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Challenges to the National Information Infrastructure: The Barriers to Product Data Sharing

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The Need for a Product Data Standard in Manufacturing

Industry has a need to share data among functions within its own enterprise and among its suppliers and partners. This data needs to be shared among different hardware platforms, different data storage paradigms and systems, and a variety of network architectures. Manufacturing concerns typically rely on a number of proprietary system solutions which are incompatible with one another. Manufacturing is becoming increasingly automated in an effort to remain competitive in the world market. These incompatibilities are having a serious impact on the time it takes to introduce new products and on their cost and quality. A standard specification for manufacturing data is needed that can support the entire product development and support life-cycle.

The STEP International Standard

The emerging international Standard for the Exchange of Product Model Data (STEP[1]) [ISO1], officially designated ISO 10303, is addressing this need by specifying what data is needed within application areas, how it should be represented in a common form, and how it should be exchanged. As a result of lessons learned from other standards work, conformance requirements for STEP implementations have been built into the standard. This will result in the building of higher quality STEP implementations.

STEP offers a number of technical advantages over earlier attempts to develop data exchange standards. The data needs are specified in a formal language called EXPRESS which is both computer interpretable and able to describe real-world constraints. Support for specific application areas is provided by *application protocols* (APs) which clearly and unambiguously describe all data needs for a particular industrial application. A consistent representation of common data needs between APs is maintained by reusing, as building blocks, a set of general data specifications called *integrated resources* (IRs). This approach is practical since there are overlapping data needs among both the business processes and industry disciplines (i.e. electrical, mechanical, civil engineering). STEP has developed a number of methods to ensure consistency and to facilitate the sharing of data across applications.

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1. STEP is being standardized under the auspices of the International Organization for Standardization (ISO) Technical Committee 184 (TC184) Subcommittee 4 (SC4).

Status of STEP

STEP has active participation from the automotive, aerospace, electrical, construction, shipbuilding, architecture, engineering, and process industries. Twenty-six nations and over 200 companies world-wide participate in the development of STEP within 76 development efforts.

Currently, STEP consists of twelve documents that were approved in May, 1994 as international standard ISO 10303. Twenty-five additional application standards are under development along with several more proposed standards. Two books have been published and many papers are available in technical journals. STEP methods have spread to other standards and development activities[1] [EUG] such as: International ElectroTechnical Commission (IEC) TC93 for the Electronic Design Interchange Format (EDIF) standard, International Organization for Standardization (ISO) TC172 on Optical Systems, the London Stock Exchange software design, Petrotechnical Open Software Corp., and the National Center for Bio-technology Information (NCBI) Human Genome Project.

The National Initiative for Product Data Engineering[2] (NIPDE) has information on over 80 STEP projects. Thirty-four are study or prototype projects and 50 are production or pilot projects. At a PDES Inc.[3]/NIPDE meeting in March, 1994, sixteen vendors described their plans for implementing STEP. In addition, fourteen auto manufacturers worldwide have signed a memorandum of understanding agreeing to migrate to STEP. For example, Ford Motor Company, General Motors, and Allied Signal successfully exchanged a complex STEP solid model of a power steering pump housing among prototype Unigraphics[4], STEP Tools Inc.[5], and PDGS[6]/ACIS[7] systems. This demonstrates the feasibility of STEP for real manufacturing applications.

The Need for a STEP Development Environment

AP developers currently use a collection of software tools which are neither integrated nor tailored to the particular demands of STEP. At the present time, AP development is a time-consuming, labor-intensive, and thereby expensive process. Current estimates indicate that a four-person effort, extending over a 1.5 year period, is required for the initial specification of a single AP [Palmer]. The Factory Automation Systems Division at the National Institute of Standards and Technology (NIST) is currently establishing a software environment to support the information

1. No approval or endorsement of any commercial product by the National Institute of Standards and Technology is intended or implied.
2. NIPDE is an organization established to accelerate digital product data exchange, development, and use. Participants include companies, corporate consortia, standards organizations, and government agencies.
3. PDES Inc. is an industrial consortia to promote and accelerate the development and implementation of STEP technologies.
4. Unigraphics is a commercial computer-aided design/computer-aided manufacturing (CAD/CAM) system.
5. STEP Tools Inc. provides software used to build STEP-based products.
6. Product Development Graphics System (PDGS) is Ford Motor Company's CAD/CAM system.
7. ACIS is an open solid modeling system marketed by Spatial Technologies.

processing needs of STEP AP developers. This environment, called the Application Protocol Development Environment (APDE) [Barnard], will be a production quality system that improves AP quality, speeds AP development, and facilitates AP implementation.

Status of the STEP Development Environment

Several tools supporting the development of STEP are presently in place. Some of these are accessible remotely. For example, in 1994 there were, on average, 400 requests per month for remote execution of APDE software. Between January and August of 1994 there were almost 10,000 documents retrieved via APDE services. There are over 50 users actively tracking enhancements to NIST APDE software. The APDE STEP document project has identified numerous inconsistencies in ISO document guidelines and proposed ISO documents.

The efforts to decrease development time and increase quality are also paying off. For example, automated generation of one annex of an AP document has eliminated six person-weeks of effort and two-thirds of new draft standards are now being approved on their first ballot.

The Need for an Information Base for STEP

When developing data standards, it is desirable to reuse existing data standards where possible. This makes the standards' content more consistent between application areas and within an application area. It also facilitates the exchange of common information and makes the standard easier to understand and use. Reuse also saves development time since the same content does not have to be developed more than once. Where possible, STEP AP developers are building from IRs and are reusing overlapping information from related APs.

The desire to reuse information leads to the problems of knowing what potentially reusable information exists, where it is, and how it can be found. The APDE is addressing these problems. The APDE is being designed as an integrated suite of software tools accessing a central data repository called the *Application Protocol Information Base* (APIB). The APIB will contain the information content of existing STEP standards, standards in development, and a host of related information. The APIB will provide ready access to potentially useful information, thus encouraging information sharing and exchange.

Using the SGML Standard for Structuring and Managing STEP Information

Computers can be used to manage information provided the information is in a computer-interpretable format. Most of the information that is to be reused by AP developers is in the form of text documents. STEP and ISO guidelines specify many restrictions and structural constraints on these documents; however, the structure is not in a format that can be interpreted by a computer or queried and accessed as part of the APIB. An ISO standard for structuring text and exchanging text data, called the Standard Generalized Markup Language[1] (SGML) [Goldfarb],

1. Officially international standard ISO 8879

will be used to make the document information interpretable and usable by the APIB. Additional information called SGML tags will be added to the documents. The tags will function as paths into the information that a user can query and access via the APIB. SGML and related software within the APDE will also make it possible to ensure and enforce document consistency with the STEP and ISO documentation guidelines as well as make it easier to develop new STEP documents [Phillips].

Barriers to the Success of STEP

In spite of the success STEP is enjoying, there are many barriers to the development and acceptance of the standard. Barriers include issues related to the international standardization process, lack of software which supports use and development of the standard, and difficulties introducing new technologies into related markets.

Inherent to the international standardization process are barriers which increase the amount of time it takes to develop the standard. For example, teams of international developers must work together to achieve consensus. Developers must overcome cultural and technological barriers. Developers may favor different solutions which are, overall, equally good based on directions local industry or implementors have chosen. Each of these and other issues increase development time.

While the standard is in development, it is impractical for developers of STEP-related software to maintain compatibility with the most recent changes to the evolving standard. Until the standard becomes stable, software developers are reluctant to invest resources in support of the standard. This includes software necessary for ensuring the usability and completeness of the standard. However, feedback from implementation is necessary to ensure that the standard is workable. The absence of software to help in development of the standard causes the development of the standard to take even more time.

Another barrier is related to technology insertion. Market building for the standard is needed. The market is specialized, and until there is a sufficient customer base, vendors will not invest in developing software to support the standard. Until there is software to support the standard, industry has limited use of the standard.

Barriers to the APDE

The goal of the APDE project is to integrate software, documents, and computer resources to aid in the development of STEP in a single software environment. Where possible, the APDE project is using commercial off-the-shelf software to reduce development time and costs. Unfortunately, there is not a large amount of STEP development software. The existing STEP software needs to be validated to ensure that it meets STEP requirements.

STEP AP developers are using general purpose software tools such as word processors to meet STEP development software requirements. Having a word processor that could be extended to interact with the APIB would make the developers' job easier, faster, and more

efficient. Unfortunately commercial off-the-shelf software which provides partial solutions to developers' needs is not always extensible to better support STEP AP development. This poses tough choices to developers of tools for the APDE; is it worthwhile to add STEP extensions to an extensible word processor with fewer features or should developers continue to use a more feature-rich non-extensible word processor?

Dealing with copyrighted standards and licensing requirements has added more requirements and constraints which have made the development of an APDE more challenging. Dealing with an emerging standard's evolving methods of development, access specifications, and data representations has made software development more challenging and has increased the maintenance work load.

Users of STEP and the NII

The primary users of the APDE will be developers of STEP APs and IRs. Other users include STEP implementors, users of EXPRESS, and potential end-users of STEP APs.

Since users of the APDE are an internationally distributed work force, remote access to the APDE must be provided. A remotely accessible APDE will save travel time and expense and allow for constant access to the STEP information and tools. The National Information Infrastructure [NII] could provide the vehicle for access to the software applications in the APDE. The enhanced availability of the current STEP standards, STEP tools, and work in process would facilitate development of STEP as well as promote acceptance and use of the international standard. U.S. acceptance and use of STEP could help U.S. industry to be more productive, more fully automated, and more competitive in a world market.

Benefits of Accessing the APDE and STEP Through the NII

Access to the APDE and STEP standards through the NII would help make the many benefits of STEP available to U.S. industry. Use of STEP APs would provide all players in the manufacturing process for an application area with a standard representation of the product. Adoption of common representations would make software tools for manufacturing more likely to interoperate. Manufacturers of products that are supported by STEP would not need to specify all of their data representation needs but could use the standard representation. Several of the manufacturing stages within a product's life-cycle have overlapping data needs. Using STEP, data about the product could be passed between stages in the products life-cycle in a computer-interpretable format. For example, geometric information from the design stage can be directly used and modified by downstream manufacturing processes.

Companies which have traditionally implemented solutions in proprietary ways are now choosing to adopt standards into their solutions to facilitate the concept of enterprise integration. Enterprise integration refers to the increased inter-operations between work that companies do which makes the work more efficient, cost-effective, and productive and end results

more timely. Adopting standards into software development allows vendors to write software that could fit into the overall manufacturing process in a standard way creating more of a market for the software.

An example of this benefit of conforming to STEP is the facilitation of contracting out work in the manufacturing process to subcontractors. Where contractors within an application area use STEP for specifying and exchanging product data, subcontractors could transparently deal with many potential contractors. This would result in more opportunity for subcontractors. The increased ability of subcontractors to deal with data from contractors would result in a larger selection of potential subcontractors for the contractor.

The APDE contains software 'toolkits' that can be used as building blocks for writing STEP applications. The software contains the data structures necessary to represent STEP data in various programming languages. The software provides necessary functionality such as input, output, and validation of data which would not have to be re-implemented by developers. Use of the software will help to encourage implementors of STEP to build applications since there will be less code that needs to be developed and thus application development would be faster and less expensive.

The APDE will contain SGML related software for browsing, accessing, modifying, and publishing STEP documents. SGML provides mechanisms for the definition of document structure. A definition has been written to match STEP and ISO guidelines for STEP documents. This definition of structure in conjunction with the SGML editing software will ensure document compliance with the guidelines and ensure consistent document structure within types of STEP documents.

The SGML editing software will facilitate the development of new documents. Since it allows for the definition of structure, the definition will be used to customize an editor to prompt developers for the appropriate sections of the document in the appropriate places. It will also automatically fill in required parts of the document that require a predefined wording. A customized document editor will help ease the learning curve of new developers who are not familiar with the guidelines and format necessary for a new standard.

Documents in SGML format provide paths into the information content of the documents which could then reside in a text database. This text database will be the heart of the APIB. SGML editing software will be customized to interact with the APIB so that new developers of STEP application protocols can reuse parts of the existing standard. This helps speed development of new standards and makes the standard more consistent, allowing information to be represented the same way among different application areas.

A primary goal of the APDE is to automate as much of the AP development process as is possible. Automation of tasks will ease the work load of developers allowing them to concentrate on tasks that require their technical expertise. Automation of tasks will also help to reduce the number of errors. Tasks which cannot be fully automated do allow for partial automation and error

checking to eliminate invalid or inconsistent information. The result of automation will be the acceleration of standards development and higher quality standards. This will encourage acceptance and use of the resulting standards.

A general benefit of having the APDE on the NII is the value of having an example of how complex documents and an SGML-based database could be used together. This solution could be used by companies interested in building a system that provides structured, intelligent access to large amounts of technical information in documents.

Future Direction

The goal of the APDE is to break down barriers to the development and acceptance of STEP. Barriers may have a cyclic ripple effect that can negatively impact solutions. If solution 'A' was achieved, it would remove a barrier to solution 'B'. Solution 'A' is taking longer to achieve because of the lack of a solution for 'B'. Breaking the cycles will prove to be challenging. As more software tools are put into place in the APDE, more barriers will be removed and more cycles will be broken. Future work will concentrate on developing the APIB, customizing software for dealing with the specific requirements of STEP documents and information, extending the software toolkit building blocks, facilitating STEP implementors, integrating AP development tools, and providing remote access to the APDE.