/Cable Entity Relation Diagram. With each component instance are stored its associated port instances. This component/port infrastructure forms the basis for the cable database.

The physical implementation of this model is sufficient for the vast majority of cabling situations. It reflects the real-life physical action of connecting a cable between two facility components. In the process of adding a cable to the database, the cable application leverages off the searchable hierarchical structures provided by the IRMIS schema to provide drill-down mechanisms for locating target component ports. The component database provides the name space for the connected ports, so that there is no free-text data entry except for the optional cable color and/or label. The cable database does not rely on the ancillary cable label, color, or other physical identifying feature for its integrity. The primary identifying feature of a cable instance is its port-port connection.

EXTENDED CABLE DATABASE – SIGNALS, PINS, AND CONDUCTORS

Signals

A signal represents as a flow of information or energy. Signals both originate and terminate in components, so that the signal retains its meaning even if the connecting cable is removed. In the present discussion, the terms 'signal' refers to 'field' signals, i.e., energy or information flow between components external to the control system. This includes, for example, the high current flow from a power supply terminal lug to a magnet coil, or the feedback signal between a power supply and a regulator.

Pins

A port may contain several pins. The energy or information flows defined above are directly associated with these pins. Differential signals, for example, require two pins for their transmission.

The basic cable model described in the previous section is sufficient for those cases in which the connecting cable is 'intact' in the sense that there is a pin-by-pin match between sending port and receiving port (as defined in the port templates). Not all cables adhere to this constraint, however. Ribbon cables may be split, or the order of individual conductors may be changed or 'pig-tailed' as shown, for example, in Figure 2a. The situation also arises in which several multiconductor (sub)cables are used to bridge between dissimilar port types, as shown in Figure 2b.

Figure 2a. An example of a signal concentrator ribbon cable. Detailed conductor-by-conductor information is required for this situation.

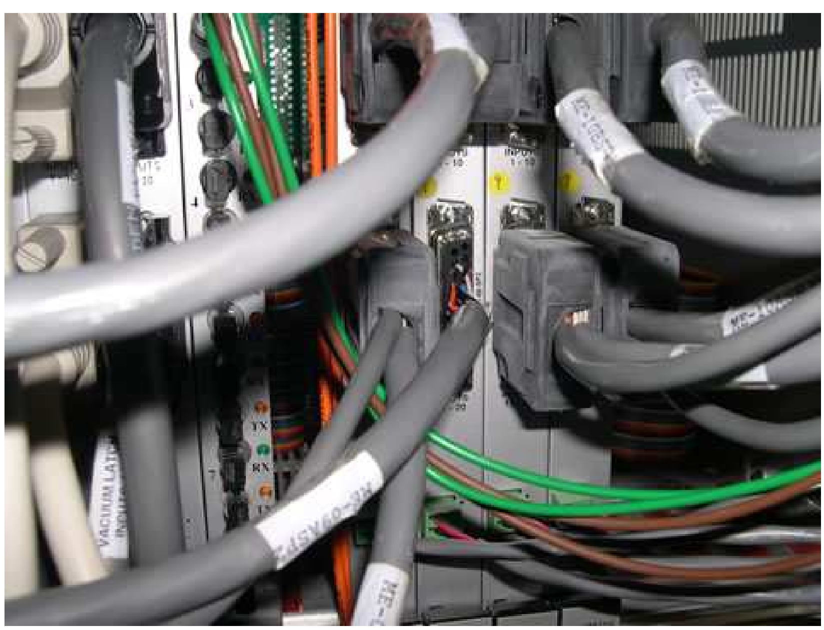

Figure 2b. Examples of two (sub)cables connected to a single component port.

The basic cable model has been extended to address the issues arising from the nonstandard cables described above. The port definitions in the base cable model are extended to include their pin detail, using a standard set of pin templates. With the pin definitions for any component type in place, a conductor represents a single pin-pin connection. The pin template extensions to the base cable Entity Relation Diagram is shown in Figure 3.

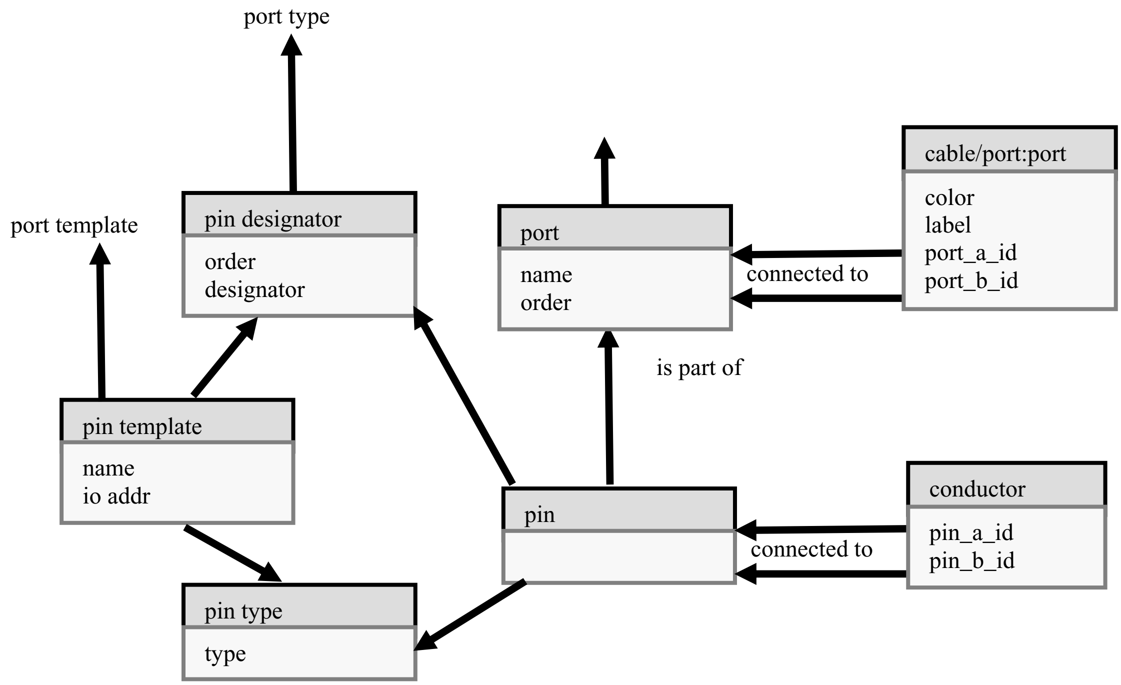

Figure 3. Extended Cable Entity Relation Diagram. Ports are detailed with their constituent pins. Conductors represent pin-pin connections. The port-to-port connection cable that a given conductor belongs to is derived from the pin-port relationships. This handles the situation in which a given conductor does not belong to a single intact cable.

Conductors

In the general case, a conductor belongs to a specific port-port connection. Normally, this corresponds to a single, physically identifiable cable connecting the two ports. For the unusual case in which the internal conductor arrangement of a multistrand cable has been altered or split, there may be no single, identifiable cable to which the conductor belongs. In this case, the user is supplied the two ports containing the connected pins. The user infers from this information the (sub)cable to which the conductor belongs. This enhancement to the basic cable model thus accommodates all known types of cable connections.

When a new component is added to the facility, the cable application creates instances of all the ports contained in the port template for this component type. In addition, entries are inserted into the database corresponding to all the pins contained in the pin template for each instantiated port. This provides the framework for associating signals to instantiated pins.

DISCUSSION

Control Components and Field Bus Segments

The items that are directly addressable by the control system (e.g., processors, backplanes, I/O modules) form a subset of the complete set of facility components. The fact that every control system component is commanded by or passes data to a deterministic control parent defines a control flow hierarchy. At the end of this hierarchy (the ‘leaf’ devices) are the I/O modules, where the conversion between external signal flow and control flow takes place. Communication between the IOC and leaf devices typically takes place by means of field bus cables. These field bus segments are connected to ports on both the parent controller module and the child leaf components. These port-port connections are documented in the general cable database described above.

Wiring Lists

The IRMIS model accommodates all field component types (power supplies, BPMS, magnets, etc.) In the cable schema described here, the terminal lug wiring connections, for example between control system reference outputs and power supply regulator inputs, are treated as normal port-port connections. There is no need to maintain a separate wiring list dictionary correlating field wiring to control system I/O module inputs. By including the wiring list information in a centralized port-port database, the application developer can immediately view the relationships between the control application under development and the target equipment wiring configuration.

The relational nature of the cable database described here provides powerful signal tracing capabilities. Combined with the drill-down mechanisms inherent in the underlying hierarchical component infrastructure, the combined component and cable database is a valuable aid in fault diagnosis and tracing. It is an extensive foundation for further analysis (single point of failure, flow analysis, Petri net, etc.) of the accelerator facility in general and the control system in particular.

The cable model described in this paper is general in nature and is not restricted to any particular accelerator facility. The schema accommodates all known types of cabling situations, providing, in principle, a framework for the exhaustive coverage of the site cabling plant.

REFERENCES

[1] D. A. Dohan, “Component/Connection/Signal Modeling of Accelerator Systems,” PAC 2005, Knoxville, Tennessee, May 2005, to be published.

[2] D. A. Dohan and N. D. Arnold, “Integrated Relational Modeling of Software, Hardware, and Cable Databases at the APS,” Proceedings of ICALEPCS2003, Gyeongju, Korea, October 2003, 365-367 (2004).