An Information Integration Framework Based on XML to Support Mechatronics Multi-disciplinary Design

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***Abstract*—To implement the information integration of multi-disciplinary applications, an information integration framework of mechatronics system multi-disciplinary design is developed. This developed integration framework adopts a XML Web service based architecture which facilitates the seamless information integration in Internet environments. MSCIM (Mechatronics System Common Information Model) is defined as well as the standard data access interfaces are specified. MSCIM includes all the major objects and the relationships of objects in the process of mechatronics systems design. As a neutral and Web-friendly industry standard, the XML Schema is used as the formal definition language of the MSCIM. DAF (Data access facility) is adopted as the standard data access interface and the accurate definition is given via WSDL. Standard data access interfaces are implemented through SOAP (Simple Object Access Protocol) over HTTP which provides the multi-disciplinary design application with a generic way to exchange information and access public data. Furthermore, this information integration framework provides the multi-disciplinary engineers with an integrated logical view of mechatronics systems and realizes cooperation of multi-disciplinary teams which shortens the development cycle and saves the cost at the same time in mechatronics multi-disciplinary design.**

***Keywords*—mechatronics multi-disciplinary design, MSCIM, XML, SOAP**

I. INTRODUCTION *(HEADING 1)*

In the process of mechatronics system multi-disciplinary design, multi-disciplinary engineers work cooperatively with different design and simulation tools in a distributed environment. However, most of these design and simulation tools are independently developed at different time and by different manufactures. As a result, almost every design and simulation tool has its own private information model which leads to information "islands" in the process of mechatronics systems multi-disciplinary design. There are obstacles of data exchange and sharing among these design and simulation tools because of the problem aforementioned. How to utilize the plenty of data effectively is urgent to solution.

With the development of information technology, there are lots of research results on integration of autonomous and heterogeneous information in many fields besides mechatronics systems design. Researchers have developed many projects for heterogeneous information integration of their research fields [1-5]. An information-integrated framework for E-commerce was proposed to solve the problems faced by companies because the storage systems lack structural and application homogeneity [6]. Heterogeneous information processing and integration methods were proposed in enterprise management information systems [7-9]. An information integration system for Virtual Learning Environment (VLE) was developed in [10] in order to build a good virtual learning environment which could deliver relevant information to the learners' at the most appropriate time and locations.

In order to shorten the development cycle, from the information communication point of view, it is necessary to integrate mechanical subsystem design, hydraulic subsystem design and control system design by information exchange and data sharing based on a unified standard. IGES (Initial Graphics Exchange Specification) [11] and STEP (Standard for Exchange of Product Data) [12] are existing information exchange standards which are often used in mechanical engineering and product development. However, these information exchange standards have limitations in information exchange and communication in the internet environments. The rapid rise in the popularity of XML (the eXtensible Markup Language) provides a platform-independent data structuring syntax for the presentation and exchange of information and it has been widely used in e-business [13], data exchange among heterogeneous database for virtual enterprises [14], and e-manufacturing [15]. However, little research has been done about the information integration of mechatronics multi-disciplinary through XML and related technologies.

The objective of this paper is to create an information integrated framework for mechatronics multi-disciplinary design using XML and related technologies. The integration unifies the representation of multi-disciplinary design information with the common information model and bridges the gap between different models, as well as streamlines

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information exchange and communication between different workgroup. Furthermore, information integration provides an integrated and coherent view of data in multiple, possibly inhomogeneous information sources which is one of the core problems in mechatronics system multi-disciplinary design. The main contributions of the paper are:

- The presentation of the information integration framework. The framework can meet the requirement of mechatronics system multi-disciplinary design and guarantee extendibility of the system at the same time. (Section 2)
- A discussion in favor of Mechatronics System Common Information Model (MSCIM) in the integration framework. WSDL-described definition specifies the format and rules for producing a both machine readable and human readable form of MSCIM. It describes a MSCIM vocabulary to support the data access facility and associated MSCIM semantics. (Section 3)
- Design of standard data access interfaces of the information integration framework. Standard application interfaces implemented through SOAP over HTTP provide the multi-disciplinary design application with a generic way to exchange information and access public data. (Section 4)

II. THE INFORMATION INTEGRATION FRAMEWORK

A. *Design of the information integration framework*

To implement information integration between multi-disciplinary design applications, the information processing must be supported by an architecture providing distribution technology and transparent access to information through heterogeneous networks and environments. The information integration framework adopts neutral technology as much as possible to improve the compatibility and applies mainstream technology to get wider application support. The information integration framework defines the following two important parts.

- MSCIM (Mechatronics System Common Information Model). MSCIM is an abstract model that represents all the major objects in mechatronics system multi-disciplinary design. By providing a standard way of representing mechatronics system resources as object classes and attributes, along with their relationships, MSCIM facilitates the integration of multi-disciplinary applications developed independently.
- Standard data access interfaces. The purpose of defining the standard data access interfaces is to specify the interfaces which are used to exchange information among applications in a standard way. It is based on existing international or industry standards to the maximum extent possible which facilitates the integration of applications developed by different manufactures.

B. *An Information-integraed framework based on XML and Web Services*

An information integration framework supporting mechatronics multi-disciplinary design is shown in figure 1. Individual applications are interconnected via XML and Web Services. In order to exchange information in a standard way, an application must provide a standard interface that enables other applications to invoke its functions and to access and manipulate the data within it. The legacy wrapper is used to encapsulate a legacy application (such as Pro/E) which does not conform to the standard interfaces. It converts a legacy program input/output into one or more standard interfaces which permits a legacy application to operate as a seamless integrated application capable of exchanging information with other applications via a common infrastructure.

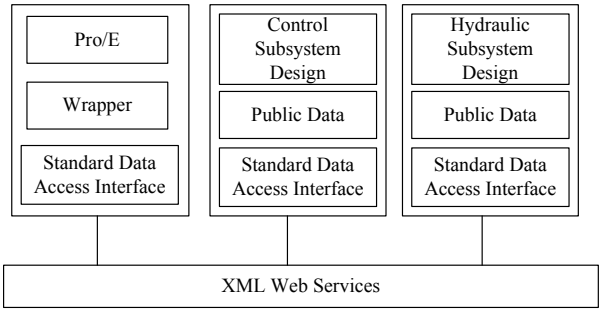

Figure 1. A specific system which adopts general integration architecture

III. MECHATRONICS SYSTEM COMMON INFORMATION MODEL (MSCIM)

A. *What is MSCIM?*

In order to describe the objects in the real and virtual world, various applications have defined their corresponding information models. However, these applications usually adopt different information models which present difficulty in information exchange and sharing. Therefore, the definition of common information model which allows for information exchange in a platform-independent and technology-neutral way is necessary for information integration.

IEC (International Electrotechnical Commission) 61970 Standard and DMTF (Distributed Management Task Force) have both advanced the CIM (Common Information Model) conception. The CIM in IEC 61970 is an abstract model that represents all the major objects in an electric utility enterprise typically involved in utility operations. By providing a standard way of representing power system resources as object classes and attributes, along with their relationships, the CIM facilitates the integration of applications developed independently by different vendors [16]. DMTF is the industry organization leading the development of management standards and the promotion of interoperability for enterprise and Internet environments. CIM of DMTF is an object-oriented model, describing an organization's computing and networking environments [17, 18].

MSCIM provides an integrated logical view of mechatronics system multi-disciplinary design information. It is an abstract model that represents all the major objects in

mechatronics system multi-disciplinary design. By expressing mechatronics system design and simulation resources as object classes and attributes, along with their relationships in a standard way, the MSCIM facilitates the integration of multi-disciplinary applications developed independently.

In the MSCIM, a class is a description of an object found in mechatronics system such as a hydraulic pump or reversal valve which needs to be represented as part of the overall mechatronics system model. Other types of objects include things such as measurements that applications also need to process, analyze and store. A particular object in a mechatronics system with a unique identity is modeled as an instance of the class to which it belongs. MSCIM also contains classes and attributes that will be exchanged over interfaces between applications. MSCIM only has generic features from which a detailed implementation may be derived as much as possible.

B. XML Schema-based MSCIM

In our wok, we take the XML-based approach to define MSCIM because most scientific communities are these days working or planning on converting their scientific data or its metadata into XML documents. XML is a Markup Language that makes information portable. It is a neutral and Web-friendly industry standard, a cross-plat-form independent software and hardware for representing and transmitting data. With the explosive growth of Internet, XML makes transmitting data over the Web inexpensive and efficient. The common descriptive specification framework enhances the reusability of the software document and facilitates the sharing of information on the internet.

The XML schema language provides the necessary framework for creating XML documents by specifying the valid structure, constrains and data types for the various elements and attributes of an XML document. Schema language provides enhanced as well as more comprehensive and powerful features than a DTD (Document Type Definition), the traditional mechanism used to describe the structure and content of XML documents [19].

It offers at least the following advantages [20-22]:

- It is both machine readable and human readable, although primarily intended for programmatic access.
- The XML schema language provides the rich data typing associated with ordinary programming languages. The W3C XML schema specification defines several different built-in data types such as string, integer, boolean, date and time. The specification also provides the capability for defining new types. Users can use built-in as well as user-defined data types to effectively define and constrain XML document attributes and element values.
- Because schema language supports inheritance, namespaces, and so on, it can model complex data efficiently, making it easier for computers to process.
- XML schemas are also valid XML document. It can be parsed using an XML parser, manipulated using XML DOM (Document Object Model) or SAX (Simple API for XML), edited using XML editors, or transformed using XSL (Extensible Stylesheet Language).

XML schema is used to create and validate MSCIM efficiently and effectively. XML schema-based MSCIM represents the format of data fully and correctly, it can be published and shared with all the mechatronics applications, ensuring the accuracy of both the syntax and semantics of the transmitted XML data.

With the MSCIM XML schema, a hydromotor class can be described as following.

```
<Schema xmlns="schemas-microsoft-com:xml-data"
  xmlns:dt="schemas-microsoft-com:datatypes">
<AttributeType name='ID' dt:type='string' required='yes'/>
<ElementType name='VolumFlow'  dt:type='double'/>
<ElementType name='RotationalSpeed' dt:type='double'/>
<ElementType name='LoadTorque'  dt:type='double'/>
<ElementType name='InternalLeakage' dt:type='double'/>
<ElementType name='ExternalLeakage' dt:type='double'/>
<ElementType name='Hydromotor' content='mixed'>
    <attribute type='ID'/>
    <element type='VolumFlow'/>
    <element type='RotationalSpeed'/>
    <element type='LoadTorque'/>
    <element type='InternalLeakage'/>
    <element type='ExternalLeakage'/>
</ElementType>
<ElementType name='class' content='eltOnly'>
     <element type='Hydromotor'/>
</ElementType>
</Schema>
```

XML Schema-based MSCIM supports a mechanism for software from independent suppliers to produce and consume MSCIM described modeling information based on a common format.

IV. DESIGN AND IMPELMENTION OF STANDARD DATA ACCESS INTERFACES

In the process of mechatronics multi-disciplinary design, the need for accessing the public data conforming to MSCIM is evident. The standard interfaces for public data accessing should provide both read and write abilities. Standard data access interfaces specify methods, events and attributes to make the applications exchange information with others in a unified way. The interfaces used in our work are derived from the industry standard DAF (Data Access Facility) of OMG [23].

A. Data Access Facility

DAF provides a generic request/reply-oriented data read mechanism. It was defined for application of UMS (Utility Management Systems). The applications in a UMS employ extensive physical models representing networks, production facilities and demand behavior among other things. For example, one model in an application may contain several classes representing both physical and theoretical concepts.

Parts of this model must be understood by other applications that hope to interpret the data. However， this model is implemented in one or another proprietary database management system. There are no standard query languages or APIs to access them. DAF was presented to solve this problem.

The same question exists in the mechatronics multi-disciplinary design process and therefore DAF is adopted as the interface to achieve data exchange and sharing in a generic way. DAF provides an approach for exchanging information among applications including information describing of a real or simulated state of the system together with the system's physical model data. DAF is sufficient for integrating many applications and systems in a near-real-time or non-real-time mode. Moreover, this facility is also intended to work in concert with future facilities to integrate more applications.

B. Definition of standard data access interfaces with WSDL

The DAF was described with the IDL and there is no accurate interface definition for other models. However the XML Web service is described with WSDL (Web Services Description Language) which provides a simple way for service providers to describe the basic format of requests to their systems regardless of the underlying protocol (such as SOAP or XML) [24]. Therefore, the IDL-described DAF must be transferred into WSDL-described interface. Some of the WSDL-described DAF interfaces are shown as following.

```
<portType name ="ResourceQueryService">
  <operation name = "get_values">
    <input message = " tns: ResourceQueryService.  get_values  " />
    <output message = " tns: ResourceQueryService. get_resource_idsResponse " />
  </operation>
  <operation name = "get_extend_values">
    <input message = " tns: ResourceQueryService. get_extend_values"/>
    <output message = " tns: ResourceQueryService. get_extend_valuesResponse"/>
  </operation>
  <operation name = "get_related_values">
    <input message = " tns: ResourceQueryService. get_related_values"/>
    <output message = " tns: ResourceQueryService. get_related_valuesResponse"/>
  </operation>
</proType>
```

Get_values requests a resource description for a single resource given by its resource identifier. get_extent_values requests a description for each resource of a given class. get_related_values requests a description for each resource associated with a given source resource.

```
<portType name =="ResourceUpdateService">
  <operation name = "create_resource">
    <input message = " tns: ResourceUpdateService. create_resource"/>
    <output message = " tns: ResourceUpdateService. create_resourceResponse"/>
  </operation>
  <operation name = "set_values">
    <input message = " tns: ResourceUpdateService. set_values"/>
    <output message = " tns: ResourceUpdateService. set_valuesResponse"/>
  </operation>
  <operation name = "delete_values">
    <input message = " tns: ResourceUpdateService. delete_values"/>
    <output message = " tns: ResourceUpdateService. delete_valuesResponse"/>
  </operation>
</proType>
```

In the ResourceUpdateService interface, create_resource, set_values and delete_resource operations create, update and delete individual resources that are MSCIM-defined resources corresponding to classes and properties.

C. Implementation of standard data access interfaces with SOAP

SOAP is a simple XML based protocol to let applications exchange information over HTTP and a protocol for accessing a Web Service. It is a lightweight protocol for exchange of information in a distributed environment and consists of three parts: an envelope that defines a framework for describing what is in a message and how to process it, a set of encoding rules for expressing instances of application-defined datatypes, and a convention for representing remote procedure calls and responses [25].

SOAP can potentially be used in combination with a variety of other protocols and allows Internet communication between programs. It provides a way to communicate between applications running on different operating systems, with different technologies and programming languages. Today's applications communicate using RPC (Remote Procedure Calls) (such as DCOM and CORBA which represents a compatibility and security problem and are normally blocked by firewalls and proxy servers. A better way to communicate between applications is over HTTP, because HTTP is supported by all Internet browsers and servers. SOAP was created to accomplish this. Therefore, SOAP is an appropriate implementation technology for the standard data access interfaces in internet environments. The process of data access performed through WSDL-described DAF is shown in figure 2.

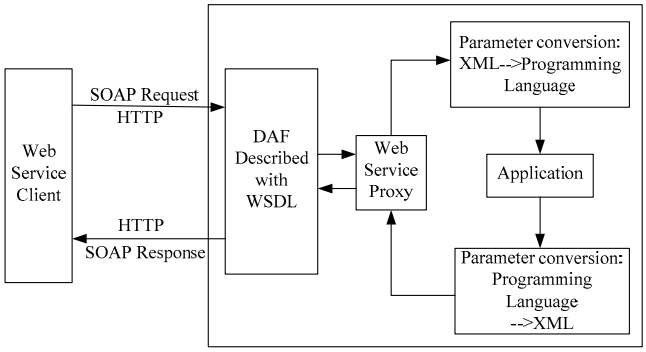

Figure 2. the working process of data access

V. A MULTI-DISCIPLINARY DESIGN SYSTEM BASED ON INFORMATION INTEGRATION FRAMEWORK

Figure 3 shows a multi-disciplinary design system adopting the XML and Web services based information integration framework. The design of a large-scale hydraulic-driven erecting vehicle involves the interaction and integration of multi-disciplinary, such as hydraulic, mechanical dynamics and control sub systems. In this case, DSHplus is used as the modeling/simulation for hydraulic sub system, ADAMS is for mechanical dynamics system and Matlab Simulink is for control system. They are integrated into the information integration framework. However, they are legacy applications which have their own private information models and data access interfaces. In order to integrate them into the integration framework, legacy wrappers are needed for transforming their private internal information models and data access interfaces

into the MSCIM and the standard interfaces. MSCIMServer, which is a newly developed application based on the MSCIM and the standard interfaces, performs management of the information used for the multi-disciplinary design and facilities their collaborative design.

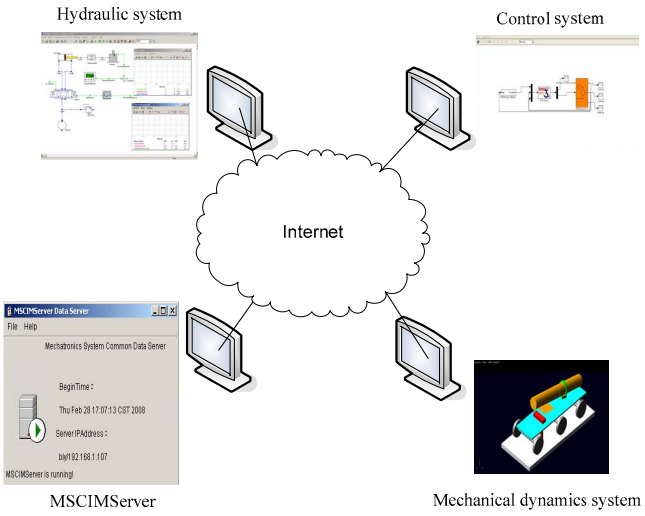

Figure 3. A multi-disciplinary design project based on the xml-based information integration framework

VI. CONCLUSION AND FUTURE WORK

Information integration is one of most challenging problems in mechatronics system multi-disciplinary design due to lacking of common information model and unified interfaces. An XML-based information integration framework for information integration of mechatronics system multi-disciplinary design is presented. The method of defining and describing the mechatronics system common information model are proposed and the standard data access interfaces are also defined.

Our current work mainly focuses on the validation of the information integration framework. More effort should be made to the perfection of the MSCIM and the extension of standard data access interfaces as well as integrating more applications.

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